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DORTMUND, GERMANY (HELD ONLINE)

#CITIESR4LIVING

SMART CITIES THROUGH PROJECTS: ACHIEVING QUALITY OF LIFE?

- Achieving Smart Cities through Projects
- Transforming towards Digital Delivery
- Ensuring Diversity in Smart Cities
- Viewing Smart Cities from the Gender Perspective
- Being Mobile in Smart Cities
- Forming Digital Ecosystems
- Urbanizing Sustainably
- Engineering Smart Cities
- Securing Privacy in Smart Cities
- Training & Educating
- Definitions of Quality of Life in Smart Cities
- Managerial and economical impact of Industry 4.0

CFP21H96-USB

IEEE TEMS

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Dear friends, colleagues and all IEEE E-TEMS 2021 participants,

At the heart of future cities, one must find a reflection of the diverse qualities, interests, challenges and aspirations of its citizens. Continuously improving citizens' quality of life can come through robust digital transformation and collaboration on projects and programmes. It is with these ideas in mind, that we welcome you to **IEEE E-TEMS 2021**!

Addressing city complexities is not easy and will be an ongoing effort of research, industry and government stakeholders in close collaboration with its citizens. A key challenge is to find ways how to combine the different players within complex project ecosystems. We must find ways to share our thoughts, questions and project insights in order to create a sustainable future that serves us all. **IEEE E-TEMS 2021** is one such way where we focus on the question "**Smart Cities through Projects: Achieving Quality of Life?**"

Building on the success of IEEE E-TEMS 2020, a conference series **IEEE E-TEMS 2021-2025** is launched. Over the course of the series, the European Partnership on Project & Innovation Management (EuroPIM) will bring research, practitioner and industry perspectives to emphasize the social accountability that must be associated with project management, digital transformation and smart cities. Each event will try to deliver a hybrid conference model (with both virtual and in-person events) and include international experts, educational workshops, doctoral symposia, poster sessions and dialogues amongst our EuroPIM partners.

IEEE E-TEMS 2021 is the first of the series and we sincerely welcome you! It is the fourth summit of the **IEEE Technology and Engineering Society (TEMS)** in Europe and is taking place virtually at the Dortmund University of Applied Sciences and Arts, in the heart of one of the biggest European metropolitan areas – the Ruhr Valley. Contributions have been diverse and universally high quality and are captured in these conference publications. We hope you enjoy them and are inspired, perhaps, to contribute next years. More information on the series will be presented throughout the event.

In the meantime, please do enjoy yourself along with the papers, conversations and networking opportunities. Feedback last year told us that our event was substantial and relaxed; a good atmosphere for **technology and project management** researchers and practitioners trying to offer solutions to some of society's biggest problems. We seek to do the same this year and look forward to 'seeing' you over the coming few days to do just that!

Best wishes,
Dr. Beverly Pasian, Conference Chair
Prof. Dr. Carsten Wolff, Programme Chair

2021 IEEE European Technology & Engineering Management Summit
18-20 March 2021
Smart Cities: Achieving Quality of Life?
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A **special thank you** to our colleagues and friends, who enthusiastically contributed to the **IEEE E-TEMS 2021** Conference. The **quality of the Conference** is a direct reflection of their professionalism, creativity and attention to detail.

Every paper went through several review steps and was reviewed by up-to 6 **reviewers**. Those are professors, lecturers, representatives of industry as well as young researchers in different fields of expertise.

Content-specific reviews:

- Peter Arras
- Andreas Becker
- Sergey Bushuyev
- Ruta Ciutiene
- Uwe Grossmann
- Thomas Holzmann
- Bassam Hussein
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- Nigel Williams
- Kevin Wittek
- Carsten Wolff

"Coaching" reviews, quality and template check:

- Alexia Nalewaik
- Nargiza Mikhridinova
- Anastasiya Kurylchyk

A **big thank you** goes to **local organising team**, who worked hard to make the conference happen by contributing to the elements of the conference, creating the website and virtual portal as well as facilitating the conference.

- Anna Badasian
- Nargiza Mikhridinova
- Sabina Culicovscaia
- Areej Aldaghamin
- Anastasiya Kurylchyk
- Kristoph Reimann
- Jorge Maldonado
- Matthias Smukal
- Thorsten Ruben

We want to emphasize how pleasant it is to work together with such reliable team and we look forward to extend this experience during the **IEEE E-TEMS series**.

Sincerely yours,
Conference core team:
Beverly Pasian, Conference Chair
Carsten Wolff, Programme Chair
Anna Badasian, Conference Manager
Nargiza Mikhridinova, Programme Manager

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Table of Content

Empowering Citizens in a Smart City Project One Step at a Time: a Norwegian Case Study

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***Abstract*—Considering public participation as one of the key components of "smart cities", efforts have been made by local governments to provide opportunities for citizens to take an active role in smart cities planning. This paper presents preliminary results of a collaboration between academics and municipal staff to identify the best practices in terms of public participation in smart and sustainable development projects. From the legal framework enforcing minimum requirements for public participation as information and consultation to the implementation one of the first online participatory budget initiative in Norway; this study analyzes the context in which public participation initiatives work in practice to achieve the highest degree of participation, namely citizen empowerment. Documents provided by the municipality as well as other publicly available ones were analyzed in order to identify the different degree of public participation at each step of the project. Results from this study indicate that pushing the threshold a little bit higher at each step can help concretizing citizen empowerment at the neighborhood level.**

Keywords—smart city, public participation, citizen empowerment, collaborative evaluation

I. Introduction

Considering public participation as one of the key components of "smart cities", efforts have been made by local governments to provide opportunities for public participation in smart cities projects. Some municipalities even opened specific positions within their staff that solely focus on citizen participation. Improving the quality of life of citizens as well as empowering them to become active participants in city governance has become a priority in the recent smart cities' projects in Nordic countries [1–3]. In these projects, surveys have been used to collect feedback and data on specific aspects of the city development project, participatory budgeting for the co-management of green spaces, collaborative maps for community building. One of the goals is to empower citizens to actively participate in shaping the future development of the city, one that matches their needs and expectations [4]. Empowerment is the highest degree of citizen participation on Arnstein's ladder [5] which is still a reference to this day. However, in the case of a new development area, it can be challenging to empower citizens at all stages and scales of the project.

As part of the collaboration between Oslo municipality and NTNU, a problem was posed by the municipality team to the academic partner to identify the best practices of public participation in their urban development projects. In order to address this problem, we propose a joint evaluation of the participatory actions in practice. The first case for the joint evaluation presented in this paper focuses on how the highest degree of participation could be achieved in the context of smart and sustainable development.

Public participation in planning can be defined as the different initiatives or mechanisms looking to make room for the general public to take an active part in the planning process [6], ranging from consultation, involvement, information to partnerships [5,7,8]. When looking to evaluate to which extent the citizens are included in decision-making, Arnstein's ladder of participation [5] is still considered to be a solid theoretical reference, with three categories of non-participation, tokenism and citizen power. An important stream of literature on public participation focuses on urban planning at large as this is the original field, however in the context of smart cities, looking to improve the quality of life of its citizens, it is a topic that has increasingly gained focus [2,3,9,10]. A growing stream of smart city literature focusing on public participation has emerged to give it a more citizen-centric definition, shifting from the original focus on technology [3,10,11]. A smart city in this context, can be defined as a space in which local governments, citizens, and other stakeholders could carry initiatives aiming to make the city a better place to live [12,13]. Initiatives looking to involve citizens in decision-making are considered to be a way to minimize conflict and rejections of the planning proposals and it is argued that citizens, as the primary beneficiary of the smart city services and environment should have a say in the development process [2,9]. However, it can be argued that citizens' participation might not be needed all the time at all stage of the project if their community representatives are given a substantial role in the development of the planning proposal [10]. Citizens' input may positively impact the development of the city but as the main responsible body for facilitating the public participation process, municipalities must plan it carefully [2]. Internet-based participatory platforms can enable citizens to actively participate and become co-creators in the planning process and is often referred to as e-participation [3,14,15]. Citizens as co-creators can bring ideas that contribute to achieving better quality of life in the smart city [1,3,10,14]. Online participatory budgeting is a form of e-participation that has the potential to realize the role of citizens as co-creators by enabling a voting system on which proposal of a set of proposed actions should receive funding [2,13,16] .

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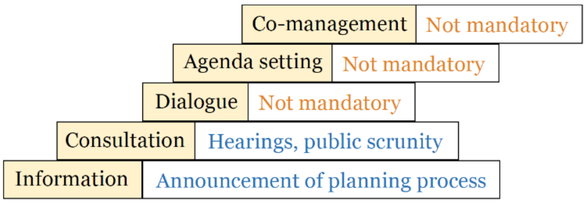

Fig. 1. A modified version of Arnstein's ladder of participation including the requirements of the Norwegian Planning and Building Act by Ringholm et al. (2018) [17].

Based on an analysis of the legal text of the Norwegian Planning and Building Act, Ringholm et al. (2018) [17] adapted Arnstein's ladder of participation to illustrate where the legal requirements are situated (Fig.1). We can see that the Act puts the requirement on the two lowest levels, namely *Information* and *Consultation*. It is stated that "anyone who presents a planning proposal shall facilitate public participation"[18]. The municipality is thereby solely responsible for ensuring that this requirement is met in any planning process carried out by other public or private bodies. This includes announcing the planning process and facilitating hearings and public scrutiny.

The three higher steps of *Dialogue*, *Agenda setting* and *Co-management* are not mentioned in the Norwegian Planning and Building Act, see Fig 1.

Dialogue is understood as a two-way communication between the municipality and those affected by the plan. The Planning and Building Act imposes showing how comments were received and considered but the municipality is not required to integrate them in substance into the final planning proposal.

Agenda setting aims to identify what the most important societal challenges are and how to integrate them in the planning. The preparation of a strategic plan and its publication open for this step to be taken [17]. Participants are given the opportunity to bring forward themes that should be considered in the strategic plan. Although

Co-management is not clearly defined in Ringholm et al.'s study [17], one can assume that it refers to the highest degree of citizen participation as defined by Arnstein, "citizen power". At that level, citizens are able to engage in a deal with the authorities (Partnership), are given the authority to decide on a plan or program (Delegated Power), and/or full executive power (Citizen Control) [19]. In order to reach the highest degree on Arnstein's ladder, Gohari et al. (2020) [10] defined the arena in which direct participation can occur as a combination of invited, claimed and invented spaces.

Scope of the Paper

This study is a part of a bigger ongoing project titled "Citizens as Pilots of Smart Cities (CaPs)". CaPs is a collaborative research project between three universities in Norway, Finland and Denmark aiming to investigate "the barriers to, and opportunities for, citizen participation in Nordic municipalities". This will be followed by developing a scalable and easy-to-adopt methods that promote citizen participation in smart and sustainable urban development in the Nordic context.

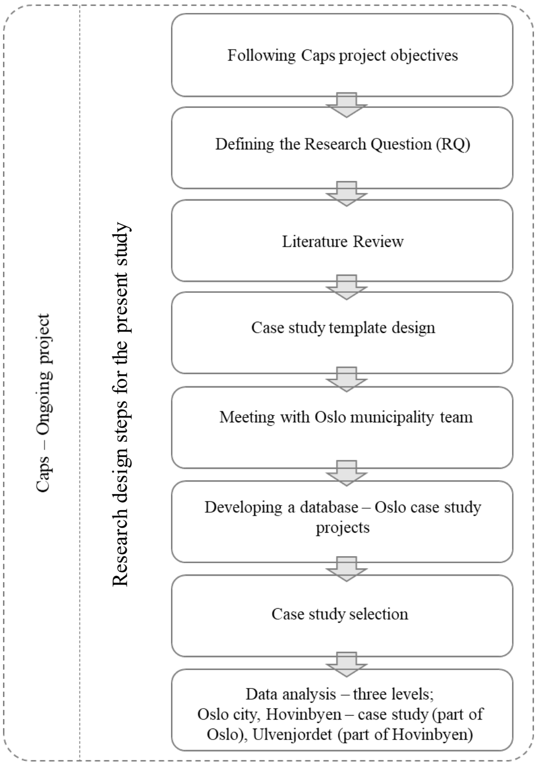

Fig. 2. Research design steps.

The present study is a step toward the CaPs project objective, by addressing the following research question:

RQ: How does public participation work in practice to achieve citizen empowerment in the smart city context?

II. Method and Research Design

This study was conducted through a deductive theory testing approach. Deductive approach develops a hypothesis (or hypotheses) based on existing theory, and then designs a research strategy to test the hypothesis [20]. In other words, deductive approach moves from a general to a particular theory, involving formulation of hypotheses to testing during the research process [21].

Having identified the scope of this study, the following steps were taken to address the research question (Fig. 2).

A. Defining the Research Question

The research question for this study was formulated in order to contribute to the CaPs research project objective of mapping the current ways citizens are participating in smart cities project and the means in place to achieve greater degree of participation.

B. Literature Review

First, a literature search in the field of public participation in smart cities at large was conducted in order to understand their interconnexion, followed by a search on the Norwegian context of public participation in planning.

C. Case Study Template Design

As a result of an inclusive literature review (on the smart city development and the existing frameworks to evaluate smart city projects) for CaPs project, a case study template was designed. This template covers basic information about the area, the objectives of the project, the time-period and relevant information regarding the public participation processes.

D. Meeting with Oslo Municipality Team

Academics at NTNU arranged a meeting with the 'Planning and Building Agency' team from Oslo municipality to get an insight into the ongoing urban development projects in Oslo. As a result of this meeting, the academic team at NTNU obtained access to the ongoing and completed urban development projects as well as a goal for the analysis.

E. Developing a Database – Oslo case study projects

Following access to the Oslo case study documents, the project information was summarized in the designed templates. In this way the information for each Norwegian case study project was available in a comparable way.

F. Case Study Selection

Considering the objective of this study, Hovinbyen (as a developing urban area) in Oslo was selected to be further analyzed. The case study was chosen based on the available data on the public participation from the preparation of the strategic plan to the implementation of one of the first ever online participatory budget in Norway.

G. Data Analysis

The available data on the urban development strategy in Hovinbyen and the results of the public participation processes was qualitatively analyzed to assess the extent to which each step contributed to climbing the ladder of participation. The following documents and sources of information were consulted and analyzed for the purpose of this study:

- The report on the participatory activities that took place during the preparation of the strategic plan for the development of Hovinbyen
- The strategic plan itself with a special focus on the public participation section
- The social media channels managed by the Planning and Building Agency
- The participatory platform managed by one of Hovinbyen's district authorities with a special focus on the participatory budget initiative "Ulven Budget"

1) Public participation system in Oslo

In the case of Oslo municipality, the strategic plan is prepared by the municipal Planning and Building Agency in accordance to the law. Elected representatives of the affected districts are also given a voice in the development of the plan as well as being responsible to further develop and implement it at the neighborhood level. Representatives of the citizens associations and parliaments are also taking part in these discussions. This is an indirect form of participation, but the Norwegian Planning and Building Act also calls for ensuring that all affected parties, including individuals are given the possibility to comment any planning proposal. This can be done in the form of a physical or digital letter addressed to the authorities during the time period when the plan is open for comments. A specific section of the law also enforces facilitating the participation of groups who are not capable of participating directly with a special focus on the children and youth.

Fig. 3. Hovinbyen location (source: Oslo Kommune ©MapTiler).

2) Hovinbyen as the case study

Hovinbyen, located east of Norway's capital, Oslo (Fig. 3), is the largest urban development area in the city, stretched onto four districts, Bjerke, Alna, Grünerløkka and Gamle Oslo. In Norway, municipalities usually have the authority in urban planning. In Oslo, districts' representatives also take part in the decision-making process. Hovinbyen currently has about 40,000 inhabitants and 50,000 job positions. Considering the projected population growth in Oslo, the development of 27,000 new dwellings and 2.5 mill. m2 new commercial area in Hovinbyen is planned. This corresponds to 50,000-60,000 new inhabitants and 50,000-100,000 new jobs [22].

The development plan in Hovinbyen aims to make this area as a self-sufficient area with shops, restaurant and services to create a well-functioning and independent extension of the inner city in Oslo. This area is being transformed from a built environment characterized by large storage and industrial areas, to become an attractive urban area with new dwellings, workplaces with a blue-green structure.

Hovinbyen is advertised as a future-oriented and climate-smart urban area, with a diversity of attractive urban spaces, closely intertwined with each other and the rest of the city. Walking, cycling and public transport is planned to be as the easiest and most attractive ways to travel in this neighborhood [22].

3) Ulvenjordet, one of the first online participatory budgeting in Norway

Located south-west in Hovinbyen, in the district of Alna, Ulvenjordet is an unbuilt area surrounded by the housing cooperatives of Ulven Terrasse, Ulven borettslag, Helsfyr borettslag and Gullhaug borettslag. The district advertised available funds of 100 000 NOK with a maximum financing of 10 000 NOK for each proposal for the development of this area. The idea was to finance grassroot initiatives to make Ulvenjordet a more attractive place and improve the well-being of the surrounding community. This is to be achieved through one of the first online participatory budgeting initiative in Norway, hosted on the districts' participatory platform "Alnainvolverer" ("Alna involves")[23]. The dedicated space on the platform [24] allowed any local resident to submit an idea for improving the area and build a sense of co-ownership. The idea being to fund multiple initiatives, each of them could apply for up to one fifth of the total available funds. The platform was open for submissions for fifty days in July and August 2020 and received 21 proposals. The proposed initiatives were then reviewed in four days by the district authorities to ensure their feasibility within the budget and regulatory constraints which resulted in 14 proposals on which the local community was invited to comment and vote for. The inclusion and exclusion reasons were made publicly available on the platform through a comment from the organizers justifying their choice to send it forward or not. Votes were open for 12 days where people could choose how to distribute the total available funding between different initiatives. In the end, six ideas were allocated funds and the implementation process will start soon.

III. Results and Discussion

The available information on the strategic plans and citizen participation in Hovinbyen were analyzed in terms of 1) legal requirement, 2) citizen participation actions, and 3) degree of citizen participation. The results of this analysis are shown in Fig. 4.

To the left, on the vertical axis are the documents analyzed to frame the Hovinbyen project participation process, from the legal requirement (*Planning and Building Act*) to the implementation of one local project (*Participatory Budget initiative of Ulven*).

On the horizontal axis, the different steps of the adapted version of Arnstein's ladder of participation by Ringholm et al. (2018) [17]. (from *Information* to *Co-management*)

To the right vertical axis, more detailed information about participation requirements and actions are provided, as reported in each of the documents. This shows the increasingly active participation measures, compared to the minimum legal requirement (*advertising the plan* and *collecting comments*) contributed to reaching the highest degree of participation in one of the implemented projects.

The arrows drawing from documents to actions show the degree of participation achieved as identified in each document. The partial arrow illustrates the assumption that a step was taken.

In Norway, the *Planning and Building Act* enforces the legal requirements regarding public participation in planning. In accordance to Ringholm, et al. (2018) [17], the text positions itself on the lowest levels of citizen participation, namely *Information* and *Consultation*.

The *Report on the participatory process for the strategic plan* [25] shows how Oslo's Planning and Building Agency went beyond the minimum legal requirement and took a step towards *Dialogue.* This was done by organizing workshops with local community representatives, schools and youth parliament and providing more opportunities for direct input from citizens. The partial arrow towards *Dialogue* shows that the present study was not able to assess the extent to which the communication went both ways and the influence of the direct participation methods on the outcome. However, the indirect participation of citizens though their local representatives is well documented in the preamble of the strategic plan. Based on the fact that the main input from these workshops seems to be reflected in the main goals of the strategic plan, one can assume that a form of dialogue did take place even if it is considered of an indirect type. All citizens were also invited during the exhibition of the architecture competition results to give direct input and share their vision of Hovinbyen (*postcards*). In addition, the Planning and Building Agency launched social media campaigns using the incentive of winning a prize. For example, they invited all citizens to share pictures of what they would like to see in Hovinbyen and children between 10 and 18 years old to share drawings of their vision for the future urban environment.

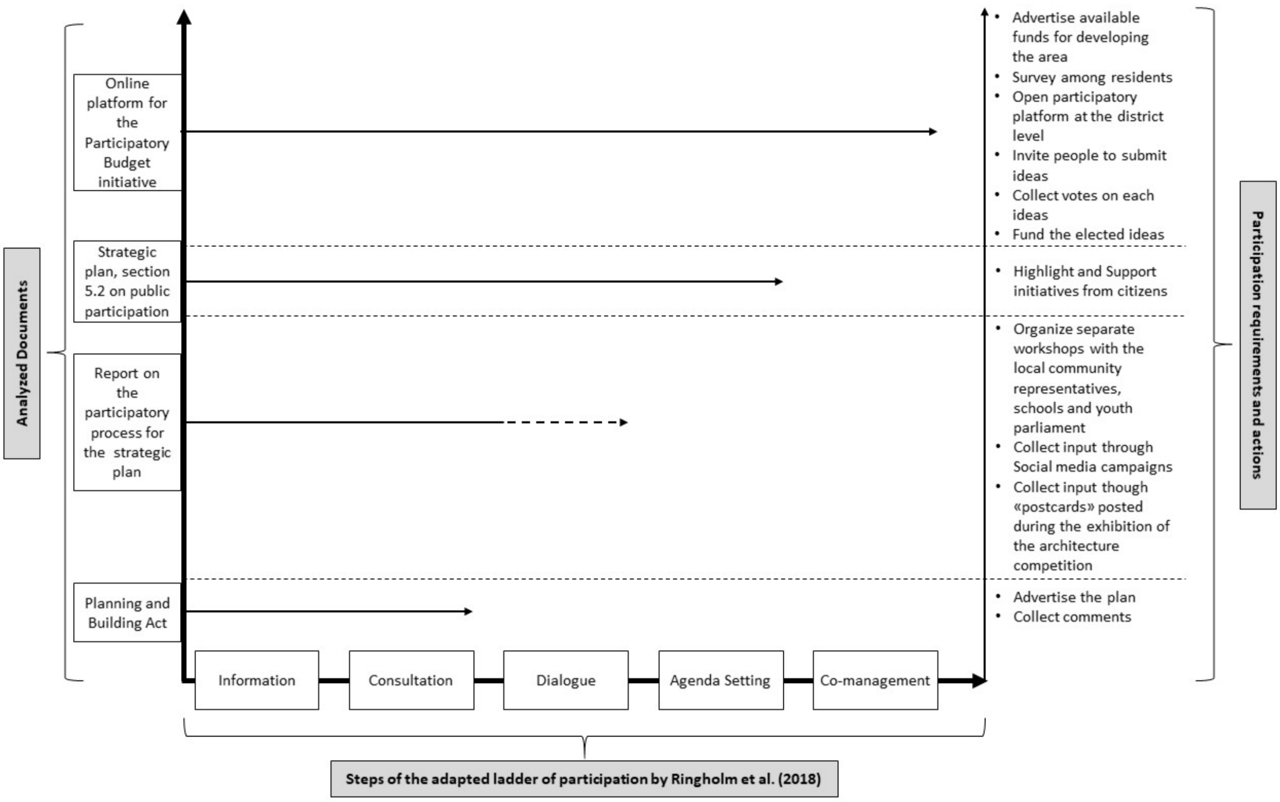

Fig. 4. Degrees of citizen participation achieved in the context of Hovinbyen development project.

The *Strategic plan, section 5.2* [22] provides guidelines on how public participation should contribute to the development and implementation of the projects in Hovinbyen. In addition to the minimum requirements to facilitate the participation of citizens in all planning proposals, it also calls for *supporting and highlighting citizen initiatives*. The title of *Section 5.2* "Involvement and co-creation" also indicates the will to include citizens both as active participants and as co-creators, alongside all the relevant stakeholders. This can be considered as a step towards including citizens in *Agenda Setting* as they should be supported by the municipality to take a co-creator role to generate valuable ideas that can meet social needs as defined by [3,13,14].

Finally, as seen on Fig. 4, the implementation of the *Platform for participatory budgeting* by the district of Alna seems to be climbing all steps of the ladder of participation. The district authorities invited citizens to be a part of the decision-making by surveying them, providing a platform to submit ideas and vote on them, and empowered them to make use of the available funds as they wish in accordance with the initial goal of improving the quality of life in the neighborhood. This platform was launched as part of a more global strategy to seek active citizens participation in the district of Alna. Other in-persons events such as community festivals, public hearings and paper-based surveys were also used to secure the participation of those who might not otherwise have used the online platform. The analysis focuses on the example of participatory budgeting as this can be considered as one of the methods that can help achieve a higher degree of citizen participation. Citizens ideas will be concretized with the support from the municipality in financial and human resource. This can be considered as a form of partnership for *Co-management*, in which citizens were empowered to take the role of co-creators in accordance with the theory on participatory budgeting [2,13,16].

Looking at the evaluation of public participation from the municipal stakeholders' point of view, we are considering the process from the initiative to the delivery of the opportunity. One might deem this standpoint as partial in the sense that the number of actual participants is not being considered. However, this study takes a starting point in the minimum legal requirement that expresses no obligation to show results but insists on the responsibility of municipal stakeholders to facilitate the participation of citizens. By showing how the planning and building agency takes further steps to provide opportunity for higher degree of citizen participation at the local level, the analysis considers the role of the authorities as facilitators such as prescribed by the Planning and Building Act.

IV. Conclusion

This paper presents the evaluation of a smart and sustainable development project jointly conducted by actors in academia and municipalities. The purpose of this study was to identify the best practices of public participation in the smart and sustainable development projects. This paper presents a new method of analyzing the municipality's participatory actions. A stronger emphasis is therefore put on the policy-makers' initiatives and their ambition to achieve the highest degree of citizen participation at the local level.

The analytical method exposed in this paper considers the legal context, the preparation of the strategic plan, the plan itself and the implementation of the first project as the basis for analyzing the citizens' degree of participation in smart and sustainable development projects. The results of this study show that the highest degree of citizen participation i.e. empowerment could be achieved by facilitating more active participatory actions already in the preparation of the strategic plan.

This paper is the first step of a joint evaluation by academic and municipal actors seeking to improve quality of life in smart cities by shedding light on participatory processes that could effectively result in citizens being empowered. The academic partner contributed with scientific background, findings from the literature, case study and proposing an analytical tool. The municipality provided access to the projects' information, key people, insider knowledge and practical fieldwork experience and defined the goal of the joint evaluation. In the next step, findings from this study will be presented to the municipal partner in order to assess their relevance and collect feedback on potential gaps that were not identified through the document-based analysis. As a next step in the joint evaluation, the municipality will provide a case in which only minimum legal requirements of public participation were fulfilled.

Findings from this paper can only be considered in the context of the ongoing evaluation. The extent to which citizens were actually given the possibility to influence the project outcomes as well as how much they did involve themselves will be considered in further work. This will also provide the opportunity to look deeper into non-digital processes and how they perform with regards to the different degrees of citizen participation and securing the participation of those who would not otherwise engage in online solutions.

As part of a larger research project in Scandinavia, the analytical method based on the national legal framework and context-specific models of governance has a potential to provide a comparable dataset to identify trends or discrepancies within Nordic municipalities and in other international smart city projects.

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Smart City Assessment: An Integrated Framework

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***Abstract*—This paper presents a two-dimensional model for assessing the readiness of the city for smart transformation. The first dimension of the model is aimed at the evaluation of the readiness of six city divisions (economy, people, environment, living, mobility, and governance). The second dimension measures the development level of different types of city infrastructure, such as information and communication technology (ICT) and non-ICT infrastructure. Non-ICT infrastructure includes buildings, roads, education, and healthcare system. ICT infrastructure is related to the whole technological base of the city (ICT hardware), web and mobile applications available for citizens and guests (ICT software), and digital literacy of the population. The model has been applied to assess the readiness of Turkistan city, which currently undergoes a huge transformation from an ancient town to a smart city convenient for the residents and tourists.**

Keywords - smart city transformation, Kazakhstan, assessment model

I. Introduction

The digitalization process has prompted countries around the world to transform their cities to become "smarter" [1], and Kazakhstan is not an exception. In 2017 the government of Kazakhstan has approved the "Digital Kazakhstan" state program aimed at the digital transformation of the whole country [2] - [3]. According to this program, it is planned to apply smart city projects all over the country, with the priority to the largest cities and cities with good developing potential. One of the cities with high potential is Turkistan, which is located in southern Kazakhstan [4]. The city has 1500 years of rich history being the capital of the Kazakh Khanate and one of the ancient trade centers due to its location on the Silk Road [4]. Turkistan is famous for many tourists mainly by the mausoleum of Khoja Ahmed Yassawi, who has been an influential Turkic Muslim religious scholar. The mausoleum is considered a masterpiece of medieval architecture and is included in the list of the world cultural heritage of UNESCO [4]. Understanding the historical and cultural significance of the city and its high touristic potential, the government of Kazakhstan is currently paying attention to the development of Turkistan [5]. The city has been assigned the status of the regional center of the Turkistan region in 2018 and then, the plan of the city transformation from a small ancient town into a city convenient for the residents and the guests has been approved [5]. Since that time about 450 billion Tenge (about US$ 1.05 billion) has been invested in Turkistan [6], which led to the development of the city in all aspects including the city's smartness. According to government statistics, Turkestan is currently ranked eleventh in the internal ranking of the cities' smartness [3]. However, since Turkistan is an ancient city with old infrastructure, in order to achieve successful smart transformation it is important first to assess the city's readiness for that transformation.

A thorough literature review has been conducted to analyze different models of evaluation of the city readiness for the smart city transformation. The first model has been proposed in [7]. The model is based on six dimensions, such as Smart Governance, Smart Environment, Smart Mobility, Smart Economy, Smart People, and Smart Living. Each dimension is measured based on 3-7 criteria. For example, the level of smartness of the economy is measured based on the innovative spirit of the city, entrepreneurship, city image, productivity, labor market, and international integration. All of the criteria are evaluated based on the indicators (74 indicators in total). The indicators are standardized by z-transformation, and each dimension is calculated as an average of the standardized criteria [7]. This model has been used in many recent works [8]–[10] as well as for the evaluation of the smartness of medium-sized European cities.

Another model is described in [11], which suggests evaluating the city readiness for transformations in three directions. First, to assess the information and communication technology (ICT) of the city, including hardware (wired and wireless networks), software (social, business, and government applications), and the level of digital literacy of the population.

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Secondly, to evaluate non-ICT based infrastructure, such as buildings, roads, laws, regulations, healthcare, and education systems. And finally, to check whether there are any already implemented smart solutions and evaluate the results of their implementations.

McKinsey Global Institute (MGI) proposed a model [12] which evaluates the city in terms of its ICT-based hardware and ICT-based software infrastructures, as well as digital literacy. ICT-based hardware infrastructure, which includes sensing devices, communication networks, and open data portals, constitutes the technological base of the city. ICT-based software infrastructure, which includes websites and mobile applications, is called an application roll-out. Finally, digital literacy is not only about people's ability to use the technology but also about their adoption of the applied smart solutions. MGI provides 32 indicators to assess ICT-based infrastructure and digital literacy.

In this paper, the assessment model of the city readiness for smart transformation is developed based on the three aforementioned models. After that, Turkistan city's readiness is evaluated according to the designed model. The rest of the paper is constructed as follows: Section II describes the proposed assessment model and the methodology of Turkistan city assessment; Section III provides the results of the city's evaluation and discusses how they can be used for smart transformation of Turkistan; Section IV concludes the paper.

II. Methodology

A. Smart city readiness assessment model

The developed model for smart city transformation readiness is illustrated in Fig. 1. The city is proposed to be evaluated in terms of its six divisions given in [7] and at the same time in terms of its ICT and non-ICT based infrastructure as suggested in [11]. ICT-based infrastructure is further divided to software (applications and web systems), hardware (devices and technologies), and digital literacy (public adoption) as proposed by MGI [12]. This model can be used to identify the strengths and weaknesses of urban divisions and types of infrastructure by assessing them separately, as well as to evaluate the city from a broader perspective by combining the two dimensions into one matrix. There are 72 indicators in total, and the amount of indicators corresponding to each city division and type of infrastructure is shown in the yellow boxes in Fig. 1. The indicators have been taken from the papers presenting the assessment models [7], [12] - [13], from the reports of International Telecommunication Union [14] - [15] and from the collection of key performance indicators developed within the United for Smart Sustainable Cities framework [16]. The residents' satisfaction with the city services has been also added as an indicator for each city division. The list of indicators is given in Table I. Each division of the city and the type of infrastructure is evaluated by calculating the score as an average of all corresponding indicators (see Fig. 1).

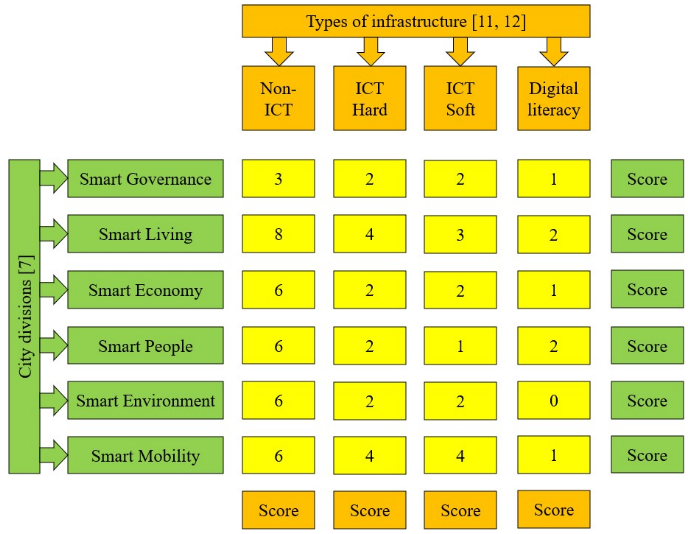

Fig. 1. Two-dimensional smart city readiness assessment model. The numbers in the yellow boxes show the number of indicators used to evaluate each division and type of infrastructure.

TABLE I
THE LIST OF INDICATORS USED TO EVALUATE EACH DIMENSION OF SMART CITY ASSESSMENT MODEL

Smart Governance	
Non-ICT	1) Population awareness about urban development plan [16] 2) People satisfaction with city development 3) People satisfaction with government development
ICT Hard	1) Proportion of government organizations using computer devices [12] 2) Proportion of government organizations connected to internet [12]
ICT Soft	1) Existence of applications for public services [12] 2) Presence of the platform for the dialogue between citizens and the government [12]
Digital literacy	1) Proportion of people using e-government services [14]
Smart Living	
Non-ICT	1) Average living area per inhabitant [7] 2) Percentage of households with access to safe water [16] 3) Average life expectancy [7] 4) Number of doctors per inhabitant [7] 5) Number of public hospitals beds per inhabitant [7] 6) Poverty rate [7] 7) Death rate by assault per 100,000 inhabitants [7] 8) People satisfaction with living conditions
ICT Hard	1) Proportion of smart houses [15] 2) Availability of fixed broadband subscriptions [15] 3) Proportion of households with at least one mobile phone [14] 4) Proportion of households with internet access [14]
ICT Soft	1) Existence of utility applications [12] 2) Existence of safety and security applications [12] 3) Existence of healthcare applications [12]
Digital literacy	1) Proportion of people using an electronic payment system for payment of utilities bills [12] 2) Proportion of people using healthcare applications [14]

Smart Economy	
Non-ICT	1) GDP per capita [13] 2) Number of SMEs per 1000 inhabitants [14] 3) Unemployment rate [7] 4) Self-employment rate [7] 5) Research and development expenditure as a proportion of city GDP [7] 6) People satisfaction with salaries
ICT Hard	1) Proportion of businesses using computer devices [12] 2) Existence of the platform for the exchange of goods and services [12]
ICT Soft	1) Existence of economic development applications [12] 2) Existence of mobile payment system [15]
Digital literacy	1) Proportion of people using online payment systems [12]
Smart People	
Non-ICT	1) Proportion of city inhabitants with higher education degrees [16] 2) Percentage of preschool aged children covered by day-care centers [16] 3) Number of school teacher per 1000 inhabitants [16] 4) Students per inhabitant [7] 5) Percentage of young people participating in volunteer work [7] 6) People satisfaction with the quality of education facilities
ICT Hard	1) Proportion of students with classroom access to ICT facilities [14] 2) Existence of schools with 3D equipment [12]
ICT Soft	1) Existence of education applications [12]
Digital literacy	1) Education of adults on the use of digital tools 2) Education of children on the use of 3D printing, programming and robotics
Smart Environment	
Non-ICT	1) Green space share [7] 2) Sunshine hours [7] 3) Greenhouse gas emissions per capita [13] 4) Percentage of renewable energy consumed in the city [13] 5) Proportion of wastewater receiving treatment [13] 6) People satisfaction with ecological situation
ICT Hard	1) Proportion of waste receptacle sensors [12] 2) Existence of the platform with waste collection information [12]
ICT Soft	1) Existence of applications in air and water quality tracking [12] 2) Existence of the smart waste management system [12]
Smart Mobility	
Non-ICT	1) International accessibility level [7] 2) Public bus per capita [13] 3) Cars per capita [13] 4) People satisfaction with pedestrian [16] 5) People satisfaction with the quality of roads 6) People satisfaction with parking
ICT Hard	1) Free public Wi-Fi coverage [12] 2) Proportion of busses equipped with GPS sensors [15] 3) Presence of the platform with real-time information on transport system [12] 4) Coverage of regions by mobile connection [15]
ICT Soft	1) Existence of applications in sharing and e-hailing [12] 2) Existence of applications in traffic management and data services [12] 3) Existence of applications in urban cargo [12] 4) Existence of navigation application cargo [12]
Digital literacy	1)Proportion of people willing of smart mobility solutions [12]

B. Turkistan assessment methodology

The proposed model has been applied to evaluate the readiness of Turkistan city for smart transformation. The assessment has been conducted according to the five-point Likert scale, where 5 corresponds to the highest level of the city readiness. The values of the indicators related to Turkistan has been taken mostly from the official strategy of city development [17], which contains statistical information about Turkistan and surveys of residents about their satisfaction with the city. The rest of the values have been taken from the ”Smart Turkistan” website dedicated to the forum on digitalization of the Turkestan region [18], from the online newspaper about the south of Kazakhstan [19] - [20], from the paper presented on the student forum of the University of Turkistan [21], and from the websites which publish official data and statistics about Kazakhstan [22]–[27]. The conversion of values to the five points Likert scale differs depending on the indicator. For example, the indicators measured by non-quantifiable values are assigned a particular score, namely ”yes” (score = 5), ”no” (score = 0), and ”equipped, but not used” (score = 2.5). The indicators measured as a percentage (proportions, satisfaction rates) are converted to scores by taking 5 as 100%. The conversion of the rest of the indicators to the scores is performed with the following equations:

$$Score = (1 \pm \frac{Value - Benchmark}{Benchmark}) \times 2.5 \qquad (1)$$

The equation has been taken from [13], who have also presented the smart city assessment model with the list of the indicators. Regarding the $\pm$ sign in this equation, the plus sign is used for the indicators that have a positive influence on the city ranking (the higher the value the higher the score), while the minus sign is applied to calculate the score of the indicators with a negative influence. Since the assessment model is mostly based on the model proposed in [7], which has been used to assess the European cities, the benchmark for the indicators is assumed to be equal to the average value of all European cities. Therefore, the benchmark values have been mostly taken from the ”Eurostat” website which provides the statistics about Europen countries [28] and from [13].

III. Results and Discussion

Figure 2 and Figure 3 provide the results of the Turkistan city evaluation according to the proposed smart city assessment model. The scores for each model dimension (city division and type of infrastructure) were calculated as an average of the scores of all corresponding indicators (listed in Table I). The average score of city readiness is 2.56 out of 5, which implies that not all city divisions are prepared for the smart transformation.

The readiness level of each city division is illustrated in Fig. 2. As can be seen, the Smart Governance division is the most prepared for smart transformation (scores = 3.89). This is because of the strong ICT hardware and software base, namely the digitized governmental services and convenient applications. Smart People division has also obtained a high

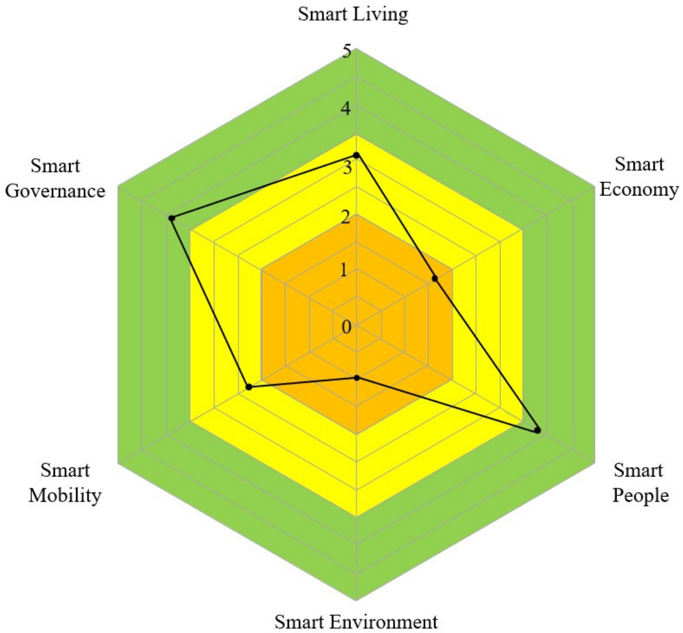

Fig. 2. The results of the assessment of the city divisions of Turkistan. The level of readiness is divided into good (green zone), average (yellow), unsatisfactory (orange).

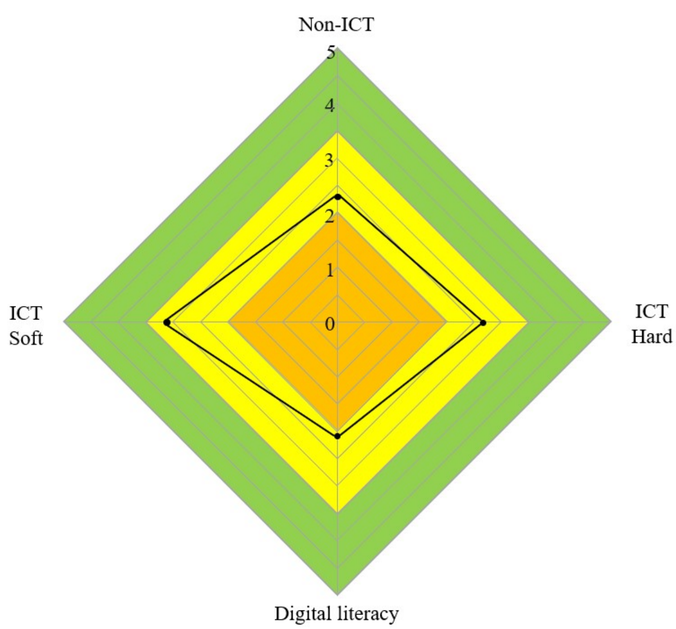

Fig. 3. The results of the assessment by the type of infrastructures. The level of readiness is divided into good (green zone), average (yellow), unsatisfactory (orange).

score of 3.87 because of the good non-ICT and ICT infrastructure, but there is no information about the digital literacy of city residents. The two aforementioned divisions are in the green zone in Fig. 2, but the rest of the them are less prepared for the transformation. Smart Living is in the yellow zone (score=3.06), because the non-ICT living conditions have scored less than an average (living area per inhabitant and household access to drinking water). Moreover, despite the developing ICT hardware and strong ICT software infrastructure (several applications for every-day life), the digital literacy is lower than average. On the other hand, the Smart Mobility division has a relatively high score of digital literacy, but lacks the ICT hardware (absence of free public Wi-Fi and real-time information about transport system) and software infrastructure (absence of navigation applications). The quality of roads can be also improved, therefore Smart Mobility has scored 2.31. Smart Economy with a score of 1.68 and Smart Environment with a score of 0.54 are the most lagging divisions of the city. The economic situation in the city (GDP, salary level) is poor, and despite the introduction of some ICT solutions, their usage is also very low. The ecological situation in the city is moderate (the warm weather and low carbon emissions, but a small number of parks). However, there is no usage of renewable sources (while the sunshine hours allow application of solar panels) and undeveloped ICT infrastructure.

Thus, the assessment of Turkistan has shown that most of the efforts have been put on Smart Governance and Smart People, while the rest of the divisions still needs to be developed. Smart Mobility has a good level of digital literacy, but non-ICT infrastructure (roads) and ICT infrastructure (applications and Wi-Fi coverage) should be improved. The oldness of the city has influenced mostly Smart Economy and Smart Living divisions, so their non-ICT infrastructure is not ready for smart transformation. Therefore, more attention should be paid on the living conditions, the number of SMEs, and salary levels of the city residents. Smart Environment division has the lowest score, but the potential of Turkistan in this division is promising because of the good weather conditions. So, more renewable energy sources and waste treatment systems should be applied in the city.

IV. Conclusion

The proposed model for assessment of city readiness for smart solutions evaluates the city in terms of two dimensions: six city divisions and four types of infrastructure. This allows identifying the weaknesses of the city and pay attention to them before and during the smart transformation process. For example, the evaluation of Turkistan city with this model helped to identify that more effort should be put into the Smart Economy, Smart Environment and Smart Living divisions because of a low score of their non-ICT infrastructure. ICT (both hardware and software) infrastructure should be developed for Smart Mobility and Smart Environment, and digital literacy should be improved for almost all divisions, especially Smart Economy. Moreover, this model can be further extended to a

3D matrix by adding time as a third dimension. As a result, the model can be applied to measure the development of each city division and type of infrastructure with time during the smart transformation process.

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Analysis of Potential Project Work Accidents: A Case Study of a Construction Project in Malaysia

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***Abstract*—The Construction Industry has always been regarded as one of the most taxing job domains with extreme high hazards and risks as well as occupational safety issues. Hence, there is extreme importance set upon the task of identifying the hazards and the cause of accidents on-site to reduce and diminish the injuries and fatalities rate. The main goal of this research is to identify and assess the hazards of a construction project using Decision Tree Analysis and Python Programming. This research also aims to determine the cause of the hazards and occurrence and propose recommendations. The discoveries through this research shows a lack of approach to the cause of accidents, which is a weakness in the current construction industry. By using Decision Tree Analysis through Python Programming, the cause of accidents and hazards were determined. The research results showed the cause of accidents through various categories and affirms the cause of accidents in the construction project. Based on the research outcome, recommendations are proposed to mitigate and reduce the cause of accidents.**

Keywords—construction project, cause of accidents, decision tree analysis, python programming

I. Introduction

A lot have been said about the obligation of companies, factories, industries and institutes to care for the safety and well-being of workers. However, to include them as parties that care for these aspects seems to be lost. There is no denying that Southeast Asian countries are on the rise of developments in multiple sectors including construction projects and that includes Malaysia. However, these uncontrollable developments have taken quite a toll on the safety aspects which can no longer be ignored and pushed away. Industries and companies have always been vague about the implementation of safety and health management but with the recent increase in accidents in the construction industry, this area has become a central point that joins the narrative of this research. The death of a Bangladesh worker killed by a collapsed scaffolding while walking onsite further strengthens the current notion [1].

Construction Industry in Malaysia has been categorized as one of the demanding job domains with extreme high hazards and risks as well as occupational safety issues [2]. However, the lack of indication on the exact extent of execution of health and safety management and the state of maturity of these operations in local construction industries makes it more challenging for the identification of potential work hazards [3]. This situation makes it a common occurrence to hear incidents in the construction that results in injuries, illnesses and fatalities to workers and members of the public.

With the massive expansion of the construction industry, there is bound to be the problems faced in this industry. Unsafe work behaviour is one of the many causes of accidents but to highlight just one would be a wrong statement. Negligence seems to be the more apparent cause for accidents in the construction site [4]. Besides, the failure to report near misses develops a lack of sensitivity to the safety aspect in the construction industry. Near misses are defined as "an anomaly that signals the potential for more severe consequences that may occur in the future, due to causes that are discernible from the occurrence today" [4]. Similarly, the negligence to avoid keeping data on near misses seems to contribute to the apparent cause of accidents. Moreover, the straining work hours for long periods are bound to be part of the cause of accidents because workers will end up losing concentration which results in injuries and fatalities.

In addition to that, the lack of legal action and enforcement on work accidents makes it easier for corporations to escape from the brunt of the law. In most cases, the law enforcement is weak to the extent that fatalities in the construction industry are almost pushed aside and corporate leaders can escape by mere actions of resigning without facing a substantial fine or number of years behind bars. The surprise resignation of CEO of MRT Corp was seen by many as a virtue after three men had been killed in a worksite accident but this is merely publicity in order to subside the issue at hand and wait it out until the right time to face the media in the future [5]. The underlying question here is why the corporation was not charged and why is there no news regarding the resignation of the responsible staffs on site that are related to this incident [5].

However, a more prominent cause to the accidents in the local scene is because of influx of foreign laborers without experience and valid permit. For example, the collapsed structure in Taman Desa condominium construction project was built by illegal foreign workers without valid permit [6]. This shows a profound reason for why accidents in the construction site are continuously associated with foreign workers.

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However, most companies choose to disregard these issues because there is no substantial proof to validate such reasoning. Hence, in this study, we will introduce Decision Tree Analysis (DTA) with the aid of Python Programming to analyze a set of data from a construction project within the Golden Triangle of Kuala Lumpur in Malaysia. The project owner/client is a well-known international retail chain who provided the researcher with safety incidents data. The results uncover the causes of accidents and thus affirms the current problems in the industry at large.

II. Literature Review

The literature review explores the fundamental accident theories and how each theory brought up new information and understanding to the safety analysis in the industry. Besides, the literature review will also navigate through different types of analysis and select the best method to be used in this research. The literature review will explain briefly on how the hazards are identified and assessed based on the data collected from a construction project.

A. *Accident Theories*

Accident theories started with Heinrich's Pyramid. Heinrich's Pyramid worked on the principle that invariably, the event of injury outcomes from a series of variables where the accident itself is one variable. Heinrich claimed that there must be five elements involved in an incident including heritage and social environment, hazardous behaviour, motorized or physical hazard, personal responsibility and the injury as shown in Fig. 1. These factors then correspond to a Domino Theory for accident causation which represents a causal chain of events based on the foundation of the pyramid. According to Heinrich, the injury will not occur, if this series is elimination by the exclusion of even one of the many comprised factors [7].

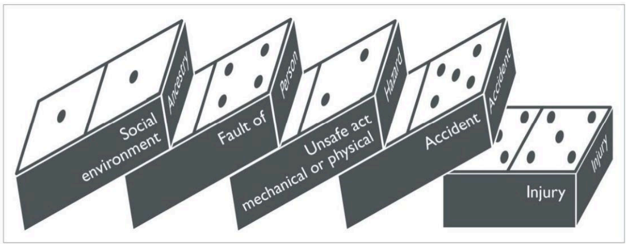

Fig. 1. The Domino model of Accident Causation

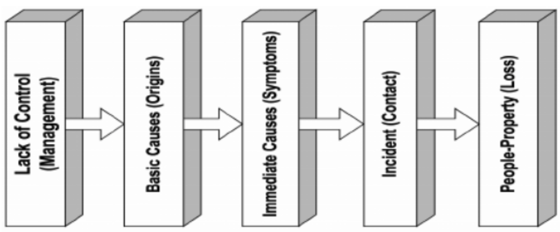

Fig. 2. The Domino Sequence introduced by Frank Bird

However, this was later improved by Frank E.Bird's Modified Domino theory. Bird critiqued the pyramid due to the primary constraints of associating too much risk with inner variables towards workers and overlooking the significance of external variables. The proposed modification presented actions of management failure and error into the hazard causation sequence as shown in Fig. 2 [8]. The main two new concepts that were attributed by Bird was the inclusion of the influence of management and managerial error, accidents and hazards due to production losses, properties damages or wastage of other assets as well the injuries. Although workers agreed with Bird's theory, construction managers did not accept this Domino Theory as broadly because Heinrich's proposed theory leaves them out of the equation as blaming workers is easier and less costly than training workers [8].

Through the years, these two accident theories were later improved in the 80's by three engineers. The Hazard Control Model as shown in Fig. 3 by Dawson, Poynter and Stevens proposed a model to control and reduce hazards. Their proposed method works on the basis of anticipating and realizing a hazard followed mainly by the control method of elimination, containment and mitigation. This was mainly to improve on the linearity of the proposed Domino Models by Heinrich and Bird [8].

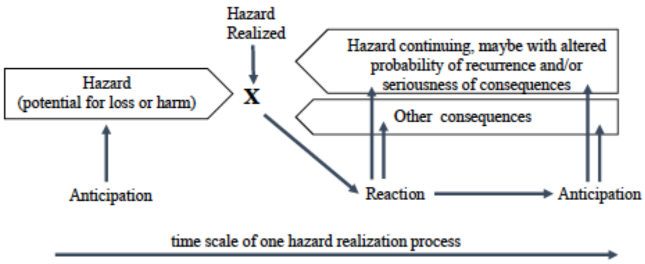

Fig. 3. Anticipation and reaction in the hazard realization process

B. *Various Methods for Safety Analysis*

Various methods for Safety Analysis were researched and analysed to determine the best possible application.

Fault Tree Analysis (FTA) and Event Tree Analysis (ETA) methods are mainly traditional methods in the eyes of data mining industry. FTA is an inferential top-down investigative technique that visually illustrates a failure route or chain. The fundamental notion of FTA follows the Boolean logic, which makes it possible to create a sequence of reports built on a true or false concept. ETA bases itself on the same proposition that includes binary logics for situations where incidents have occurred or when a particular constituent have failed. ETA is a constructive and modelling way of detecting and analysing the different events of pragmatic accident possibilities with safety features following an initial event [9]. However, these two applications do not introduce a more comprehensive way to determine the cause of accidents and will not improve the current construction industry.

Decision Tree Analysis (DTA) is an alternate method to FTA and ETA and is widely used for Data Mining and Data Analysis. DTA has been regarded as one of the most practical ways for creating inductive reasoning over sets of data. A decision tree is a process, based on different attributes, which classifies the categorical data. In addition, a decision tree can be used to analyse vast amounts of data which are largely used in applications involving data mining. Constructing decision tree does not require the knowledge of the domain which is why it so useful to implement them in different domains for analysis. Furthermore, the way the decision tree represents the data makes it easy for non-domain individuals to understand as the tree form is very intuitive [10]. In a sense, it uses a set of data to determine the probability of each outcome whereby one category leads to another and can be visualized for easier understanding and analysis. Although DTA has been widely used for many industries but rarely applied to the safety industries mainly because safety officers choose to adapt the previous methods as it is more convenient. As mentioned in [11], the decision tree was able to be used for analysis and prediction of diabetes complication diseases and was able to be used for doctors to help predict these complications. The only limitation here is that it requires expert from data mining or individuals who have been trained in python programming to create the decision tree using coding and programming. Fig. 4 shows the DTA used in Wireless Indoor Localization employing Python programming.

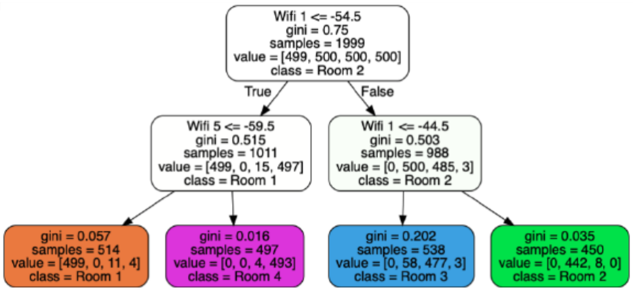

Fig. 4. DTA with Python Programing for a Wireless Indoor Localization

Failure Mode and Effect Analysis (FMEA) worked on the principle of identifying future errors that may occur in the development of a product or process in the production line and manufacturing industry hence it is not to be included to determine the cause of accidents in the construction industry. Structural Equation Modelling (SEM) on the other hand focusses on the multilevel safety intervention behaviour between a set of parameters whereas Monte Carlo Simulation is widely used for probabilistic, graphical and sensitivity analysis.

In this research, among these analysis methods, the DTA was selected mainly because it can relate each categorical outcome to one another. The DTA through Python Programming can be visualized and are simple to interpret and understand. Besides, they require little data preparation while other strategies also include data normalization, dummy variables formation and blank values removal [10]. The cost of using the Python Programming to create the tree analysis is also cheaper when compared to creating it with FTA or any other application because they require a specific type of programs. Whereas, Python Programming is a freeware. In addition, DTA through Python Programming can handle both categorical and numerical data whereas other techniques are specialized for only one type of variables [11]. Lastly, the DTA by Python Programming is a new tool that has not been incorporated in the construction industry because engineers choose to rely on older applications and stay within their comfort zones instead of broadening their horizons through the data mining industry.

C. *Decision Tree Analysis and Python Programming*

The Python Programming relied on several libraries such as NumPy, Pandas, Statsmodels and Sklearn. The algorithm used are ID3, CART and GINI Index. These libraries and algorithm were necessary to create the DTA. The Identification of the Hazards was done by interpreting the raw data and then classifying them according to specific type of work and their respective hazards. This was done with the advice and discussion with the Safety Director of the project owner/client. These Type of Works and Hazard Identification will be the fundamental classification when the DTA is created through Python Programming.

III. Methodology

The methodology of the DTA is based on a Python Programming Method and Knowledge Discovery Databases (KDD). Through this method, a comprehensive data selection was done through the means of extracting raw data and creating a Hazard Identification and Assessment. Then, data pre-processing was conducted through means of rectifying missing data, cleaning and retracing them [12].

These data are then transformed through a data transformation process and assigned unique values based on several categories. These are then imported into Data Mining with the help of libraries and algorithms. The Data Mining here includes checking data, transforming them and creating the DTA with the right coding. The created DTA will be then analysed with proper knowledge and understanding of the engineering domain. Fig. 5 depicts the KDD methodology employed in this research.

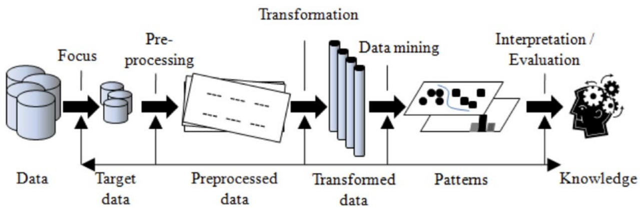

Fig. 5. The KDD Process

A. *Type of work and Hazard Classification*

The type of work and hazard classification for analysis throughout this research was based on the selected construction project. The focus here was on general works which occurred on a daily basis.

The Identification of the Hazards was done by interpreting the raw data and then classifying them according to specific type of work and their respective hazards. This was done with the advice and discussion with the Safety Director of the project owner/client. These Type of Works and Hazard Identification will be the fundamental classification when the DTA is created through Python Programming. The type of work and possible hazard classification is generalized to make it easier for data mining analysis. Table I shows the parts of raw data before the identification and assessment of hazards. Table II shows the Type of Work and Possible Hazard Classification.

TABLE I. Parts of Raw Data before the Identification and Assessment of Hazards

Brief description of sample accidents
• Ground condition gave away while relocating elevated work platform. • Table form work topple down to ground level from Zone 1 temporary Loading Bay. • Worker was too close to circular saw when plugged in to socket thus injuring his left leg with deep cuts. • While lifting bundle of roof metal sheet, the lifting belt slipped and made the roof metal slanted causing it to drop onto the same level slab. • While worker was transporting debris to waste bin, operator lift the bobcat basket to avoid collision between the plywood for finish floor protection. However, the bobcat arm lift-up mechanism malfunction causing bucket to lift non-stop until hit overhead fire sprinkler main pipe and air conditioning ducting above. • Worker having minor cuts after exposed to sharp edges of hacked debris while cleaning up the tile debris.

TABLE II. TYPE OF WORK AND HAZARDS

Type of Work	Hazard Identification
Lifting Object	• Equipment Falling due to Human Error • Equipment Falling due to Machinery Failure • Machinery Failure • Struck by Object • Environment Condition
Dismantling	• Equipment Falling due to Human Error
Hacking and Demolishing	• Equipment Falling due to Human Error • Struck by Object
Installation	• Equipment Falling due to Human Error • Struck by Object
Transfer equipment, material or object	• Equipment Falling due to Human Error • Struck by Object • Machinery Failure
Cutting Materials	• Human Error • Struck by Object
Compressing Materials	• Human Error
Plumbing	• Human Error • Struck by Object

B. Data Selection and Preprocessing

From the Incident Reports obtained from the construction project, data were arranged according to “Date”, “Project”, “Project Type”, “Contracted By”, “Brief Description”, “Age”, “Gender”, “Nationality”, “Name of Injured Person”, “Months on Project”, “Location”, “Working Hours”, “Incident Time”, “Type of Work”, “Injury Type”, “Mechanism of Injury, “Hazard Type”, and “Authorities Reported”. In order to determine the authenticity of data, the author did the cleaning and retracing multiple times to allow for easy creation of the decision tree. Table III shows the parts of the data after cleaning and retracing.

TABLE III. PARTS OF THE DATA AFTER CLEANING AND RETRACING

A[a]	N[a]	TW[a]	H[a]	W[a]	T[a]	M[a]	L[a]
31	MYS	Lifting Object	Environment Condition	12	11 00	24	B
41	MYS	Lifting Object	Environment Condition	12	10 00	60	I
37	BGD	Lifting Object	Equipment Falling due to Machinery Failure	20	10 30	24	B
32	BGD	Lifting Object	Equipment Falling due to Machinery Failure	20	11 30	18	B
28	BGD	Hacking & Demolishing	Equipment Falling due to Human Error	20	11 00	7	B
31	BGD	Installation	Equipment Falling due to Human Error	20	11 30	15	B
41	PAK	Compressing Object	Human Error	20	16 10	60	I
35	PAK	Cutting Object	Human Error	20	19 50	7	
28	BGD	Lifting Object	Machinery Failure	20	20 30	12	B
26	BGD	Transfer Object	Machinery Failure	20	09 45	11	B
33	PAK	Hacking & Demolishing	Struck by Object	20	11 30	9	B
31	BGD	Lifting Object	Struck by Object	20	08 20	8	B

[a.] A– Age; N – Nationality; TW –Type of Work; H – Hazard Type; W – Working Hours; T – Incident Time; M – Months on Project; L – Knowledge Level; B – Beginner; I – Intermediate

C. Data Transformation

Once the data has been collected, cleaned, retraced and reverted to clear and simple terms. The data will be transformed into unique values. The unique values here refer to how the data will be analysed for the creation of the decision tree. Based on the preprocessed data, the data transformation will assign unique values to a certain column for the algorithm to analyse the decision tree. For an example, “Nationality” will be assigned unique values based on the number 0,1,2,3,4. “Type of Work” will be assigned unique values based on the number 0,1,2,3,4,5,6,7 and so on. Table IV shows the parts of data with assigned unique values.

TABLE IV. PARTS OF DATA WITH ASSIGNED UNIQUE VALUES

A[a]	N[a]	TW[a]	H[a]	W[a]	T[a]	E[a]	L[a]
31	3	5	0	12	1100	24	0
41	3	5	0	12	1000	60	2
37	0	5	2	20	1030	24	0
32	0	5	2	20	1130	18	0
28	0	3	1	20	1100	7	0
31	0	4	1	20	1130	15	0
41	1	0	3	20	1610	60	2
35	1	1	3	20	1950	7	0
28	0	5	4	20	2030	12	0
26	0	7	4	20	0945	11	0
33	1	3	5	20	1130	9	0
31	0	5	5	20	0820	8	0

[a.] A– Age; N – Nationality; TW –Type of Work; H – Hazard Type; W – Working Hours; T – Incident Time; M – Months on Project; L – Knowledge Level

D. Data Mining and Decision Tree Creation

After data transformation, data mining was carried to create the decision tree. Fig. 6 and Fig. 7 shows Transformation of Data and Decision Tree Creation respectively using Python Programming.

```
In [10]: class MultiColumnLabelEncoder:
             def __init__(self,columns = None):
                 self.columns = columns # array of column names to encode

             def fit(self,X,y=None):
                 return self # not relevant here

             def transform(self,X):
                 '''
                 Transforms columns of X specified in self.columns using
                 LabelEncoder(). If no columns specified, transforms all
                 columns in X.
                 '''
                 output = X.copy()
                 if self.columns is not None:
                     for col in self.columns:
                         output[col] = LabelEncoder().fit_transform(output[col])
                 else:
                     for colname,col in output.iteritems():
                         output[colname] = LabelEncoder().fit_transform(col)
                 return output

             def fit_transform(self,X,y=None):
                 return self.fit(X,y).transform(X)
```

Fig. 6. Data Transformation

E. Interpretation and Evaluation

Once the data is created, the researcher is to interpret and evaluate the decision tree.

F. Knowledge

During this phase, the researcher to apply necessary knowledge to understand and propose recommendations based on the results and discussion.

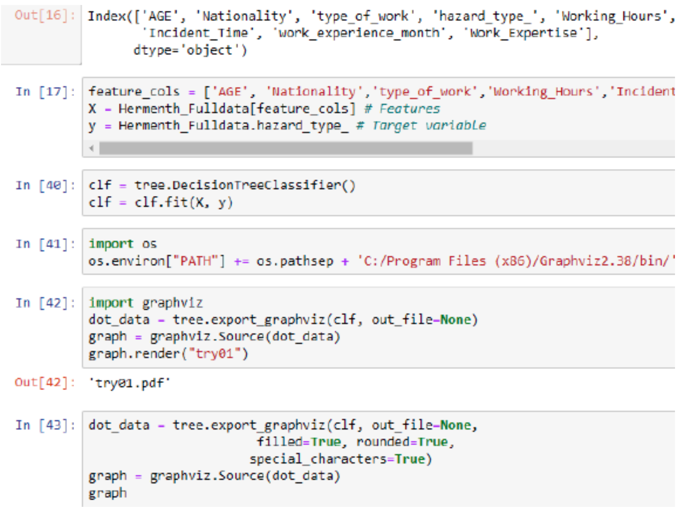

Fig. 7. Decision Tree Creation.

IV. Analysis And Discussion

Fig. 8 shows part of the decision tree created through Python Programming.

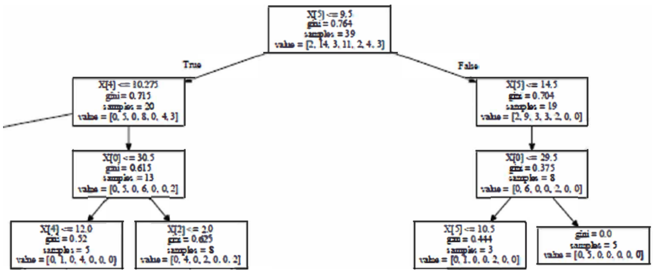

Fig. 8. Part of the Decision Tree

Decision tree will always show two different set of probabilities when it is evolving to the next set of categorised data. It will breakdown the probabilities into "True" and "False" and those will be further broken down into the next nodes until the tree cannot be evolved. GINI Index shows percentage of the category from occurring or not. If it is more than 50%, it is likely to happen, if it is less than 50%, it is likely to not occur. The samples indicate how many data is used for analysis and the value sums up the total number of samples for each category that is used to analyse the Decision Tree.

For illustration purpose, the following section demonstrates the Left Node of the Decision Tree for Knowledge creation and understanding of the cause of incidents.

In order to interpret the Decision Tree, three different colours have been assigned for easy understanding. Yellow colour represents the "True", Red colour will represent the "False" and green will represent "Neutral". Neutral here represent the end point of the Decision Tree, this means that the Decision Tree cannot be evolved anymore. Fig. 9 depicts the Left Node of the Decision Tree which breaks down the "True" and "False" node for analysis.

When analysing the Left Node, it can be concluded that accidents occurs around 9.50 pm because workers have been working for long extreme hours which is around 10.3 hours duration. This accident that occurred involved Lifting works which cause possible hazards such as Equipment Falling due to Human Error, Equipment Falling due to Machinery Failure and Human Error, Machinery Failure, Struck by Object and Environmental Condition. In addition to long working hours, the workers who are working on this type of work are foreign workers specifically Pakistan nationalities and they fall under the age group of 34 or lower which is classified as beginners based on working expertise and working duration on their job in months.

Meaning	Colour
True	
False	
Neutral	

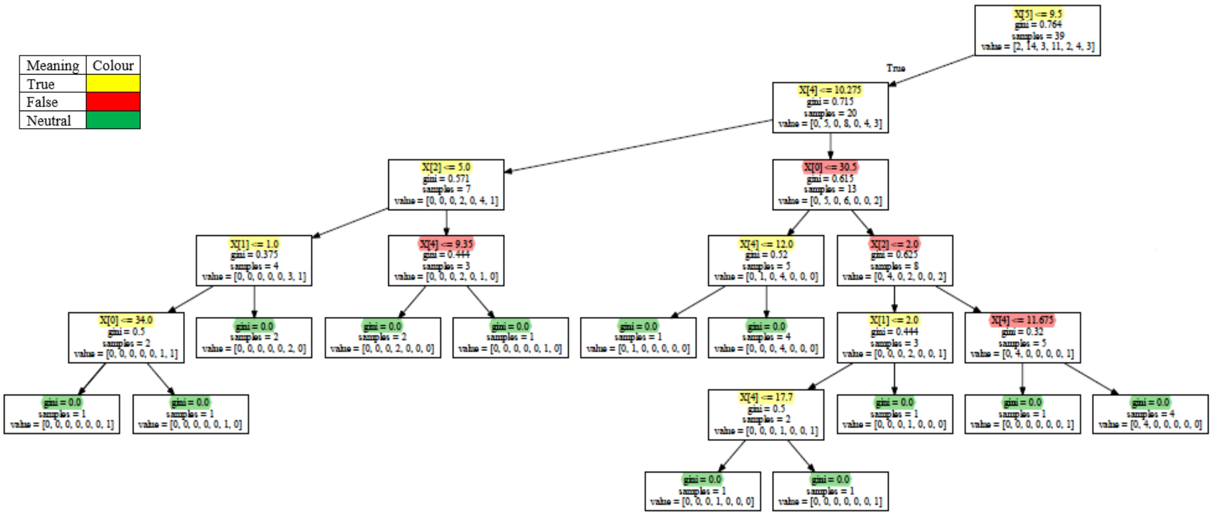

Fig. 9. Left Node of the Decision Tree

When comparing the validity of the "True" value, the GINI index shows that the possibility of the Incident Time and Working Hours is at 76.4 % and 71.5 %, the probability of the type of work being Lifting Work is 57.1% and the probability of working expertise at age of 34 and lower is around 50%. As such, it can be concluded that this entire node shows the causes of accident related to the specific type of work which is Lifting Work which cause potential hazards as discussed before in Table II.

V. Conclusion And Recommendations

The research shows how the Decision Tree Analysis (DTA) can be applied to construct the cause of accidents and hazards. The DTA was able to show in detail the cause of such accidents happening at a specific time frame due to working hours, nationality, workers expertise level which falls under the age and the duration of work in months. This can be further analysed with the help of GINI index to determine the validity of each categorised data. Hence, DTA is extremely useful to show categorical relation between a set of data to help to minimize accidents specifically in the construction industry.

A major recommendation is to ensure workers are equipped with knowledge from OSHA Safety Checklist and DOSH Guidelines in the industry. Ignorant workers are the most dangerous and their mistakes put everyone else at risk which is why understanding of perils in hand and having a state of alertness is the best way to prevent accidents [13]. In addition, training is required for the foreign labors. These workers are usually brought in with no filtration on working expertise [14]. As such, necessary training is required to educate workers regardless of experience to reduce the number of injuries and fatalities. Construction companies should adopt genuine documentation instead of blurring pictures and keep missing data intentionally as this will help predict future accidents.

Local construction companies should adopt a proper standard of procedure such as ISO 45001:2018. This allows a framework to improve employee safety, reduce workplace risks and create better and safe working conditions through yearly audits [15]. Construction companies should be strict with the enforcement of personal protective equipment (PPEs) which can minimize the exposure to injuries in the workplace [16]. Lastly, local companies should adopt a healthy work life balance by providing adequate living quarters, adopting alternating work schedules and reducing long working hours [17]. These as a whole, can substantially reduce the number of accidents in the construction industry.

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Smart City Replication and Group Model Building: A Conceptual Comparison

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***Abstract*—In order to accelerate the sustainability transition in cities and to overcome existing challenges in urban areas, local authorities are pressured to find effective means and solutions. Due to that, the concept of replication has been attracting more attention. Replication is based on the common understanding that cities benefit from a more or less formalized exchange of information, experiences, ideas and technical solutions. Policymakers such as the European Commission have incorporated the idea of replication into their smart city initiatives and funding schemes. However, replication strategies fall short of expectations and, in their current form, have limited applicability to urban transformation projects. Therefore, this paper aims to identify the current challenges in this area and discuss the possibilities to overcome them using the problem-solving technique of Group Model Building (GMB). Advantages of Modeling results in advantages regarding the generation, perception and handling of information. However, there are also fundamental and structural barriers in the replication process that cannot be addressed by GMB.**

Keywords—smart city, replication, group model building, system dynamics, urban transition

I. Introduction

The omnipresent global challenge of climate change becomes in particular apparent in cities where extreme weather events lead to temporary but also lasting interferences on basic urban infrastructure, services and therefore on urban life. At the same time, cities contribute to this development significantly since their CO2 consumption account for 75 percent of global CO2 emissions [1]. However, cities are not only seen as victims and drivers of climate change, but also as potential solution. While pursuing and meeting sustainability goals at the global level is difficult, there is consensus that sustainability goals are achievable through systemic changes in technology, new policies, and behavioral incentives at the city level [2]. As Michael Bloomberg, former Mayor of New York put it, “While Nations talk, cities act”[1]. This premise is also valid in light of the fact that cities itself are considered complex adaptive systems, with non-linear dynamics, high diversity, and unpredictability [3].

With the emergence of this narrative, the concept of replication gained momentum. Replication is perceived as an essential building block of urban transformation and based on the common understanding that cities benefit from a more or less formalized exchange of information, experiences, ideas and technical solutions. It is assumed that cities, albeit different in many characteristics, deal with similar challenges and are therefore able to exploit the knowledge about successfully implemented practices. The European Commission incorporated the idea of replication into their smart city initiatives and funding schemes, which shed further light on corresponding approaches for local authorities and smart city research [4]. This development led to further use cases and empirical data in this specific area. Through this broader theoretical and practical basis, weaknesses and shortcomings of replication activities also became clearer, which is why the replication approach chosen by the European Commission is not without criticism.

In this paper, the author picks up the state-of-the-art findings in this field, reflect on the identified gaps as well as existing challenges and then match these demands with the possibilities of group model building, a complex-problem-solving technique.

Therefore, in section II the fundamentals from literature about replication and system modelling are introduced. Based on that, the research approach has been defined which comprises a systematic snowballing literature and a conceptual comparison with the possibilities of group model building. The research design is described in section III. Detailed findings are shown and discussed in section IV, which allowed to draw further conclusions and to give recommendations (section V).

II. Fundamentals

A. Replication of Best Practices

In smart city literature and urban development, the process of replication refers to the respective translation to another location [5]. The results from one pilot case are transported or "copied" to other geographic areas, albeit under possibly different boundary conditions [4].

In this context, it is rather loosely defined what actually could be the object of replication. This is due to the close link of the concept of replication with the notion of best practices. Best practices can be broadly seen as specific technical, regulatory, strategic, informational, financial or restructuring measures [6]. Using best practices follows the prevailing view that the best solution does not have to be developed individually. Instead, it is systematically examined which solutions are already available in other institutions and whether these can be transferred to one's own context [6].

B. System Dynamics

System Dynamics (SD) is a methodology for holistic analysis and simulation of complex and dynamic systems developed by Jay W. Forrester. It provides effective decision support in situations characterized by both cause-effect relationships and feedback relationships. Qualitative systems thinking and quantitative systems simulations provide a framework construct that can be used to identify

[1] Mike Bloomberg on Twitter: "While nations talk, cities act. The @C40Cities Mayors Summit will advance urban solutions to combat climate change: http://t.co/y6BFlbAmuH" / Twitter

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interrelationships instead of linear cause-effect chains. This supports the understanding of complex and dynamic systems [7]. Because cities evolve organically over time, this system dynamics approach is suitable for providing policy makers with evidence to consider in their efforts to make cities more livable and sustainable [8].

The goal of such an approach is to understand how such dynamic behavior patterns are generated and to find starting points that have the potential to change a negative trend in a desirable direction. Due to its long-term perspective, SD is particularly useful for sustainability issues [7].

C. Group Model Building

Group Model Building (GMB) as participatory form of SD allows the interaction with stakeholders and their engagement into a wide range of processes and activities, such as policy making, strategy development and implementation as well as intra- and inter-organizational agreement [9]. According to [10], GMB is "a process in which team members exchange their perceptions of a problem and explore questions such as: what exactly is the problem we face? How did the problematic situation originate? What might be its underlying causes? How can the problem be tackled?" GMB is used in group decision-making and problem structuring. It is usually conducted within formal workshop settings, that include the following steps: Articulating the problem, Formulating dynamic hypotheses about the system's behavior, Formulating a system dynamics model, Testing the model and Formulating potential strategies and evaluation [11]. The exercises often revolve around the construction and discussion of a causal loop diagrams from SD.

With the increasing application of GMB across different disciplines and use cases, various benefits have been documented in academic literature. The comprehensive review in [23] revealed six distinct benefits for the modeling approach: Accordingly, GMB enables the harmonization and alignment of different ideas (1), the questioning of existing preferences (2), the streamlining of information and communication flows in a process (3), a better use of information (4), an enhanced problem understanding (5) and an increased confidence in decision-making (6). Further summarized, modeling provides Attached importance to critical information, enhanced problem understanding and increased confidence in decision-making.

III. Research Design

This paper aims to identify the potentials of GMB in replication processes following the research question "How can replication processes benefit from GMB activities?" Results are obtained from a systematic literature review and a conceptual comparison of the two research fields.

In a first step, relevant publications were analyzed and barriers in the replication of smart city initiatives were identified. For this, a systematic literature review has been conducted, complemented by snowballing approach based on [12] has been applied to extract relevant publications from the databases Web of Science and SCOPUS. Since the topic is of application-based nature, there are also relevant findings that have been published in form of grey literature e.g. by municipalities, policy makers or applied science. To make sure to cover also these information sources Google Scholar has been used to add further documents that are not listed in journals but are still of relevance. A five-year period was chosen for the sample (from 2016) to capture the current debate.

Starting with the keyword „smart city" in combination with "replication", "transition" and "best practice" a start set of papers has been chosen and selectively complemented by publications that the snowballing revealed. Again, only publications from 2016 or later were taken into account.

The papers shown in Table I have been regarded.

TABLE I. Sources of Literature Reveiw

Reference	Author(s)	Publication Year	Source / Snowballing
[13]	S. O. M. Boulanger and N. C. Nagorny	2018	Google Scholar
[14]	P. Cardullo and R. Kitchin	2018	Web of Science / SCOPUS
[15]	A. Labaeye	2019	Web of Science / SCOPUS
[16]	A. J. Meijer, J. R. Gil-Garcia, and M. P. R. Bolívar	2016	Web of Science / SCOPUS
[17]	W. van Winden and D. van den Buuse	2017	Web of Science / SCOPUS
[18]	M. W. Wathne and H. Haarstad	2020	Google Scholar
[19]	H. Vandevyvere	2018	Google Scholar
[20]	A. L. Azevdo, S. Stöffler, and T. Fernandez	2020	Forward from [13]
[21]	I. Calzada	2020	Forward from [18]
[22]	L. Woltering, K. Fehlenberg, B. Gerard, J. Ubels, and L. Cooley	2019	Forward from [17]

The challenges identified were then categorized according to barrier type (Understanding, Acceptance, Acting) [23] and compared with potential benefits of GMB. For this, the author uses the findings from [24] using the three focuses Attached Importance to Critical Information, Insight into the Problem and Confidence in Decision Making (see section IV). The challenges and requirements are compared conceptually to find out to what extent and in what areas GMB supports the replication activities and helps to overcome current challenges. The insights gained from this were translated into recommendations and possible applications for further activities.

IV. Main Findings

A. Replication challenges

Based on the review of the identified papers (see Table I), eight challenges were identified:

1) Context-sensitivity

Replication refers to the transfer of relevant knowledge between two or more cities. This can be a major obstacle since available resources and boundary conditions differ. Therefore, contextual knowledge of these local conditions [13, 16] has to be provided including both tacit and explicit information [17, 20].

Context related differences refer to different needs [13], varying (national and international) regulations polices and cultural values [17, 20, 21] as well as partner and stakeholder networks [17, 20]. Van Winden [19] confirms that a unique transfer context requires individualized solutions, but not without stressing out that there are common requirements and components in all of these solutions that can be jointly developed and procured. Common standards could be an enabler for this e.g. in data transfer and protection [17]. Context related differences refer to different needs [13], varying (national and international) regulations polices and cultural values [20, 21] as well as partner and stakeholder networks [17, 20]. Vandevyvere [19] confirms that a unique transfer context requires individualized solutions, but not without stressing out that there are common requirements and components in all of these solutions that can be jointly developed and procured. Common standards could be an enabler for this e.g. in data transfer and protection [17].

2) Inherent limitations

Municipalities and city administrations often lack the resources for proper replication activities. This can bee seen as "bounded rationality" [13]. Limited requirements in terms of time, technical skills, mindset, organizational readiness and financial incentives can be identified [13, 17]. External support is required to back up and guide the replication activities of local authorities and actors [20]. According to Cardullo and Kitchin [14] these shortcomings are caused by a politics of austerity municipalities are pushed into.

3) Overwhelming complexity

Replicated smart city initiatives and policies take on current challenges within the urban system. These challenges are complex and systemic in nature and require therefore elaborated solutions [21]. However, the more complex a practice is the less likely is its replication [13, 17]. It is not just the solution and the implementation context that is hard to grasp but also the expected outcome. Improvements in sustainability and systemic changes are difficult to measure, monitor and attribute [22] which complicates the operational interaction between public and private sector [17, 19]. Each measure and each project have to be integrated into a bigger picture [18, 22] to overcome short-term thinking that goes beyond political cycles, existing organizational silo-structures, the lack of incentives and current citizen and user preferences [19].

4) Shortfalling systematics

Although different frameworks and guidelines are provided, hands-on replication activities, in many cases, are based on rather informal, less structured processes that are coined from personal relationships, individual choices and priorities [13, 18]. Thus, these rather pragmatic approaches hamper systematic replication outcomes and the learning process in the long-term [13]. However, they may be a reaction to the fact that predefined hierarchical models (e.g. from European SCC projects) that prove to be impracticable [20, 21].

5) Lack of stakeholder involvement

Smart City initiatives have to be aligned with citizen needs. Corresponding efforts in terms of participation and stakeholder involvement are crucial to develop and customize projects in order to achieve adoption, create impact and trigger change. However, how replication and implementation processes are planned does not go well with serious participation efforts. Citizens are only involved in particular stages of the development and deployment [14] or there is no funding to incorporate citizen feedback [20]. This in turn overrides democratic accountability and weakens the role of local stakeholders [21].

6) Challenging operationalization

Novel projects have to overcome the gap between innovation and operation. Replicating pilots and bringing them into other locales may be complicated by niche protection measures that shield them from real-world legislation and market dynamics. Building a bridge between experimentation and exploitation facilitates replication of successful practices [17]. This requires early on defined exit strategies [22], comprising non-public funding opportunities [17, 21], necessary regulatory adjustments [19, 21], social acceptance [21], operating models as well as data ownership and privacy [21].

7) Lack of Political Will

Political barriers can slow down or prevent replication efforts. These barriers stem from interpersonal problems, individual preferences or political values. The political feasibility of a given project can change quickly due a shift in pursued political goals and strategies or due to expiring political cycles [13]. Strategic articulation [20] of pursued replication and smart city activities can help to legitimate and secure the implementation of planned measures.

8) Neglected and/or selective knowledge transfer

The initial purpose of replication was the provision of knowledge and information to enable the transfer of successfully proven solutions [15]. The literature reveals that replication in practice is rather about the process than about the result. Replication activities are perceived as process of self-awareness [20] and Learning [21] that initiates organizational change and progress by contextualizing explicit and tacit knowledge [17] ideally from the interaction from a wide range of stakeholders [21].

The notion of replication goes usually hand in hand with the communication and the exchange of so-called best practices. What is overlooked here is that the problems the project encountered, the barriers and failures during the implementation are valuable information as well. Sometimes this can be even more valuable than the success factors [13]. These negative experiences are undercommunicated [18].

B. Benefits from Group Building Modelling

The following section compares the previously identified barriers with the potential GMB benefits presented in section II. In doing so, the author follows the perspective that GMB is used to incorporate existing knowledge into a systemic model that is tailored to the application environment of the replicating city. In other words, a city uses GMB to build a model of the cause-and-effect relationships of a best practice that will influence the implementation and operation.

In [24] three focal points have been defined that contain the benefits: Attached Importance to Critical Information, Insight into the Problem and Confidence in Decision Making (see Table II).

1) Attached importance to critical information

GMB can provide clarity in recognizing what is important. The method comes with benefits such as the harmonization and alignment of different ideas, the questioning of existing preferences, the streamlining of information and communication flows as well as a better use of information [24]. GMB facilitates the processing of information and allows resolving conflicting views among partners and stakeholders.

Therefore, the barrier of *Overwhelming Complexity* can be addressed since system boundaries are defined and emphasis can be put on the most relevant influencing factors. Also, GMB generates context information from which applicable knowledge of action can be obtained *(Context Sensitivity, Challenging Operationalization)*. This knowledge generation happens in a transparent and participative process, which offers options for stakeholders and policy makers to participate and contribute. By means of GMB, prevailing preferences and euphemistic assumptions can be challenged through collective knowledge and a systemic view. In terms of replication practices, this means, that there is a formal procedure, which provides guidance for the knowledge transfer. In this procedure, variable and relations are used to present information, which gives less space for a selective or biased knowledge transfer that only consists of "glossy" success stories [18].

2) Insight into the problem

GMB provides an increased insight into the problem. Modeling fosters learning and understanding. The modeling process but also the modeling outputs can be seen as means of communication to create understanding, acceptance and to encourage implementation.

A visual representation of a complex issue such as the replication system in a city serves multiple purposes and is of relevance for involved partners but also for associated or affected third parties. In an uncertain environment, these visualizations provide guidance and thus the opportunity to act and decide (*Overwhelming Complexity*, *Context Sensitivity, Knowledge Transfer)*. They can be used to create understanding and legitimize measures at the political level, but also among stakeholders. Parties have to believe in the necessity for change [23]. In the replication context, this means modeling supports "strategic formulation" [20] of replication activities (*Lack of Political Will, Shortfalling Systematics, Lack of Stakeholder Involvement*).

3) Confidence in decision making

GMB does not only lead to an increased understanding about a problem and provides means for communication. There is also more confidence about model-related decisions. In complex systems, it's not about having all the information. Rather, it is about having clear and compelling rationales to come to a decision [24]. These decisions form the basis for further actions. GMB can bridge the gap between planning and action, especially when these gaps relate to insufficient knowledge (*Context Sensitivity*). In most cases replication does not happen 1:1 [13]. The systemic decomposition of a best practice creates the ability to act by revealing subcomponents and interrelationships that enable partial technology transfers or such excercises stimulate the development of similar applications (Knowledge Transfer). The opportunity to participate in and shape decision-making can also accelerate and strengthen replication projects (Lack of Political Will, Lack of Stakeholder involvement).

TABLE II. COMPARISON OF REPLICATION BARRIERS AND GMB BENEFITS

Replication Barriers				
Type of Barrier	***Barrier***	***Addressable by GMB***		
		Critical Information	***Insight into the problem***	***Confidence in decision making***
Understanding	Overwhelming Complexity	●	●	●
	Knowledge Transfer	◑	●	●
Acceptance	Shortfalling Systematics	○	◑	○
	Lack of Political Will	◑	◑	◑
Acting	Challenging Operationalization	◑	◑	○
	Inherent Limitations	◑	◑	○
	Context Sensitivity	●	●	●
	Lack of Stakeholder Involvement	◑	◑	◑
● GMB fully applicable ◑ GMB partly applicable ○ GMB not applicable				

With the analysis, it is clear that GMB can improve the handling of information during replication. This includes the generation, presentation, communication and interpretation of information. However, the two-step approach also shows that some barriers cannot be overcome by improved knowledge utilization. Instead, in some cases there are structural and cultural problems that need to be solved in other ways (e.g. *Inherent Limitations, Lack of Political Will*).

For example, the barrier *Lack of Stakeholder involvement* does not stem from a lack of understanding about the need for participation, nor from a lack of methodological means. Instead, the financing plans in public projects or contractual agreements with implementation partners simply do not leave sufficient room to identify stakeholder needs in an open-ended process and to take them into account in further implementation.

V. CONCLUSION AND RECOMMENDATION

A review of the literature shows that smart city initiatives have encountered numerous barriers of varying origins in replicating best practices in recent years. While the concept of sharing ideas and knowledge about applicable solutions between cities makes indisputably sense, so is the way in which replication is carried out still fuzzy and controversial [13, 14]. With the complexity of urban systems, various obstacles arise that limit the comparability and transferability of best practices. Replication efforts range from detailed best practice descriptions that are based on ceteris paribus assumptions neglecting the influence of changing external conditions, to an informal exchange of information and experience, where in many cases there is no concrete link to the implementation environment.

To this context, this paper contributes by connecting the notion or smart city replication with the methodical approach of GMB. The results show that modeling supports the replication activities. Nevertheless, the nature and scope of some identified barriers exceeds the possibilities of influence of GMB. Modeling is able to change how information are generated, perceived and handled in a replication process. Thus, it supports the understanding of a problem, facilitates the communication and legitimation and it can lower knowledge-related barriers that prevents the implementation. Consequently, GMB can be used at various points in the replication process. This applies for the visual representation and the existing information about the initial situation from the pilot city, but as well for the creation of a system picture of the replication environment at any time along the process.

The approach introduced in [13] contains an initial context analysis but also recommends further actions such as mentoring and shadowing to create understanding and the transfer of tacit knowledge. While the context analysis could be conducted by using GMB, the further components mentioned work only well in protected and financially backed-up project settings such as smart city initiatives on national or European level.

Large-scale dissemination of best practices can only be achieved if replication also happens outside of publicly funded projects. In order to get there, some wide-ranging barriers to replication must be overcome, which cannot be resolved by adopting an alternative methodological approach such as GMB. This observation refers to barriers grouped under the terms *Inherent Limitation*, *Challenging Operationalizat*ion, *Lack of Stakeholder Involvement* and *Political Will*.

Symptoms and causes of these barriers are the scarce resources on which public administration have to rely on, the rigid structures in which public bodies are operating and the dependence on project-related funding and external private-sector knowledge. All of these shapes the culture of public administration and limits its strategic options.

Increasingly, public administrations are no longer only responsible for maintaining and managing the status quo, but they are more and more moving into the role of change agents for the proactive development of more sustainable urban spaces and offerings. With these expectations, the societal and political role of municipal administrations has to be reconsidered.

While this paper is the result of a theoretical research approach, there are practical implications that can be drawn. As shown, there is a wide range of different barriers. These barriers can only be removed through an equally broad involvement of skills and knowledge along the process. GMB has its strengths not only in involving relevant bodies, but also in facilitating communication between them. Related to a practical application, this means that strengthening multidisciplinarity and communication in replication processes is a relevant take-away independent of the scientific and methodological setting of a given project.

The research findings discussed in this work are limited to some extent. These limitations can be understood as indicators for related research activities that can be further pursued based on the provided findings. In particular, the following three research directions appear promising.

1) Further empirical validation

The findings are the results of in-depth conceptual work. However, they still have to be empirically validated in further steps and translated into practice. In addition, it is possible that not all of the described benefits apply for the considered setting. While GBM have been picked up for modeling approaches in the urban system such as urban agriculture [25] or housing [26], the topic of replication has not been addressed specifically.

2) Agent Based Modeling for replication

Undoubted, GMB has several advantages for replication activities. Nevertheless, it is beneficial to take a look beyond the concept of SD. Agent-based modelling (ABM) is a computational study of social agents and a tool to analyze and predict individual behavior and interactions. In contrast to the top-down approach of SD, ABM explores social systems from the micro level perspective, focusing on emerging patterns and events as a result from micro level decisions of heterogeneous set of interacting agents [27]. On city-level, the interaction of citizens, private service providers and public bodies as part of an ABM could give insight about the diffusion of new approaches, potential demands and resources and therefore further insight into replication practices.

3) Urban replication ecosystem

That replication is a sophisticated task is also due to the numerous interactions between different stakeholders and partners. However, the city administration as governing actor is not equipped with the appropriate resources and power to push and implement replication. The role and responsibilities of municipalities in replication processes and the replication ecosystem has to be reconsidered since the structural barriers defined before have to be solved. A framework to investigate this further is the multiple helix innovation system [28].

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Environmental Impact of Off-grid Solar Charging Stations for Urban Micromobility Services

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***Abstract*—In face of challenges such as rising greenhouse gas emissions, air pollution, noise, traffic jams and space demand conflicts micromobility is controversially discussed as a new mobility alternative for cities. The rapid growth of the mobility sharing market raises questions about its environmental sustainability in many cities worldwide. Especially the operating and energy supply system of e-scooter sharing services was identified as main environmental impact in previous studies. This paper shows potentials of smart charging solutions for micromobility services. Based on a case study, a conceptual design of an off-grid solar charging station is proposed and evaluated using Life Cycle Assessment. The results of our case study show that the Global Warming Potential per kilowatt-hour of energy supply for sharing services can be reduced by 81-91% compared to battery swapping with diesel vans, if solar charging stations are used. However, the paper highlights the utilization rate of the solar charging station and the solar irradiation in the place of use significantly influence the environmental impact.**

Keywords—micromobility, e-scooter, mobility sharing, solar energy, off-grid charging station, charging infrastructure, Life Cycle Assessment

I. Introduction

Urban mobility is facing major transformation efforts in the face of challenges such as rising GHG-emissions, air pollution, noise, traffic jams and space demand conflicts [1]. Often cited solutions to the challenges of urban mobility include electric mobility, lightweight vehicles and new mobility services such as shared mobility. Light electric vehicles (LEV) have numerous advantages for urban mobility over conventional, fossil fuel vehicles. For example, LEVs require less energy for production and operation as well as less space than cars [2]. Thus, micromobility sharing services with LEV are emerging in cities worldwide [3][4].

According to the International Transport Forum (ITF) micromobility is defined as the use of low-speed, small, lightweight vehicles with a mass of less than 350 kg and a design speed no higher than 45 km/h [5]. Following to the Institute of for Transportation & Development Policy (ITDP) [6] the vehicles are typically electric-powered. They require battery capacities from 0.4 kWh to 10 kWh, resulting in drive ranges of 20–160 km [7]. The term light electric vehicles is often used synonymously, covering different types of vehicles in the field of micromobility from e-scooters to light four-wheeled vehicles [2]. Shared mobility describes “the shared use of a vehicle […] that enables users to have short-term access to transportation modes on an ‘as-needed’ basis [8]”.

The lack of charging infrastructure with renewable energy supply hinders the further spread of LEV sharing services and increases their negative ecological impact. Furthermore, the energy supply system, namely operational trips with service vehicles to swap and recharge the batteries were identified as a key factor influencing the environmental impact of shared LEV next to the vehicle’s lifetime [9,10,11].

The use of charging stations powered by renewable energies offers the potential to reduce the environmental impact of sharing services. However, the installation of on-grid charging stations is (e.g. due to administrative processes) inflexible and requires large investments, which has so far prevented rapid growth in the use of e-mobility [12]. Off-grid solar charging stations represent a more flexible solution [13], which, according to Nocerino et al. [14], could help to

- extend the vehicle battery life due to the opportunity to recharge more frequently.
- substitute or reduce the operational trips to swap batteries.
- increase the shift towards new transport based on renewable energy.

Furthermore, the visibility of a charging station could improve the access and availability of vehicles at hotspots. In addition, off-grid charging stations are especially suitable for LEV because of their lower battery capacity compared to conventional electric vehicles.

Several previous studies have presented concepts for off-grid solar charging stations designed for electric vehicles in general [15], [16] and for micromobility in particular [12], [13], [17]. Moreover, some Life Cycle Assessments of solar charging infrastructure have already been conducted [18][19]. However, the impact of off-grid charging stations on the life-cycle environmental impact of micromobility services has not yet been quantified. In addition, it must be investigated under which usage scenarios and manufacturing conditions lower ecological impacts can be achieved compared to other energy supply concepts.

This paper shows potentials of smart charging solutions for urban micromobility. Based on a case study, a conceptual

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design of an off-grid solar charging station for urban micromobility is proposed. The system is developed together with the company SunCrafter and tested as a pilot installation on the campus of Bochum University of Applied Sciences. Based on hourly solar irradiation data [20] and typical usage patterns of LEV sharing services [21], different scenarios for the use of the charging station are developed. To evaluate the environmental impact of the charging station, a Life Cycle Assessment (LCA) is conducted, including production, transport and use of the developed system. The paper shows the impact for 1 kWh electricity produced, allowing the comparison, e.g. to the electricity grid mix. As an outcome the parameter utilization rate and its influence on the environmental impact is discussed. Furthermore, the paper reveals the positive impact of reused materials like refurbished solar modules on lifecycle environmental impact.

II. Design of the Off-Grid Charging Station

A prototype of the proposed off-grid charging station is operating on the campus of Bochum University of Applied Sciences in the heart of the Ruhr area in western Germany (Fig. 1). It offers a high degree of autonomy, flexibility and modularity enabling it to be used accordingly to the specific use cases, mobility behaviour and local requirements of a city:

- It is autonomous from the electricity grid and has minimal installation costs (autonomy).
- It is not anchored to the ground and can be easily repositioned (flexibility).
- It is made up of three groups of 3-4 solar modules operable separately, if required, according to the needs of different mobility services (modularity).

The charging system consists of a total of 10 refurbished solar modules with 240 Wp power output each. The refurbished solar modules originate from larger, industrial photovoltaic power plants. In case of degradation or damage of individual modules within the plant, often the entire system is renewed, i.e. all modules are replaced. Before being installed in the charging system, the modules are checked for their current condition using methods such as thermographic analyses and power measurements under standard test conditions. In total 7.2 kWh battery capacity are installed in the charging station for energy storage. The e-scooters can be charged by connecting to an AC plug, providing 230V/50 Hz current. As to be seen in the block diagram in Figure 2, groups of two PV-modules are connected in series. Those groups are connected in parallel as a cluster. Each module has a voltage of 32V, i.e. a group of two modules is running at 64V at 7,5A. Combined clusters of four modules have the same voltage of 64V at 15A respectively.

Each charging cluster consists of the following components:

- 2, respectively 4 solar modules,
- control system (BOS HS1),
- multi power point tracking (MPPT) charge regulator,
- inverter to supply a maximum of 1200W at 230V AC/50Hz for power supplies of the,
- module for mobile communication (GSM),
- two $LiFePo_4$ batteries with a capacity of 1200Wh each, connected in parallel at 24V.

The control system is communicating with the other clusters, leveling the individual state of charge (SOC) and monitoring the batteries. All three control systems are linked using RJ45 connector and CAT5 wire to exchange data. The integrated GSM modules maintain a connection to the online dashboard transmitting data at configurable time intervals. These data include values of the integrated batteries (e.g. cell voltage, SOC, temperatures), photovoltaic data (e.g. power, voltage, electrical energy yield, etc.) and data generated during vehicle charging (e.g. power demand, energy consumed, etc.). Therefore, it is possible to analyze different trends over a long period of time, such as user behavior or seasonally varying energy yields.

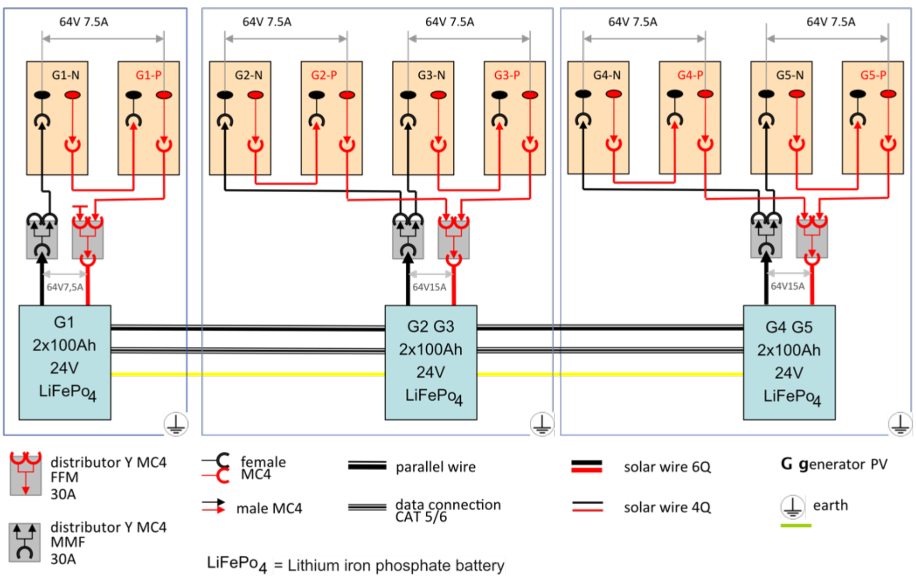

Fig. 1. Block diagram of the off-grid solar charging station.

Fig. 2. Off-Grid Solar charging station installed by the Sustainable Technology Laboratory on the campus of Bochum University of Applied Sciences.

III. Methodology

To analyze the usage and environmental impact of the solar charging station, a total of four different scenarios are considered, which vary in the following parameters:

- location of the solar station and corresponding global irradiance on the inclined plane G(i),
- utilization rate,
- power output of solar modules used P_{Solar}.

The assumptions of the scenarios are shown in Table 2.

A. Seasonal Analysis of the Usage of the Charging Station

In order to analyze the usage of the solar charging station, first the hourly potential power yield P_h of the station is calculated for an average day in winter (December-February), spring (March-May), summer (June-August) and autumn (September-November). For this purpose, the hourly global irradiance on the inclined plane G(i) from 2016 for the location of the solar charging station in Bochum (scenarios 1-3) respectively Madrid (scenario 4) is used, provided by the EU Science Hub [20]. The orientation β/α, the system efficiency η_{System} and the power output of the solar modules P_{Solar} as well as the station's internal power demand $P_{Internal}$ are considered according to own measurements. At the beginning of their use in the charging station the refurbished modules already have a service life of 8 years and thus have a power output of 240 Wp, whereas new modules have a power output of 250 Wp. Taking into account an annual degradation of the solar module output of 0.5%, the potential electricity yield P_L is extrapolated to a lifetime of 20 years.

To calculate the hourly electricity demand for charging of e-scooters, the typical usage patterns of e-scooter sharing services are used as collected by McKenzie [21] (ref. Fig. 3). As the average duration of a scooter sharing trip is merely 5 minutes according to [21], it is expected that the scooters will be parked at the station afterwards. Therefore, it is reasonable to anticipate the usage patterns of the station are consistent with those of the scooters. It is assumed that the power required to charge a scooter is 45 W, that only 60% of the scooter battery is charged and that the average charging time is 5.75 h. The number of scooters that are charged daily fluctuates seasonally, on the one hand due to the seasonal changes in the use of scooter sharing services, on the other hand due to the seasonally fluctuating solar power supply. To determine the number of scooters charged daily within the different scenarios, the utilization rates of the daily electricity yield are assumed to be 70% respectively 90%.

TABLE I. General Parameters For the Usage of the Off-Grid Charging Station.

Slope modules β	70°
Number of modules A n_a	7
Azimuth modules A α_a	60°
Number of modules B n_b	3
Azimuth modules B α_b	-30°
Efficency MPPT charge regulator μ_{MPPT}	98%
System efficiency η_{System}	80%
Internal power demand $P_{Internal}$ [W]	50
Annual degredation solar module	0.5 %
System lifetime	20 years
Battery capacity C [Wh]	7200
Battery state of charge at 00:00	50%
Power scooter charging $P_{Scooter}$ [W]	45
Average charging time (60% range gain) [h]	5:45

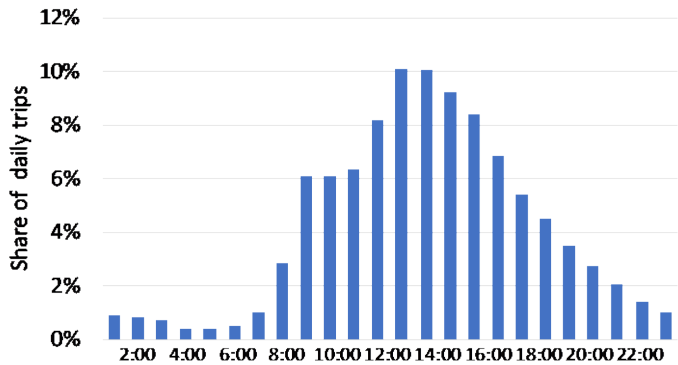

Fig. 3. hourly share of scooter sharing trips in the total daily number of scooter sharing trips [21].

The parameters applied in general and for the different usage scenarios are depicted in Tables 1 and 2.

Figure 4 shows the resulting electricity yield, electricity demand and battery state of charge (BOC) of the off-grid charging station during an average day in Germany in winter, spring, summer and fall assuming a high utilization rate for scenario 1. Ultimately, the solar station can produce 25,227 kWh of electricity over its entire lifetime of 20 years in scenario 1, of which 90% i.e., 22,704 kWh are actually used. If newly produced solar modules are installed (scenario 2), the potential electricity yield increases by 4.3% to 26,300 kWh. Assuming the solar charging station is installed in Madrid, Spain (scenario 3), the electricity yield could increase by 57% to 39,562 kWh.

TABLE II. Parameters For the Usage of the Off-Grid Charging Station in Four different Scenarios.

Parameter	D 90% utilization, refurbished module	D 70% utilization, refurbished module	D 90% utilization, new module	E 90% utilization, refurbished module
Location	Bochum, Germany (51.447N, 7.273E)			Madrid, Spain (40.420N, -3.692E)
Power output solar module P_{Solar} [Wp]	240	240	250	240
Potential electricity yield over liefetime P_L [kWh]	25,226.7	25,226.7	26,299.5	39,562.3
Electricity demand scooter over lifetime $ED_{L,Scooter}$ [kWh]	22,704.0	17,658.7	23,669.6	35,606.1
Utilization rate	90%	70%	90%	90%

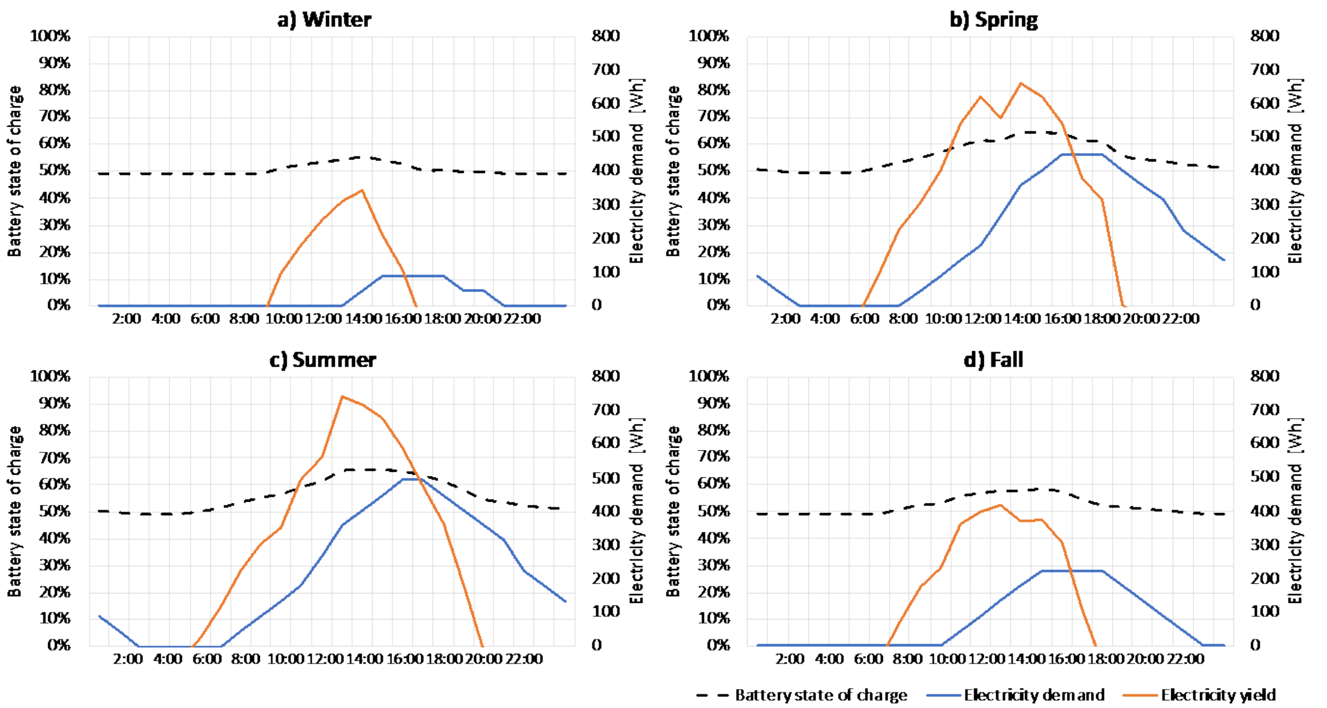

Fig. 4. Electricity yield, electricity demand and battery state of charge (BOC) of the off-grid charging station during an average day in Germany in winter, spring, summer and fall assuming a high utilization rate (scenario 1).

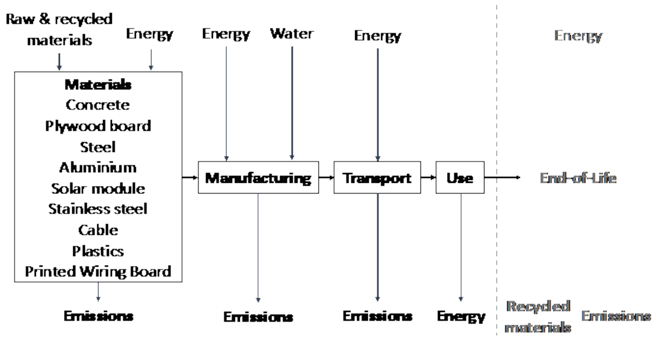

Fig. 5. System boundaries of the analysed solar charging station.

B. *Life Cycle Assessment*

To calculate the environmental impacts of the off-grid solar charging station, LCA is chosen as method. It is the most recognized and frequently used method to quantify the environmental impacts of technical systems or services throughout their entire life cycle [22], [23]. Hence it considers all life phases, from raw material extraction (cradle), production, transport, and use to end-of-life (grave).

The method involves taking an inventory of all inputs and outputs generated in the different phases, linking those inputs and outputs to substance emissions and finally linking the emissions to its environmental impact. For our case study we perform an attributional LCA using the software "Ganzheitliche Bilanzierung – GaBi, Version 9.5.2.49" [24]. In accordance with the ISO standards 14040/44, LCA consists of four phases: Goal and Scope Definition, Life Cycle Inventory, Impact Assessment and Interpretation [25], [26].

1) Goal and Scope Definition

The goal of this study is to examine the lifecycle Global Warming Potential (GWP) of an off-grid solar charging stations in consideration of the utilization rate and the efficiency. Secondly, the paper aims to identify the most impacting materials and life cycle phases and to point out measures to optimize materials and life cycle phases to reduce the environmental impact. Furthermore, the results are compared to alternative electricity supply sources.

Fig. 5 shows the system boundaries of the studied system. The scope of the LCA includes impacts caused by production of primary and secondary materials and components as well as transport and usage phase. End-of-life is excluded. The functional unit is 1 kWh. The method of impact assessment is the CML-method (version of 2016) [27].

2) Life Cycle Inventory of the Solar Charging Station

The data needed to perform the LCA of materials and the manufacturing phase are provided by the charging station manufacturer SunCrafter and are gathered from the bill of materials. The charging station has a total weight of 3,370 kg. The shares of the different materials and components is shown in Figure 6. Each material is matched with a GaBi dataset [24]. A lifetime of 20 years is assumed for the entire charging station and 10 years for the electronics and the battery. These components are therefore included twice in the calculation of the environmental impact of the production phase.

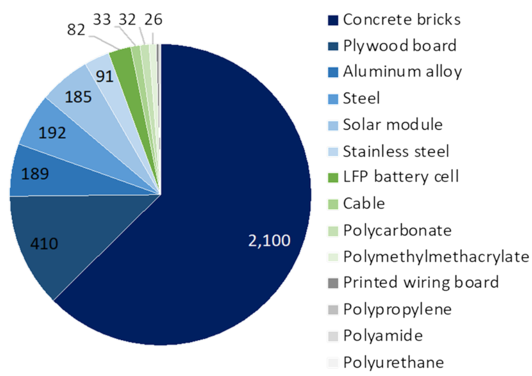

Fig. 6. Weight of materials and components of the charging station [kg].

In the analyzed charging station, refurbished solar modules are installed. Those modules have a lower power output (240 instead of 250 Wp) compared to newly produced modules, yet the environmental impact of the production is reduced as well. When calculating the environmental impact of the refurbished solar module, the production is not included as the original production has already been attributed to the full life cycle for its regular use. According to the Methodology Guidelines on Life Cycle Assessment of Photovoltaic Electricity by the International Energy Agency [28] environmental benefits and environmental impacts beyond the system boundary need to be quantified and reported separately. Thus, only additional emissions for transport and the electrical test procedure of the modules are considered. These amount to 0.81 kg CO_2e per module for an additional transport distance of 500 km. However, in order to include possible uncertainties, a scenario with newly produced solar modules was calculated as well. It is assumed that the production of a newly produced solar module accounts for 229.34 kg CO_2e [29].

The transport phase was modeled based on the data from the manufacturer. Most of the components are produced in Germany, another part (control components and the battery) in China. The Chinese components are transported by truck from the factory to the Chinese harbor (1,000 km), then shipped to a German harbor (21,000 km) and by truck to the assembly place (400 km). Afterwards all components are transported by truck to the place of use in Bochum (400 km).

To model the impacts of the use phase, data regarding the energy production and consumption are calculated. The detailed assumptions made regarding the use phase within the four scenarios can be found in section III. A.

IV. Results

The GWP of the production of the solar charging station is 4,709 kg CO_2e as shown in figure 7. The production of the aluminum components accounts for 38%, printed circuit boards for 16%, the battery for 14%, and stainless steel for 9% of production GWP. The use of newly produced solar modules instead of refurbished ones results in a 48% increase in GWP of the production phase - the share of solar modules in the GWP of production rises to 33%.

Figure 8 outlines the life cycle environmental impacts per kilowatt-hour used for each scenario (ref. section III. A). If the solar charging station is installed in Bochum, Germany, refurbished solar modules are used and the utilization rate is around 90% the average GWP is 218 g CO_2e/kWh, with 95% derived from materials, 2% from manufacturing and 3% from the transport phase. A lower utilization rate can greatly increase the environmental impact of e-scooter sharing. With a utilization rate of 70% instead of 90% (scenario 2), the GWP increases by 29% to 280 g CO_2e/kWh. The use of newly produced solar modules within the charging station (scenario 3) increases the GWP per kilowatt-hour used by 40% compared to scenario 1, caused by the higher GWP of production of 6,992 kg CO_2e. If the charging station is installed in Madrid, Spain, instead of Germany and the utilization rate remains 90%, the GWP per kilowatt-hour used can be decreased by 36% compared to scenario 1. This is due to the much higher solar radiation in Spain.

To evaluate whether the electricity produced by the solar charging station is an environmentally friendly alternative, it is compared to electricity from the grid of Germany, North-Rhine-Westphalia (NRW, federal state where Bochum is located) and Spain as well as conventional energy supply concepts for sharing services in figure 9. The GWP impact of conventional energy supply concepts is calculated according to the base case of our previous study on the environmental impact of e-scooter sharing services [10]. The GWP of 1,187 g CO_2e/kWh includes the environmental impact of charging using the German electricity mix and the impact caused by service trips with diesel vans to swap discharged batteries.

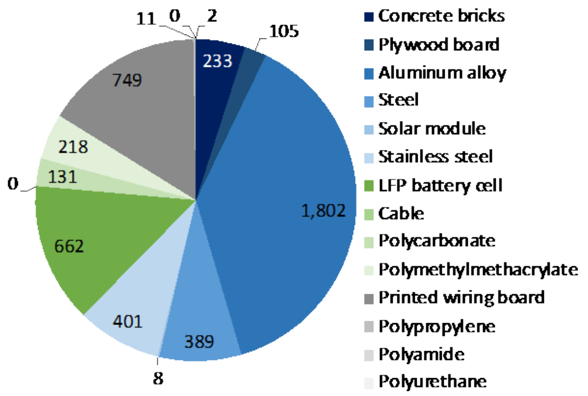

Fig. 7. Global Warming potential of production of the charging station with refurbished solar modules [kgCO_2e].

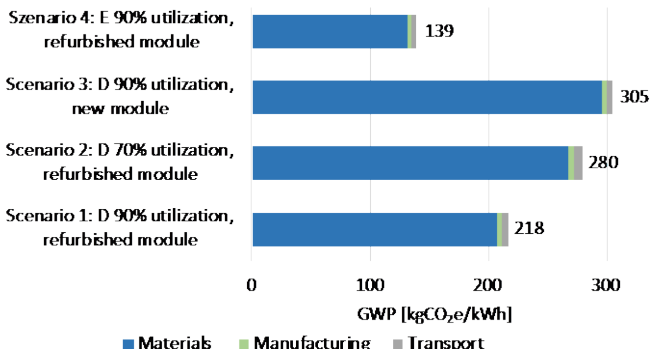

Fig. 8. Global Warming Potential of production, transport and use phase of the charging station per kilowatt-hour electricity used for different usage scenarios [kgCO_2e/kWh].

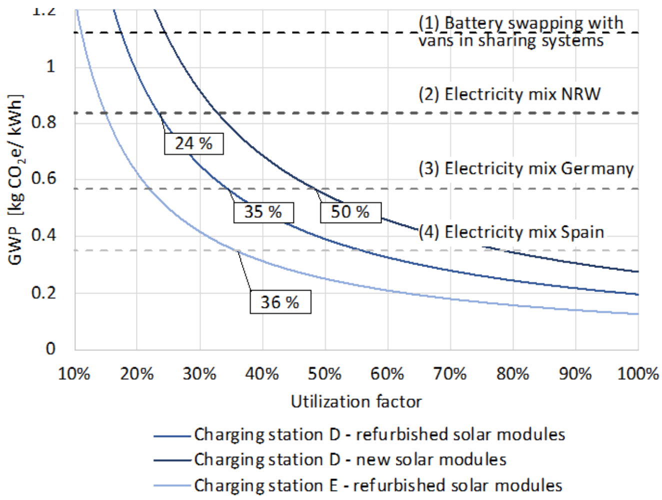

Fig. 9. Break-even-point of electricity produced by the solar charging station for different utilization rates, locations compared and solar modules compared to (1) GWP of battery swapping with vans in e-scooter sharing systems [10] (2) GWP of electricity grid mix in North-Rhine-Westphalia [30] (3) GWP of German electricity grid mix [24] and (3) GWP of Spanish electricity grid mix [24] [kgCO_2e/kWh].

In our worst-case scenario (scenario 3), the use of the solar charging station causes an 73% lower GWP than battery swapping with diesel vans in relation to a kilowatt-hour. In our best-case scenario (scenario 4) the GWP is even 88% lower.

It can be seen that in each of the cases considered, above 25% utilization rate the solar charging station has a lower GWP per kilowatt hour than battery swapping with diesel vans. To cause a lower GWP than the electricity grid mix of NRW, the solar charging station with refurbished modules installed in Bochum must achieve an utilization rate of at least 24%. Compared to the German electricity grid mix, a utilization rate of 35% must be achieved. If the charging station is installed in Madrid, a utilization rate of at least 36% is necessary to have a lower GWP than the Spanish electricity grid mix.

V. Discussion and Conclusion

Previous research has already shown the ecological potential of LEV sharing services for reducing greenhouse gas emissions in urban transport. At the same time, it has been highlighted that an efficient charging infrastructure based on renewable sources is necessary to achieve this potential. However, despite first examples, proposed solutions remain unconvincing. There is also often a lack of scientifically validated ecological assessments of different charging infrastructure solutions for micro-mobility offers.

The present Life Cycle Assessment of the pilot installation of an off-grid solar charging station enables an initial evaluation of the ecological impacts of charging infrastructure for LEVs. It demonstrates the environmental impact of the energy supply of a sharing service can be reduced by the usage of solar charging stations in comparison to reference energy supply solutions. The results of our case study show that the GWP per kilowatt hour of energy supply for LEV sharing services can be reduced by 73-88% compared to battery swapping with diesel vans, if solar charging stations are used. However, the paper highlights the importance of the utilization rate of the solar charging station in terms of its GWP: In a best-case scenario, i.e. assuming the use of refurbished solar modules and installation in a location with a high level of solar radiation such as Madrid the GWP is 139 g CO_2e/kWh. Assuming that the station is installed at a location in Germany with less radiation and that only 70% of the electricity produced is used, the GWP amounts 280 g CO_2e/kWh.

Furthermore, the paper outlines the importance of reuse of rejected solar modules. The results have shown that, using charging station with refurbished solar modules causes 29% lower Global Warming Potential per kilowatt-hour than a charging station with new components. Since a large number of refurbished solar modules will become available in the future, new fields of deployment instead of the recycling of solar modules should be discussed. In addition, the application of refurbished solar modules in charging infrastructure for micro-mobility could become a new and sustainable business field for companies. Considering the high share of aluminum in the GWP of the solar charging station production, the use of secondary aluminum appears to be appropriate as well.

Overall, the paper shows the specific potential of solar charging stations to reduce the GWP of micromobility sharing services depends heavily on the utilization rate and the solar radiation of the usage location. Therefore, further empirical analysis of the usage phase is necessary. For example, subsequent studies could examine how solar radiation and usage patterns change if the solar charging station is installed near a train station, residential neighborhoods, or commercial areas rather than on a college campus. In addition further research to optimize the utilization of charging stations according to the solar radiation is needed, e.g. with the help of user incentivation systems.

However, the data gathered in this work just allows a first indication for a Life Cycle Assessment. Especially regarding the usage patterns of solar charging stations more empirical data, e.g. from a real laboratory, is needed. To allow profound conclusions for ecological assessment further data needs to be be collected as well as possible further solutions should be developed and tested, e.g. in cooperation with companies from the field of micromobility.

Furthermore, it seems reasonable to include economic and social aspects, especially with regard to user acceptance, in the further evaluation of energy supply concepts of sharing services. Since battery swapping with service vans is quite labor-intensive, there could be potential to reduce the operating costs of the sharing services through the use of charging stations. On the other hand, investment costs for production and installation of the solar charging station need to be considered in a further analysis.

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Selecting Features for the Next Release in a System of Systems Context

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***Abstract*—Smart Cities are developing in parallel with the global trend towards urbanization. The ultimate goal of Smart City projects is to deliver a positive impact for the citizens and the socio-economic and ecological environment. This involves the challenge to derive concrete requirements for (technical) projects from overarching concepts like Quality of Life (QoL) and Subjective Well-Being (SWB). Linking long-term, impact oriented goals with project outputs and outcomes is a complex problem. Decision making on requirements and resulting features of single Smart City projects (or systems) is even more complex since cities are not like monolithic, hierarchical and well-structured systems. Nevertheless, systems engineering provides concepts which support decision making in such situations. Complex socio-technical systems such as smart cities can be characterized as systems of systems (SoS). A SoS is composed of independently developed systems that nevertheless provide a higher-level integrated functionality. To add new functionality to a SoS, either existing systems must be extended or new systems must be developed and integrated. In both cases, the extension of functionality is usually done in small increments and structured via software releases. However, the decision which features to include in the next release is complex and difficult to manage when done manually. To address this, we make use of the multi-objective next release problem (MONRP) to search for an optimal set of features for a software release in a SoS context. In order to refine the search in an early planning phase, we propose a technique to model and validate the features using the scenario modeling language for Kotlin (SMLK). This is demonstrated with a proof-of-concept implementation.**

***Keywords*—System of Systems, Multi-objective Next Release Problem, Scenario-based Requirements Modeling**

I. Introduction

Decision making, project selection and goal-setting for projects are a very relevant long time issue in politics and city planning. E.g., in Germany, there is a long history of attempts, methods and tools in order to manage the development of cities and the political decision making [1]. Several programs with top-down planning and decision making where implemented. It is an ongoing debate if they met their goal and if they had a clear goal. Cities are highly complex, highly connected and organic, self-organizing systems. The digital transformation towards Smart Cities is adding to this complexity. Decisions on which steps to take next, which projects to do, which goals to set for the projects and which features to implement are difficult. This makes the requirements engineering and project management for engineering projects in the Smart City context very difficult, too. This contribution intends to deliver a decision support approach which is based on systems engineering methodology. It is believed that the approach supports the effort to link impact-oriented indicator systems for Smart Cities like Quality of Life (QoL) or Subjective Well-Being (SWB) to the requirements for concrete engineering projects. Complex systems like smart cities can be characterized as system of systems (SoS) [2]. These SoS are composed of individual constituent systems (CSs) that are independently developed and operated but nevertheless can be integrated to provide a higher level functionality [3]. One use case in a Smart City context is smart charging of electric vehicles (EV). To realize a smart charging use case, different systems from different domains (energy conversion, energy transfer from/to EV, EV user premises etc.) must be considered and integrated [4].

In contrast to the development of complex monolithic systems, new functionality in a SoS context is usually created by selecting, adapting and integrating systems [5]. Since these systems are independently operated and managed, can have different life cycles and evolve over time, the decision which functionality shall be added is a complex task. It is necessary to make trade-off decisions based on expected costs and values for the realization of new functionalities. The estimation of the value of a new feature in the context of Smart City projects is particularly challenging as we describe in section II. Therefore, the indicators of cost and value of new functionalities form the interface to the decision-making processes of the Smart City.

In this context, we address the problem that in a SoS we do not have a fixed set of requirements that we can use to decompose the system requirements into subsystem

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requirements [6] [7] in order to estimate the cost and value for realizing these requirements.

In this paper, we propose an iterative and tool-supported process that helps the release engineer to identify a set of features that can be considered for a next release to add new functionality to a SoS. We use a software release to group a set of features, where features are used to summarize a consistent set of requirements from one or more stakeholders.

As introduced in previous work [8]–[10], we show how to specify stakeholder expectations in a comprehensive and structured form using feature files and usage scenarios. Based on this feature specification, we use a test-driven specification approach [8] to iteratively model the intended SoS behavior in form of a scenario specification [11]. By creating, executing and testing the scenario specification, we are able to refine the initial feature specification.

Subsequently we use this feature specification along with the scenario specification to manually estimate the costs it can take to realize the feature and the value it can create. This estimation is used as input to a multi objective next release problem (MONRP) [12] that we apply to automatically search for an optimal set of features. The resulting feature sets of possible release candidates can be used by the release engineer to select the next release.

We show a proof-of-concept implementation, where features are specified using the Gherkin syntax [13] within the Cucumber tooling [14]. The SoS behavior is modeled using the scenario modeling language for Kotlin (SMLK) [15], and the MONRP is implemented using the MOEA framework [16]. As a result, we see that the iterative process of 1) structured feature specification, 2) test-driven and scenario-based requirements modeling, and 3) a tool-supported search for release candidates, can be supportive to identify a next release in a SoS context.

II. Background

A. Smart City projects

Citizens expect from Smart City projects a positive impact. Nevertheless, it is difficult to define this positive impact clearly and it is even more difficult to link it to concrete events or elements within a Smart City. E.g., there are attempts to link concepts like Quality of Urban Life (QOUL) and Subjective-Well Being (SWB) to concrete features of a city [17]. This involves two underlying problems: one is the definition and measurement of indicator sets describing QOUL or SWB. The second issue is the linking of long-term impact goals like QOUL or SWB to concrete project outputs which can be described by user requirements. Systems engineering methodology requires such well-defined user requirements in order to develop features of technical systems. The systematic linking of inputs, outputs, outcomes and impact of projects is a relevant research topic in project management [18]. The cost of a new functionality in the sense of this study is derived from the inputs required by the respective project. The value is addressing the impact which is difficult to determine at the time of decision-making. This can be addressed by a result-oriented logic defining potential cause and effect chains between the different levels of results. Nevertheless, such logic remains incomplete and insufficient in complex real-world scenarios like Smart Cities due to the high level of uncertainty. This leads to a more incremental process of defining and selecting projects which add systems to the Smart City step-by-step. Decision making has to focus on selecting projects and Smart City features and functionalities which are implemented and released to the public. The management and decision-making for the release of such new features can be supported by systems engineering methodology. Doing "good" decisions can be supported by optimization methods from operations research. The following sections describe how features can be selected for inclusion into the release of a new system and how these systems can be integrated into the overall Smart City system.

B. System of Systems

SoS are distinguished from complex monolithic systems by the operational, managerial and evolutionary independence of its CSs [3]. Accordingly, each CS can perform a meaningful task, even if it's not integrated into the SoS. Since the CSs are self-administered and individually managed, this can lead to conflicting development goals between the single CSs, or between CSs and the SoS. Also, objectives and functionality of an SoS can change constantly, as they can be added, modified or removed based on experience. Therefore an SoS never appears to be fully completed [19].

Due to these SoS characteristics and in contrast to the development of complex monolithic systems, we do not have a fixed set of requirements that can be decomposed for an linear and top-down system design [6] [7] and validation [20]. However, requirements decomposition techniques and the alignment of stakeholder expectations via validation are mandatory to estimate the value and the costs of requirements and to decide which requirements should be realized with the next release.

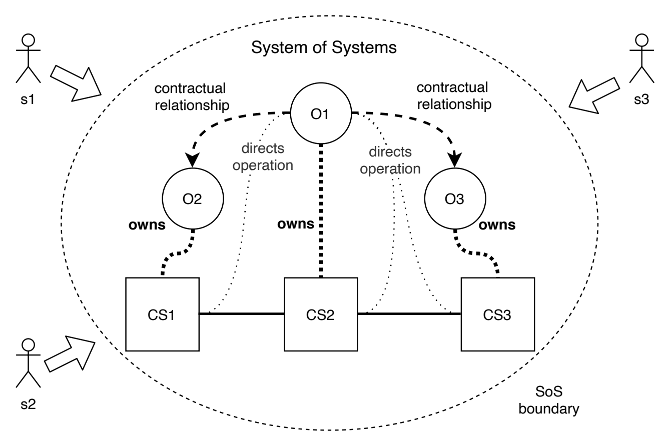

Fig. 1. Acknowledged System of Systems, based on [5] [7]

To support SoS requirements engineering, Ncube and Lim argue that it's necessary to define a SoS type in an early development phase [7]. This is fundamental to understand the dependencies and responsibilities between the SoS and its CSs, and also between the individual CSs owner and other stakeholder during SoS development [7] [6]. Therefor, in this paper we make use of an acknowledged SoS [3] [5] [19] as outlined in Fig. 1, which is suitable to describe systems like Smart Cities [7]. Here, we assume that we have three CSs (CS1, CS2, CS3) with each CS having one system owner (O1, O2, O3), who is responsible for the development and operation of the respective CS. We also see external stakeholders (s1, s2, s3), that have an interest in the SoS development (e.g. SoS user). In this acknowledged SoS, O1 directs the operation and the choice of CSs. For this, O1 can define requirements that must be fulfilled by the CSs. However, the CSs retain their independent ownership, funding, objectives, and development approaches. Hence, the realization of a SoS functionality is directed by a central authority but requires the collaboration on CS level [7].

C. Multi-Objective Next Release Problem

According to [21], a *release* is a collection of new and/or changed features that form a new version of an evolutionary product/system. Thereby, a *feature* serves to summarize a consistent bundle of requirements from one or more stakeholders [22].

If we characterize a Smart City as a SoS, the local government is an example of a central authority (O1 in Fig. 1) that defines the collection of features that should be included into the next release to form a new SoS. To support the central authority in deciding which features should be included into the next release, the application of the MONRP formulated in [12] is suitable.

As outlined in Fig. 1 we have multiple stakeholders requesting new functionality from the SoS. On an SoS level, O1 has to select a set of features for the next release, where each feature is realized by a CS or by a combination of CSs. To realize a feature, each system owner has to spend an amount of resources resulting in a certain amount of costs. At the same time, when providing a specific feature, this provides a specific value. From the perspective of O1, the goal is to minimize the costs and maximize the value. As a result we have two conflicting objectives. According to [12] and [23], finding the optimal set of features is a $\mathcal{NP}$-hard problem and cannot be resolved by exact optimization. For this reason, we use a metaheuristic search technique [12] to approximate an optimal set of features.

D. Scenario-based Requirements Modeling

In this paper, we argue that early requirements modeling and testing can support cost and value estimation of features to be implemented. Requirements modeling with scenarios and use cases gives stakeholders a better tool for decision-making since the scenarios and use cases can be formulated in natural language and they can be linked to real-life situations of the stakeholders. Therefore, on the one hand, requirements engineering based on scenarios and use cases offers a "common language" to involve non-technical stakeholders into the process. On the other hand, scenario and use case descriptions can be transformed into formal descriptions for requirements engineering by using model-based approaches. For this requirements modeling we use the scenario modeling language for Kotlin (SMLK), which is based on the concepts described in [24]–[26].

In SMLK, functional requirements are modeled with behavioral threads which we call scenarios. These scenarios are loosely coupled via shared events. Within a scenario, we can request events that shall be executed. If an event is selected for execution, it can trigger the execution of other scenarios that in turn can request additional events. By iteratively adding scenarios to a scenario specification, we obtain an increasingly complete specification of the intended system behavior over time. During execution of the scenario specification as a scenario program, the scenarios are interwoven to produce a coherent system behavior that meets the requirements of all scenarios

An example scenario specification as part of a simplified smart charging use case is shown in Listing 1.

```
1  class EVU{ // Electric Vehicle User
2      fun energyPriceInformation() = event(){}
3  }
4  class App{ // Smartphone App
5      fun enterChargingPreferences() = event(){}
6      fun calculateChargingPlan() = event(){}
7  }
8  class EV{ // Electric Vehicle
9      fun chargingPlan() = event(){}
10     fun executeChargingPlan() = event(){}
11 }
12
13 scenario(EVU sends App.enterChargingPreferences()) {
14     request(App.calculateChargingPlan())
15     request(App sends EV.chargingPlan())
16     request(EV.executeChargingPlan())
17 }
```

Listing 1. SMLK scenario specification

In this specification we modeled two CSs (smartphone app and electric vehicle) and one external stakeholder (electric vehicle user). The scenario in line 13 is triggered when a electric vehicle user enters charging preferences to the app, i.e. the event <EVU sends App.enterChargingPreferences()> is executed. In this case, the body of the scenario is executed and further events are requested.

Following the specification method we proposed in [11], we can intuitively model the SoS behavior on different levels of abstraction. Therefor, in a first step, we define the required CSs and the messages that these systems exchange (see Listing 1). In a second step, we refine the internal CS behavior by separate scenario specifications [11].

III. Feature Selection for the next Release

We propose an iterative process as shown in Fig. 2. The intent of this process is to support the definition of cost and value information that will serve as input to the automated search for an optimal set of features for the next release. We start with a specification of features (1) which are manually derived from stakeholder expectations. Subsequently we model and execute the expected system behavior in short iterations (2) in order to elaborate a formal and scenario based specification of technical requirements. In (3) we iteratively refine the

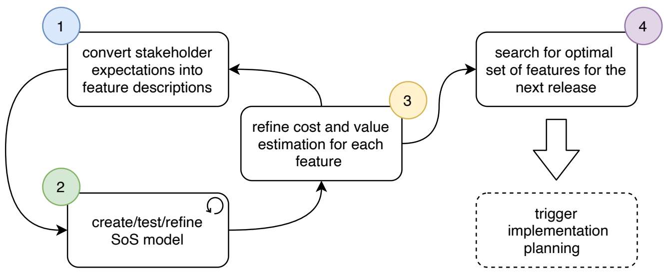

Fig. 2. Steps for the tool supported selection of features for the next release.

input data for the automated search which is executed in (4). As a result of this search, we get a set of features which can be used as a starting point for the implementation planning.

As outlined in Fig. 3, the process aims to link the business-level definitions of features with the specification of technical requirements. By utilizing usage scenarios, the artifacts in both views are connected with each other. In this way, features

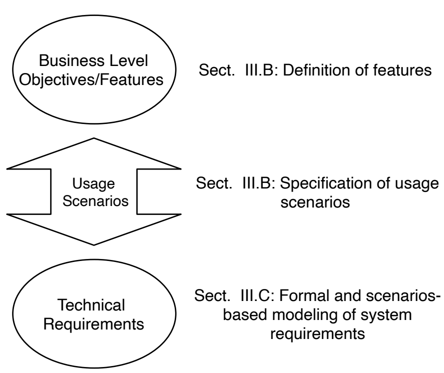

Fig. 3. Definition of features and formal, scenario-based technical requirements, that are linked via usage scenarios.

and technical requirements can be executed and refined iteratively. As a result, we obtain a feature specification that supports value estimation and a scenario-based specification of technical requirements that supports estimation of the cost of implementing a particular feature.

A. Objective Functions

To perform an automated search for an optimal set of features for the next release, we use the MONRP as proposed in [12].

We assume that we have a set of stakeholders,

$$S = \{s_1, ..., s_m\}$$

that have an legitimated interest in the realization of a new SoS functionality. Based on the desired SoS functionality, we derive a set of features,

$$F = \{f_1, ..., f_n\}$$

and for each feature $f_i(1 \leq i \leq n)$ we define the estimated costs

$$Cost = \{c_1, ..., c_n\}$$

for the realization of that feature.

According to Fig. 1, we see the stakeholder outside of the SoS boundary. Within the SoS, the system owner O1 directs the composition of the individual CSs. From the perspective of this system owner, the importance of the individual stakeholder might vary. Consequently, as proposed in [12], the relative weight for each stakeholder $s_j = (1 \leq j \leq m)$ is denoted by:

$$Weight = \{w_1, ..., w_m\}$$

with $w_j \in [0, 1]$ and $\sum_{j=1}^{m} w_j = 1$.

In addition, for each stakeholder $s_j(1 \leq j \leq m)$, we assign a value to a feature $f_i(1 \leq i \leq n)$ indicated with $value(f_i, s_j)$ where $value(f_i, s_j) > 0$ if the stakeholder j is interested in feature i and 0 otherwise.

The resulting importance of a feature is calculated with:

$$score_i = \sum_{j=1}^{m} w_j \cdot value(f_i, s_j)$$

Based on this, we can define the two objective functions for the metaheuristic search. First, we want to maximize the overall value:

$$Maximize \quad f_1(\vec{x}) = \sum_{i=1}^{n} score_i \cdot x_i$$

and second, we want to minimize the overall costs:

$$Minimize \quad f_2(\vec{x}) = \sum_{i=1}^{n} cost_i \cdot x_i$$

Within the decision vector $\vec{x} = \{x_1, ..., x_n\}$, x_i is 1 if the feature i is selected for the next release and 0 otherwise.

B. Feature Specification

To support the estimation of concrete values for $value(f_i, s_j)$, we enter the first step in the process outlined in Fig. 2. In this step, we collect stakeholder information and convert the expectations into a comprehensive and structured feature specification using the Gherkin syntax [13]. One example is shown in Listing 2. In this way, we can create multiple feature files, where each feature file contains one or more usage scenarios that describe the expected system behavior from a user's point of view.

```
Feature: User-managed charging (UMC): The user of an electric
      vehicle requests up-to-date information on energy prices
      and enters preferences into a smartphone app to calculate
      an optimized charging plan.
  Scenario: The EVU requests information on energy prices
    When the EVU request information on energy prices via the
         smartphone app
    Then the smartphone app requests these information from an
         energy information service
    And the energy information service sends this information to
         the smartphone app
    And the smartphone app displays the received information
  Scenario: The EVU user enters charging preferences
    When the EVU user enters charging preferences
    Then the smartphone app calculates an optimized charging
         plan
    And the smartphone app sends the charging plan to the
         electric vehicle
    And the electric vehicle executes this charging plan
```

Listing 2. Feature specification with the help of usage scenarios.

In the SoS example shown in Fig. 1, this step is done by the system owner O1, who directs the operation of the integrated SoS functionality. On this level of abstraction, the individual CSs are seen as black boxes and the usage scenarios are used to document how the CSs must interact to realize the expected SoS functionality.

By using this kind of feature specification, we can create separate files for each feature $f_i (1 \leq i \leq n)$ to provide an initial overview of the desired system functionality.

C. Definition of Systems and their Interaction

Based on the initial set of features, we create *scenario specifications* that include definitions of all CSs and how these CSs interact (see. example in Listing 1). By executing and testing these scenario specifications we successive refine both, the initial feature specifications and the scenario specifications. As outlined in Fig. 3, this is done by utilizing usage scenarios to link features and technical requirements. To bridge the gap from the feature specification to the technical requirements, we generate test steps from the usage scenarios and apply the test-driven scenario specification approach (TDSS) as introduced in previous work [8], [9].

As outlined in Fig. 4, we do this on two levels of abstraction within a SoS context. In a first step we define the interaction between CSs, where these systems are seen as black boxes. The focus is to identify the required systems and model their interaction. Subsequently we create separate scenario specifications to model the internal behavior of selected CSs (see. [11]).

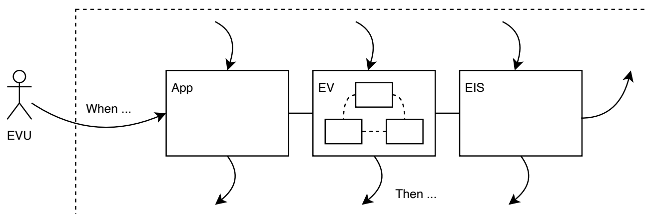

Fig. 4. Identified systems with different levels of detail.

As an example, to realize the feature specified in Listing 2, we can define three systems (smartphone app, electric vehicle, and an energy information service), where an electric vehicle user is interacting with a smartphone app. Now we can assume that the smartphone app and the energy information service are existing systems that should be integrated with an electric vehicle under development. In this case, it is also necessary to identify the components of the electric vehicle that are involved in the desired SoS functionality, which can be done in a separate scenario specification that details the internal behavior of a CS [11].

IV. Proof of Concept

To exemplary apply our approach, we integrated SMLK [15] with the Cucumber tooling [14] and the MOEA framework [16]. Subsequently we executed the steps shown in Fig. 2 and thereby created the artifact shown in Fig. 5 with the numbers 1-4 indicating the associated process step.

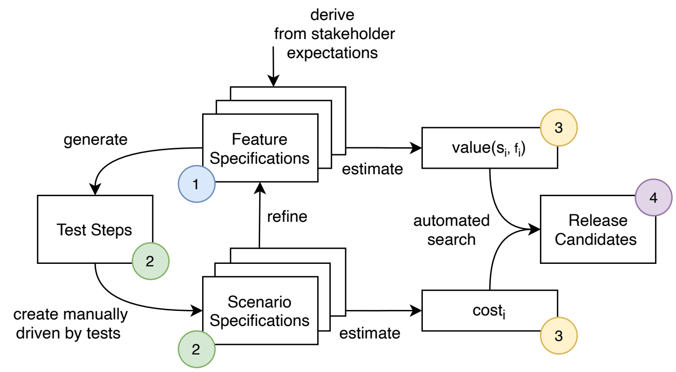

Fig. 5. Resulting artifacts when executing the process steps

We started with the creation of feature files containing usage scenarios as already shown in Listing 2. After we created a first set of features, we generated the test steps. Based on the example feature in Listing 2, we generated the test steps in Listing 3 and iterated the TDSS sub-process (step 2 in Fig. 2). In each iteration we a) added SMLK events to the generated test steps, b) executed the tests, and c) refined the scenario specification until all tests passed.

```
When("^the EVU user enters charging preferences$") {
  trigger(EVU sends App.enterChargingPreferences()) } //manually
        added event
Then("^ the smartphone app calculates an optimized charging
      plan$") {
  receive(App.calculateChargingPlan()) } //manually added event
...
```

Listing 3. Generated test step from the usage scenario in Listing 2.

After several iterations within step 2, the test results could be used to refine the initial feature specifications. Then we used these feature specifications to manually derive the value vector. To do this, we defined hypothetical values based on the amount of usage scenarios for a specific feature and the respective stakeholder. In the same way, we derived a cost vector depending on the complexity of the scenario specification with its CSs and their subsystems, representing the technical requirements of a specific SoS.

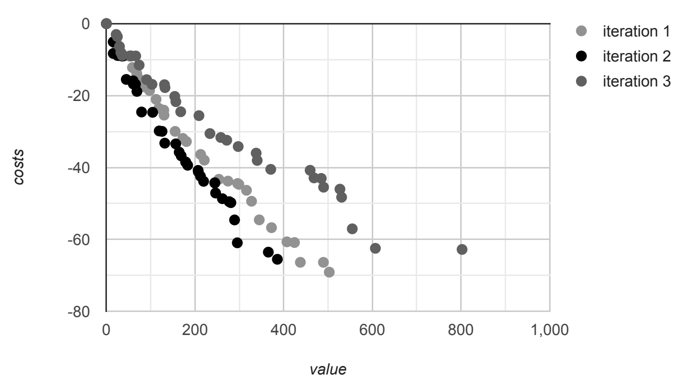

Fig. 6. Search results after three iterations with 10 stakeholder and 40 features.

With this input we exemplary executed the automated search for 10 stakeholder and 40 different features. In Fig. 6 we see the search results with the input data of three iterations. For every iteration we got a pareto optimal front, where each point indicates one possible release candidate. Each release candidate includes a vector containing all features, with 1 if the feature should be selected for the release and 0 otherwise.

V. Summary and Outlook

In this work, we combine a structured feature specification with a scenario-based modeling technique to assist the release engineer in identifying costs and values for the specified features in an early planning phase of an SoS. The cost and value are forming the link into the decision-making processes of the stakeholders in a Smart City since they can be linked to the inputs and the impact of the respective project.

Feature specifications in natural language are used to support the identification of values that these features can create. Using natural language supports the involvement of the stakeholders into the decision-making. The formal and scenario-based modeling of technical requirements is used to support the estimation of costs, depending on the effort it can take to realize the requirements via different CSs. We connect both artifacts (feature specification, scenario specification) with a test-driven specification approach based on stakeholder expectations formulated as usage scenarios.

With this approach we address SoS characteristics like evolving development of individual CSs, where requirements can change constantly but nevertheless can be part of a higher level SoS functionality. The used modeling techniques and methods [8]–[11] support the iterative analysis and refinement of the changed requirements. The iterative specification process combined with the automated search for release candidates based on the MONRP is a promising approach to support the release engineer in complex trade-off decisions.

Future work should consider how to extend the modeling capabilities to estimate more realistic input data for the search. The objective functions should also be adapted to allow the search for features in a realistic release situation. Since this first approach is based on the problem statement in [12], it is assumed that all features are independent from each other, which is an unrealistic assumption. One possible improvement would be to combine the feature specifications with goal models, as done by Aydemir et al. [27], and in this way also consider dependencies between features and requirements when searching for optimal release candidates.

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Smart Ticketing System for Kazakhstan Public Transport: Challenges and the Way Forward

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***Abstract*—Over the last decades, different ticketing systems for public transport have been introduced, and some have shown success while others have not. Kazakhstan has also introduced electronic ticketing systems in some cities. It is expected that such systems will improve the travel experience, provide transparency, reduce costs, increase tax collections, and contribute toward the smart city policy. However, the introduction of such systems requires collective actions from the participants of such complex ecosystems who have different needs to be satisfied. Hence, this paper aims to analyze the stakeholders' needs and map out the challenges and opportunities of implementing automatic fare collection systems in Kazakhstan. Therefore, the public transport system in Pavlodar city was purposefully selected as a case study. The study draws some recommendations for a smooth digital transformation of the public transport system in an average city of Kazakhstan.**

Keywords—smart ticketing, automatic fare collection, digital payment, smart card, challenges and opportunities of smart ticketing, benefits and drawbacks of digital payment

I. Introduction

The increasing urban population places challenges for sustainable development of cities, and in order to meet them and provide correct solutions, authorities have to pay attention to the provision of required infrastructure in terms of transportation, housing, energy and water supply which is consistent with the concept of smart cities. Smart cities encompass the ideas of smarter public transport, more efficient water supply and waste management, upgraded ways to provide light and heating to buildings. Given that more than 80% of Kazakhstan citizens are internet users, and 58% of the population is urbanized, the country has a good infrastructure for the further development of digitalization of the economy through its smart city policy. Information availability, the use of eco-friendly transport, availability of Intelligent/Integrated Transport System (ITS), safe road infrastructure and ***effective billing and convenient payment system*** are listed as key components of smart and sustainable city principles [1]. Major cities of the republic have already introduced electronic payment systems on their urban public transport within the Digital Kazakhstan state program and its Smart City policy. However, the average cities of Kazakhstan, not included in the list of priority cities of smart city policy, require a proactive joint effort of transport ecosystem participants and special attention in order to reach the desired outcomes of digitalization at lower costs.

In this regard, the research aims to investigate what kind of digital transformation model of payment system is more suitable for Pavlodar city public transport network through a thorough stakeholder analysis, a user study based on the design thinking approach and extensive literature review and expert interviews. Taking Pavlodar's public transport as a representative case of a public transport system in an average city of Kazakhstan, the common ***challenges*** for transport digitalization projects might be identified. In addition, managerial implications and recommendations are proposed. The following research objectives are investigated:

- **RO1:** to understand the nature of smart ticketing ecosystem and discuss its pros and cons;
- **RO2**: to research the roles of and identify challenges of digital transformation of public transport in Pavlodar for different stakeholders based on the literature review and existing Kazakhstan experience;
- **RO3**: to present recommendations on the most suitable path for the digital transformation of public transport in Pavlodar along with managerial implications.

II. Literature Review

The main interaction between customers and public transport service happens through fare collection system, and the main profit is generated through ticket sales. Thus, the ticketing scheme in public transport can be considered as a key component to assess the success or failure of the public transport system. Fare collection systems can be grouped as traditional and innovative [2]. Ticketing methods can be broadly classified as paper and electronic (or smart). E-ticketing is a method that does not require the issuance of "paper" in order to document the sale. Paperless means of payment include a transport card, a contactless debit/credit card, mobile or another electronic device through which the purchase is enabled, as well as different wearables such as bracelets, rings, key rings, etc. [3].

Although, public services, e.g. public transportation, are not aimed to be profit-generating, nonetheless, the reduction in costs should always be a priority [4]. Automatic fare collection systems can be introduced not only to reduce costs, but also to decrease the fraud rates in the public transport industry, increase the quality and make the passenger and

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driver experience simple, as well as to collect vital data about travel behavior that can be used to generate managerial implications for better governance and improved decision-making process [5-7]. It is suggested that smart ticketing system should be focused primarily on improving the efficiency of passenger transport enterprises in terms of revenue collection, reducing the cost of manufacturing and distributing ticket products, attracting passengers and improving the quality of their service [8]. Automatic fare collection can be considered as the cornerstone of ITS, which, in turn, is a vital element of the smart city concept [6]. Additionally, reduction of accidents, congestion, waiting and boarding times, as well as protection of the environment, through reducing the number of paper tickets, are of huge benefits [7][9]. Moreover, the real need for subsidies, optimal route network and accurate amount of preferential passengers (pensioners, pupils, disable people) can be identified [5][6]. By collecting and analyzing the data, operators can develop schedules that would reflect passenger demand much better [10]. Thus, the budgetary expenses for subsidizing transport enterprises can be optimized, and the collection of incomes becomes transparent and under stronger control. There was also found a 17% increase in the revenues as a result of introduction of digital payments [11]. Moreover, it was identified that the occupancy rate of validators is lower in comparison with the occupancy rate of the conductor, i.e. the time spent on paying for travel is minimized, and queues are reduced or eliminated [12].

On the contrary, the fare collection system based on the issuance of paper tickets with the use of cash is simple, has low operating costs and in most cases reliable [13]. Features such as easy and simple validation, low purchase costs as well as easy distribution and availability of the tickets are mentioned as pros of the system. However, the inability to provide information of the movement of passengers, the inflexibility of the ticket with regard to ticket type and single-purpose of the ticket (e.g. inability to use for parking or in the library) were identified as disadvantages of the paper ticket. The main drawback of the paper ticketing method is its incompatibility with ITS that is at the center of smart city concept and is aimed at improving the urban public transport system [10]. Similarly, paper tickets can be easily falsified and are not reliable if data collection if required [5][11].

Smart ticketing options are usually based on technologies such as Short Message Service (SMS), Quick Response (QR) code, Radio-Frequency IDentification (RFID), Near Field Communication (NFC) and Bluetooth. ***SMS*** ticket in public transport can be purchased through sending a message to a special number which subtracts money from the phone balance and replies with the receipt in another message and ***RFID*** technology is widespread in the use of contactless transport cards with special chips which can store data [5][14]. ***NFC technology*** can be used to scan the contactless card, to use the mobile wallet such as Apple Pay or Android Pay or smart wearables [15]. ***QR-code*** is a type of barcode which stores the required information of the system to which it is attached. The barcode can be placed in the bus, and the passenger can scan the code with the help of special application or the purchased electronic ticket with a barcode needs to be scanned at the validator or showed to the driver at the bus enter [16].

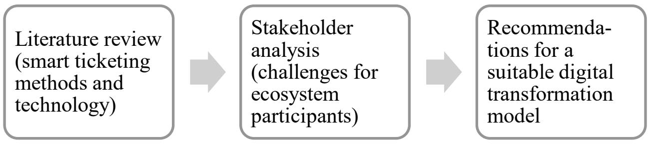

Fig. 1. Methodology of the study.

III. Methodology

The methodology of the study is presented in Fig. 1 and is based on the literature review and the stakeholder analysis and will result in recommendations on a suitable digital transformation model for Pavlodar.

Smart ticketing solutions are usually difficult to implement since it is hard to reach an agreement among different stakeholders, sometimes conflicts of interests arise [5]. Depending on political and economic background of the cities as well as the public transport environment, the stakeholders range can vary [17]. For the current project the following stakeholders are identified and studied: authorities (city municipalities, local transport authorities, tax authorities), public transport operators, passengers, system operators, suppliers and other intermediaries.

In order to define the critical issues of the available smart public transportation systems in Kazakhstan, a design thinking method was applied with the participation of those who frequently use public transport services and experienced with both traditional and smart systems in Nur-Sultan. As a result of the user study (workshop), participants were able to come up with the solutions such as changes in the existing software, introduction of ITS, efficient process of card top-up, availability of more convenient payment methods, enhancement of a mobile application, implementation of a better incentivizing discount system, development of route optimization software. Additionally, bus overcrowding, cleanness, air-conditioning, and conditions at the bus stops are among the frequently mentioned issues that are indirectly related to smart transportation systems.

The recommendations will be presented for Pavlodar city which is located in the northeastern Kazakhstan and the 7th largest city with a population around 350 thousand people. The city is one of the main industrial regions of Kazakhstan and has one of the largest oil refineries in the country. The public transport of the city is served by buses of different size and a tram network, one of the oldest in the country. It is estimated that 250 thousand people are transported daily by the public transport on average, up to 45 thousand by almost 70 trams and the share of trams in the total volume of transportation in the city is almost 40%. The payment system in the Pavlodar transport system is traditionally done by cash which serves as a base for shadow market, reduces tax contributions and provides inaccurate information of the movement of passengers in the city. In 2019, a pilot project on digital payments was introduced into the trams and one of the bus parks under the municipal control. Special portable terminals that accept payments from bank cards were bought by local municipality and rented out to carriers [18] [19].

IV. Findings

A. Stakeholder Analysis

To better understand the participants in this complex ecosystem, the most critical expectations, roles and risks of key stakeholders are provided in Table I.

TABLE I. EXPECTATIONS, ROLES AND RISKS OF STAKEHOLDERS [5-9] [17] [20]

	Expectation	Roles	Risks
Authorities (public transport, local, national level authorities, tax authorities)	- Transparent payment system that benefits all of the stakeholders. - Larger taxes	- Project facilitator - Support and standardization of the system implementation process - Control of budget revenues from taxes	- Customers and public transport operators will resist switching to the smart ticketing system - Negligent performance of obligations by the parties
Public transport operators	- Optimization of operational efficiency. - Money flow transparency - Increased revenues.	Carrier services	- Customers will resist switching to the smart ticketing system - Ignorance of system by personnel - Non-receipt or delay in receipt of payments - System failure - Reputational risk
Passengers	- Easy to use - Habitual payment method - Better travel experience	Direct users of the system and carrier services	- Lack of Personal data - Inconvenient system
System Operator	Profit generation	Initial investment, installation and supervision of the smart ticketing system	Revenues does not cover costs incurred
Suppliers		Provision of hardware and software	
Financial service providers/ Telecommunication operators		Processing electronic payments	

As it has been highlighted in Table I, the expectations of authorities, public transport operators and passengers are aligned with each other as they expect a transparent, easy to use and convenient system. These stakeholders are also the ones to bear more risk. While system operators, supplier and other intermediaries expect profit generation and bear mostly financial risks. Overall, smart ticketing system should offer a clear value proposition that will incentivize customers to transition and will encourage authorities to implement the system [17].

The next section presents the findings about the smart ticketing in Kazakhstan, principally Pavlodar, and discusses challenges and opportunities for corresponding stakeholders with regard to findings in literature review.

B. *Smart ticketing in Pavlodar and Kazakhstan*

Different electronic ticketing systems are launched in the following cities of Kazakhstan: Almaty (in 2015), Nur-Sultan (in 2016), Shymkent (in 2020), Kokshetau (in 2019), Atyrau (in 2018), Semey (in 2019), Kokshetau (in 2019) and Pavlodar (in 2019). Systems differ in their architecture (online vs. offline), funding scheme, governance. Introduction of the above digital payment systems had challenges. The obstacles that were encountered require close analysis with regard to corresponding stakeholder as per Table I in order to produce recommendations for full-scale implementation of similar electronic payment system project in Pavlodar and other cities of Kazakhstan.

C. *Authorities*

Authorities always have a great interest in public transport systems being effective and act a "driving role in policy implementation". All undertakings, projects and stages of development are determined by the rules, programs and financing of governments and administrative bodies [6]. Even though in most cases, the sector does not generate enough financial sources to cover its operating expenses, it is often subsidized to make sure that the important service is in provision [7]. In Kazakhstan, only 7 regions out of 16 are partially subsidized to cover the expenses of routes which are not economically feasible but of social importance [21]. Given the extended participation of the local municipality in the public transport system, the city authorities and corresponding offices within its structure can be identified as one of the main stakeholders whose opinion and needs should be considered in the current project. Thus, the foremost importance was given to interviewing the local authorities of Pavlodar, in particular, with the head of the Transport Department. As a result, the following useful information was obtained.

First, the introduction of a new and transparent payment system is a priority for the city, as the current conventional payment system does not satisfy the minimum level of requirements in terms of ***transparency and efficiency***. For example, the validity of the data on the number of preferential citizens that is provided by the State Center for Pension Payments cannot be confirmed by the department because there is a lack of passenger counting system.

Second, there are some economically unprofitable routes, which are considered socially significant and therefore cannot be eliminated. To cover the expenses, public transport authorities apply for government subsidies, but due to the fact that approved data on number of passengers transferred should be provided, this becomes a challenge for transport operators. As a result, ***outdated and invalid information*** is provided to the authorities when applying for subsidies.

Third, ***the Shadow cycle of money*** is claimed to be a major problem of authorities (including tax authorities) and public transport operators, as significant amounts of money being settled in the pockets of drivers and conductors [5]. For example, as a result of launching the electronic payment system in public transport, the actual passenger traffic in Atyrau, Kokshetau and Semey was obtained, which previously were estimated at a volume of 2-4 times lower. Another example, the effect of one month of differentiated tariff in Almaty was the derivation of 800 million Kazakhstani tenge as the shadow market and cash payments decreased by 4 times [22]. Moreover, in 2019, three existing carriers in Semey, altogether paid 56 million tenge of taxes, while after the introduction of the differentiated tariff in 2020 the collected amount of tax for 6 months of this year already comprise 150 million tenge [23]. This allowed to optimize the volume of subsidies.

Fourth, an effective way to incentivize citizens to use smart ticketing systems is to introduce ***a differentiated fare***.

In order to introduce this rate, pass of a special decree by the local municipality is required. According to the introduced changes into the law on road transport, city municipalities are allowed to pass the required decree at their level, thus, incentivizing passengers to use the electronic payment system as well as investors to put e-ticketing projects in place. As a result of introducing differentiated tariff in Almaty, Nur-Sultan, Atyrau, Kokshetau and Semey, the penetration of non-cash payments in these cities now comprises more than 90% of the total passenger traffic [22] [24-26]. The fare is currently in place in all cities where electronic payments are used except for Pavlodar.

Fifth, the governance and control over the transport system in the previously mentioned cities differ. Almaty still has some companies who are not reporting directly to Almaty Transport Holding, thus, the installation of equipment and fair fare collection becomes complicated. However, Nur-Sultan city requires a special contract to be signed in order to be able to operate in the city and the routes should be approved by the capital municipality. Thus, the system covers everyone and in line with the legislation [27]. In Pavlodar, the authorities were able to roll out the recent pilot project on electronic ticketing only for carriers who are directly under the municipal control. However, one of the private carriers, for example, is strongly against the proposal of local municipality to introduce electronic payments due to its high costs, questionable effectiveness and the need to share the commission with system operator and banks [19].

To sum up, the expectations, roles and risks of authorities as well as the risks on the resistance of customers and transport operators to switch totally to a new system in Kazakhstan confirm the ones provided in the literature review. The introduced projects were able to some extent provide transparent payment system with the benefit of obtaining the accurate numbers on passenger traffic and correct amount of taxes.

D. Public transport operators/carriers

In order to be able to achieve profit whilst executing electronic ticketing, public transport companies require subsidies from government for preferential passengers, and for unprofitable routes, etc. Subsidies are promised for passenger carriers by authorities in return for introduction of digital payment systems in their fleet. However, in Semey city, local authorities delay the subsidies granting and left the carriers with leasing obligations and operational losses [28]. One of the solutions is to increase the fare rate, but this will result in social tension among passengers. Thus, the initial necessary step for a successful implementation of smart ticketing system is the development of inter-organizational relations [5].

Moreover, for a passenger carrier, these are risks from personnel such as unprofessional use of the system, interference with it and its ignorance [20]. For example, in Atyrau city, since the electronic ticketing system was introduced, many bus drivers and conductors were intentionally breaking the terminals for electronic payments or were saying that they were broken in order to collect the money by cash and bypass the system, so the commission of the system operator is not deducted. Similar protests and actions were taken during the introduction of Onay system in Almaty, where bus drivers would remove the stickers from the walls of the buses that explained how to pay for the ticket through SMS or QR-code [29]. Moreover, drivers and conductors in Pavlodar took advantage of the fact that validators were placed only in one bus fleet. Since passengers will not be bothered to figure out on which buses they can pay by bank card, conductors were eager not to inform that digital payment option is available. Passengers also noted that some conductors even refused to accept non-cash payments. Explanatory work with the personnel before and during the implementation of the system is crucial for its success.

Passenger carriers may also face commercial, financial and reputational risks. First, it is the risk associated with non-receipt or delayed receipt of payments due to technology or network disruptions. There are cases of system freeze which makes the conductors in Pavlodar to put away the portable validators on the shelf and return to cash payments [19]. Second, there is also a risk of system failure. If the validator is out of service, it is assumed that a passenger can take a free ride, which also impose revenue loss on passenger carriers as well as system operators. Third, a reputational risk is also present. There were cases when extra money was charged from transport cards [19]. In this case an outflow of passengers to a carrier with similar routing is possible [20].

Since the projects under smart city initiative are directly controlled by the local authorities, it is important for passenger carriers to provide reciprocal support and understand the importance of digitization in the long term such as new young riders and international tourists who value cashless experience [11] and increase of personnel safety through minimization of personal contact, especially during coronavirus pandemic. In addition, the data generated as a result of automatic fare collection system can help to improve the fare and route formation as well as capacity planning.

E. Passengers

For passengers, smart ticketing system can potentially offer the following benefits: faster and more convenient payment process; shorter boarding time; reduced travel time; replacement of lost tickets; increased usability: no need to have change for local ticket issuing machines [17].

Applying design thinking method, problems and solutions were extracted from customers. The consumers indicate their sensitivity toward fare collection system, and how convenient and comfortable the introduced public transport service.

Currently, customers in Kazakhstan are incentivized through different promotions such as 50% when paid by visa bank card or 99% discount when paid by SMS. Thus, the fare collection system for Pavlodar should be designed based on the monetary incentive, easiness and convenience of use and as a part of a broader ITS that would also bring benefits such as universal payment for multimodal transport system (buses and trams in Pavlodar), road safety and improved transport connection along with the value for money.

F. System Operator, Intermediaries and Suppliers

System operator is an organization or company which is engaged with the implementation of the smart ticketing system. The company usually covers the initial investment either fully or partially, and is responsible for a reliable functioning of the system. Municipalities in Kazakhstan face a challenge in choosing the most suitable system and a reliable operator due to lack of proper due diligence. Developer of a local software Avtobys which operates in Semey and Atyrau states that in most cases municipalities choose foreign suppliers over local ones even though the system can be outdated [30]. For the existing pilot project in Pavlodar, a software developer from abroad was chosen, however, the system already obtained negative feedback from the end-users and carriers such as offline architecture of the system. Thus, it is important to carefully assess the suppliers, check the references of the vendors since many of them might be new in the industry [31]. Currently, the most common suppliers for public transport are the ticketing companies, vending machine suppliers and devices for ticket reading as well as software developers.

Telecommunication operators are also in the market, since for NFC payments a chip must be embedded into mobile devices. Nine out of ten people were satisfied with using NFC technology during Nokia trials which were conducted in London [32]. Consequently, it is expected that the use of NFC-enabled tickets will lead to additional GSM/UMTS transactions, and the additional services generated by NFC technology will attract and retain customers [5]. In addition, in Kazakhstan SMSBUS company made it possible for public transport users to pay the fare by sending the SMS to a designated number.

It is evident that the challenge of selecting payment system without prior due diligence may lead to poor customer experience and even a project failure. Transport operators must ensure that the implemented smart ticketing systems are adaptable, reliable and scalable, and can be adjusted over time to meet ever-changing needs. When properly implemented, such systems can revolutionize the way customers use public transport, greatly increasing convenience, efficiency and flexibility [5].

V. Conclusion and Recommendations

Based on the literature review and stakeholder analysis, this research concludes that the introduction of an efficient smart ticketing system is important to eliminate the problems in public transport such as shadow money cycle, incorrect information on passenger traffic and improve the travel experience. For a smooth project implementation, the needs of key stakeholders such as government, investors, transport operators and passengers should be aligned, and proactive participation and mutual support should be incentivized through preliminary outreach program about the benefits of the proposed change aimed at at final customer (better travel experience and overall convenience) and carriers (new reliable information, operational effectiveness, etc.) based on change management principles. The value proposition of the automated fare collection system should satisfy the needs of the foremost important stakeholders. The choice of the ticketing system should solely be done with the consideration of local characteristics (e.g. multimodality of transport system in Pavlodar) and integration with future ITS. The hardware and software for the smart ticketing system can be sourced, developed and manufactured locally.

The introduced projects of automated fare collection system were able to some extent provide transparent payment system with the benefit of obtaining the accurate numbers on passenger traffic and correct amount of taxes.

Passenger carrier benefits, e.g. commissions, shall be compensated in order to reduce the resistance against the electronic payment system. Moreover, the carriers shall be trained and encourage to inform the passengers of how to pay. There is also a need to track all system malfunctions, e.g. network problem, system failure, money-charging errors, and continuously improving the system. The system shall self-report any malfunction event and those events shall be announced/communicated to customers in order to avoid fake information.

Part of the digital transformation for public transport is to develop algorithms that provide insights based on the passenger data. The automated payment system or application is excellent step to transform the public transport, as it automates the payment process. However, the entire value chain of public transport, e.g. bus tracking, journey planner, discount offering, capacity planning shall be digitized in the further steps.

Central control and coordination is also important for successful project implementation along with municipal support. It is the role of the local authority to develop and pass the required legislative acts (e.g. introduction of differentiated tariff) in order to facilitate the project. A prior due diligence of the lessons learnt from other cities' experience and best practices is vital at project development stage. City authorities sometimes for the sake of reporting to the republication level authorities on the progress of digitalization projects in their cities, rush into the project implementation stage without proper design stage which can increase the unwanted resistance from passengers and carriers. A roadmap of the project that will include vision, sources of funding, political agreement, effective governance and measure of progress should be developed.

The financial model should be developed based on the statistics and the costs of the required systems such as: mobile application for passengers and for conductor/controller, with build-in function of checking electronic payment, the system of monitoring and reporting; routing information system, which includes the systems of dispatching, monitoring and reporting; and other required systems (e.g. physical and digital systems, vending machines, etc.). As experience showed, the final system should have the possibility to pay by cash at earlier stages along with the new digital payments systems being introduced gradually.

The project should be economically feasible and all the calculations should be made for different scenarios such as with and without the introduction of the differentiated tariff since when the tariff is introduced, it would incentivize people to use smart ticketing methods and this in turn will increase the revenues of the system operator.

The above recommendations can be extended further. For example, a survey on the readiness of citizens to use new types of payments as well as their attitudes towards technology acceptance can be implemented for a better understanding of customer needs [33].

In summary, it can be concluded that public transport transformation is inevitable for cities toward their smart cities strategy. Moreover, understanding the challenges that can arise during project implementation can provide local municipalities and other stakeholders with valuable insights to improve and be more mature.

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Shaping Smart Intermodality Between Waterborne and Landside Transport in the Coastal City of Stavanger

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***Abstract*— Worldwide, waterborne transport is the most efficient choice for moving goods in terms of tonnes per kilometer. In Europe, especially in the Nordic countries, it is a relevant mobility means for passenger traffic too, used mainly for commuting activities. Most of the vessels operating on coastal and inland waterways, for either goods or passenger transport, are equipped with conventional diesel powertrains that negatively affect the environment and endanger the well-being of the population that live and work in their immediate surroundings. Through legislation and funding programs, electrification of ferries and larger vessels has already begun and should contribute to the achievement of carbon neutral shipping in Europe by 2050. The integration of electrified vessels into existing mobility systems and urban infrastructure to optimize passenger journeys and cargo transport represents an additional challenge. With the use case of the coastal city of Stavanger, this paper presents an approach to identify and evaluate mobility services and accessibility issues with the purpose of enhancing intermodality between waterborne and landside passenger transport.**

Keywords—intermodality, mobility hub, services, smart city, waterborne transport, zero-emission

I. Introduction

Day by day, mobility in urban areas is becoming more complex, and the expectations set on it are high and as diverse as the stakeholders who are involved in this topic. Green, intermodal, seamless, digitalized and fair are some of many adjectives that describe the expectations on mobility [1] and are usually associated with the Smart City concept. Even though the term Smart City has been in use for slightly over a decade [2] and many cities around the globe have launched exciting and enriching projects, it seems that there is still much to be discussed, tested and achieved. Smart cities are one of many responses aiming to make cities more efficient to deal with current challenges. Tackling environmental, social and economic urban issues with interconnected ‘smart’ approaches can improve livability and equity in cities [3] - [6]. In this way, ‘smart’ cities and ‘smart’ mobility are somewhat intertwined [4], [7], [8].

When talking about low-emission or smart mobility, many may draw mental pictures of users commuting into the city, exiting a train and taking a shared e-scooter to ride the last mile. However, smart mobility needs to go beyond land infrastructure of paved streets and railways and also consider waterborne commuting to ensure smart intermodality. Those who commute by waterways are also highly dependent on intelligent infrastructures. Intelligence in this context can be translated into what at first sight seems a simple example of an intermodal transfer, such as having a comprehensive and reliable real-time information system to know if a bus will reach the port punctually not to miss the last ferry trip to an otherwise unreachable fjord. Taking a closer look, the fact that this requires an information system that eventually includes data from different mobility providers operating in different settings (water/land) and the lack of alternatives for this journey's execution seems to take out the simplicity of the described example.

In terms of goods transport, maritime transport is extremely relevant. Approximately 90 per cent of international trade happens on water with seaports being the nodes that link waterways with landside transport modes. Depending on geographical conditions and the origin and destination points of routes, waterborne and landside transport can be in a relationship of cooperation or competition [9], which makes the dynamics of the transport sector even more interesting.

Waterborne transport in Europe holds a long history and is of particular importance socially, commercially and ecologically. Because of its geographical conditions, i.e. islander character, Europe requires maritime transport to move a vast amount of passengers and goods through short sea operations with ferries [10]. As well as for landside transport, European authorities attempt to decarbonize maritime operations in order to achieve general GHG emission goals. The lack of market-ready zero-emission vessels and the fact that these have development and life cycles of almost 20 years, significantly exceeding those of automobiles [11], makes the sector's evolution towards decarbonization significantly slower, not to mention the huge investment in infrastructure that is associated with it [12].

These challenges shall be a motivation to follow a multidisciplinary approach in projects that deal with the decarbonization of the shipping industry. The project TrAM - Transport: Advanced and Modular seeks to develop a fast zero-emission vessel for passenger transport following a modular approach that optimizes development and manufacturing resources [13]. Additionally, it is complemented with an

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analysis of the various interactions between waterborne and landside transport in the context of smart cities. With the objective of identifying preconditions and services at interchange points that enhance smart mobility, the analysis includes different stakeholders, such as service providers and users, to address environmental, social and economic aspects. This article focuses on the method used to identify and evaluate potential services at the mobility hubs for the case study in the coastal city of Stavanger.

II. The Role of Waterborne Transport in Europe and the Context of Smart City Planning

Europe is responsible for over 35 per cent of the world's tonnage transported on waterways [14]. In a comparison based on value and carrying capacity of global commercial fleet[1], Greece scores as the economy with the highest percentages worldwide. In 2020, it held approximately 18 per cent of the world's commercial shipping capacity, significantly exceeding Japan and China's values, the second and third largest economies in this analysis, respectively. In terms of fleet value, it holds comparable market share values with the two aforementioned markets. At European level, Norway, Germany, the United Kingdom and The Netherlands are considered major players [11].

European inland waterways enable relevant goods and passenger transport as well. Europe has approximately 40,000 km of a congestion-free inland waterway network, from which 75 per cent crosses country borders and 50 per cent allow the use of 1,000-tonne vessels. Approximately 550 million tonnes are shipped through inland waterways a year. Yearly transport performance in 2018 achieved around 135 million tonne-km [15].

In terms of passenger transport, maritime waterways represent an important means of mobility in Europe too. Especially in the Scandinavian region, inhabitants require a reliable maritime infrastructure. In 2019, seven of the ten ports with the largest maritime passenger transport were situated in the Scandinavian and Baltic region [16]. Fig. 1 shows an excerpt of a classification of European ports according to their yearly passenger frequency.

In the case of Norway, some islands lack or have limited access to bridges for road transport to the mainland, making them dependable on vehicle and passenger ferries. In some cases, operating ferries in scarcely populated regions does not represent a favorable business case, but is part of a strategy to motivate citizens to move to rural areas in an effort to decongest densely populated cities and thus, achieve environmental objectives and improve the population's life quality.

According to [9], policies regarding the use of ports, inland waterway transport and short sea shipping occurring at European, national and regional level can be categorized in three areas: (1) Infrastructure policy, (2) Transport and logistics policy and (3) Environmental and spatial policy. Many of the financial and non-financial measures proposed at these three categories aim to optimize waterborne connectivity with hinterland transport through road and railways. In other words, these measures are directed towards

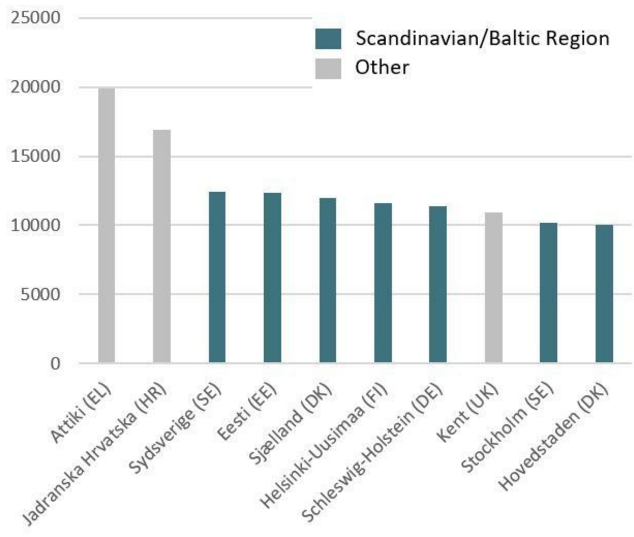


Fig. 1. Maritime transport of passengers in Europe in 2019, in thousand passengers per annum [16].

the enhancement of intermodal transport. Such measures include not only investments in port and inland waterway facilities but also investments in railway and road connections. Information and Communication Technologies (ICT) are recognized as relevant enablers of intermodality, reinforcing the idea of the efficiency in smart scenarios. Environmental policies focus on the legislation of emission levels, water quality and safety. The implementation of energy-efficient and low- and emission-free vessels should contribute to the achievement of environmental objectives.

Europe's maritime industry is undergoing a hybridization process that includes new energy storage systems (ESSs) and renewable energy sources (RESs). The challenges posed on the electrification of ferries go beyond the sole development of their electric powertrains; they also include infrastructural and operational issues related to charging equipment and routines as well as the use of lightweight materials in shipbuilding [10]. In terms of volume, private leisure boats have become the segment with the highest share of electrification with tens of thousands sold every year. Such ships are comparable to private passenger cars on road transport. Given their usually short-range requirements, they do not lead to significant charging issues. Market-value-wise, deep-sea vessels represent the sector with the highest potential [17].

According to the analysis carried out by [10], Europe occupies a leading position in terms of electric passenger ferries in operation with Norway and Denmark having seven and five electrified vessels, respectively, as shown in Fig. 2. Approximately 65 per cent of hybrid and electric vessels are used for commuting, 23 per cent for tourism and 12 per cent for various purposes.

Most likely, no other global phenomenon has affected economies as much as the current Covid-19 pandemic. For waterborne passenger transport, this meant hardly any cruise and excursions taking place in the first half of 2020. Everyday commuting trips to school and work were substituted by home office and homeschooling activities. Covid-19 preventive measures forced mobility providers to reduce the allowed occupancy of their vessels in order to ensure the mandatory

[1] Value estimated for commercial ships of 1,000 gross tonnes and above.

social distance imposed by authorities, affecting the providers' revenue. The consequences for cargo transport were less severe in general terms. Preliminary calculations from [15] estimate a reduction of cargo transport on waterways of 20 to 25 per cent. Consequences of the Covid-19 crisis, such as production shortages and reductions in budget and liquidity, threaten to lead Europe to a dependency on Asian suppliers. According to the European Shipbuilding and Maritime Equipment Association's estimations, this can imply a loss of approximately 120 billion Euro value added and one million jobs. It may affect Europe's competitive advantage in the shipbuilding and maritime manufacturing sector in the long term. As a consequence, it could hinder the achievement of carbon neutral shipping by 2050 as stated in the European Green Deal [11] and the reduction of at least 50 per cent in total annual GHG emissions by 2050 compared with 2008 levels as foreseen by the International Maritime Organization's strategy [18].

Transport and smart cities planning are interconnected and play key roles in the path of decarbonization in Europe and in tackling other urban issues such as efficient use of resources and equity [12], [19], [20]. Sustainable waterborne transport represents another great alternative to old transport systems that demand excessive fossil fuel consumption and valuable urban land [8], [12]. Due to the already existing relevance in Europe, it is a sure course that waterborne transport should be sustainably developed within smart cities, increasing the possibilities in the much needed intermodality and interconnectivity. For instance, inland waterways can contribute with freight and in cities with the last mile of commuting [12], [19], [20].

Unforeseen events, such as the current pandemic, as much as the largely discussed climate change require the public, industrial and service sectors to work together to shape smart cities with resilient mobility systems. For waterborne transport in Europe, this means exploiting opportunities to electrify passenger fleet and optimize on and off board service offerings at their fullest.

III. The Project TrAM

Mobility providers who strive a shift towards sustainable solutions for waterborne transport face important organizational and technical challenges. The development of novel electrified powertrains for vessels requires extensive knowledge, time and financial resources. Unlike automobiles, vessels are produced in small batches, making the proportion of development costs per produced ship very high [21], [22].

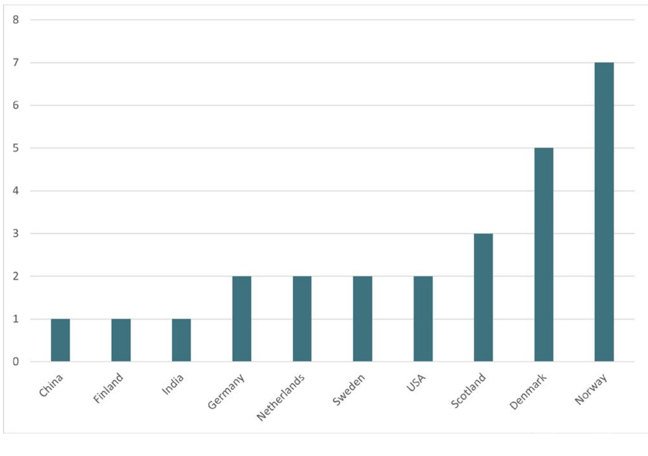


Fig. 1. Comparison of the number of hybrid and fully electric passenger ferries per country [10].

A multidisciplinary consortium made of fourteen project partners, including research and academic institutions, manufacturers and suppliers of the shipbuilding industry, governmental authorities and mobility providers, has been working together since 2018 on the project TrAM. The goal of this project is to develop a zero-emission fast-speed passenger vessel following an advanced modular production approach. The use of new manufacturing methods should help achieve a reduction of 70 per cent in engineering hours and 25 per cent in production costs. Therefore, the emphasis is not only on the powertrain system per se, but also on bringing innovation into the methods that will be followed to manufacture vessels in the future. Outputs of the project, besides at least one physical demonstrator, should be a toolkit of methods and software that can be adopted by the shipbuilding industry in future inshore vessel projects, for either small or large series. With the appropriate modularization of components and systems, vessel customization should be achievable at competitive costs. The project consortium will launch at least one physical demonstrator with a fully electric powertrain, which will be used as a fast passenger ferry to cover a multi-stop route in Stavanger, Norway. The two additional case studies correspond to the route of a river bus on the Thames in London and a cargo vessel that will navigate through a canal in Belgium [13].

In this project, the role of Fraunhofer IAO has been to support the mobility providers Kolumbus (Stavanger), Thames Clippers (London) and the institution De Vlaamse Waterveg (Flanders) with their activities towards the creation of Smart City concepts. In the project's context, this mainly includes the identification and evaluation of potential service proposals to be implemented at or around their mobility hubs with the purpose of optimizing intermodal trips. Expected outputs are a list of the requirements for the implementation of selected services as well as the identification of relevant stakeholders in the planning and decision-making processes. The work carried out during the project has included interviews and workshops with the mobility providers, preliminary assessments of the services' feasibility and online and on-site customer surveys.

IV. Case Study: Mobility Hub Planning in Stavanger

A. Smart Mobility Hubs

The term mobility hub is often associated with the Smart City since it elevates the state of 'stations' by relying on connectivity and added services. As mobility demands increased, and transport operators and stations naturally sought ways to adjust to it, different cities gave different names for these improved stations and stops. The hubs, nodes, stations or stops can have different sizes, services and relevance in the system depending on location, city and operator [23], [24]. Even though there is no standardized definition for this term, there is a common understanding of its functions and requirements. Mobility hubs are understood as places that provide users with different options to execute a journey. In other words, such a hub serves as an interchange point for diverse transport modes. The operation of a smart mobility hub implies that the integration of mobility services should be seamless and practically effortless for its users. Additional services and amenities, which are not strictly mobility offerings, can become essential elements of smart hubs that enrich the overall customer experience making it more efficient, safer, inclusive, more comfortable and sustainable. This way, many different actors, especially users, can profit from the hub's emergence [23] – [27].

Aspects to be considered during the planning of a mobility hub include, but are not limited to, non-motorized transport, shared mobility services, eco-friendly transport modes, integrated journey-planning and ticket services, leisure and food services, real-time information systems, accessibility and proper signaling. The decision regarding the choice of services that will be offered is partly influenced by the local context, user needs and preferences. A set of services that prove successful at a hub in one particular European country may show lower acceptance in another country in the same continent because local particularities and habits or geographical conditions play an important role in a user's transport mode choice. Nonetheless, the core idea of effective choices and seamless integration shall be prioritized during planning. In the best case, the process will be designed for the relevant stakeholders to be involved at an early development stage.

While water-land and land-land mobility hubs pursue the same general objective, the latter is more challenging as they tend to have more conflicting factors. They must satisfy context-specific, i.e. geographic requirements without sacrificing the effectiveness and efficiency of the transport mode interchanges. Just as physical products can be designed following a modular approach, it should be possible to approach services for a mobility hub as interdependent modules. These can be categorized, for example, as mandatory or optional modules.

Besides the local context, the role of waterborne transport in the region and, consequently, the type of vessels operated at the port are determinant for the selection of services at the mobility hub. Factors such as location in the city or region, scalability, age and historical value influence the degree of freedom with which a hub can be (re)designed.

B. Mobility in the City of Stavanger, Rogaland County

Stavanger city and Hommersåk town are areas that belong to the Rogaland County in southwest Norway. Their population accounts for 133,209 and 6,495 inhabitants [28], respectively. Kolumbus is the mobility provider for the whole county, responsible for operating buses and boats, and connecting other transport modes, e.g. trains, bikes, walking, car sharing, to their operations.

Kolumbus has the goal of stagnating growth in passenger car traffic and offering a completely fossil free transport choice by 2024, combining the new TrAM electric vessel and organic HVO diesel, hybrid operation and fully electric vehicles. This mobility provider has a total of 450 buses, ten fast ferries and three ferries. From Monday to Friday, the company offers approximately 111,383 daily trips for its customers [29]. Rogaland county council and Kolumbus work closely to achieve a better quality of life through Smart City concepts.

In 2019, Kolumbus had 26.2 million travels on their buses and 0.7 million travels on their boats [29]. In the area around Stavanger, the increase in the use of public transport was 13 per cent in the one-year period from 2018 to 2019 [29].

According to [29], inhabitants of Stavanger usually commute from residential areas into either the city center of Stavanger or towards the main industrial area at Forus, or a combination of these. Kolumbus performs a user survey on a yearly basis to track the population’s mobility habits and viewpoints. When asked which mode of transport people have used over the past 3 months, the commuters in Rogaland answer that private cars (traditional and electrical) are used by 68 per cent (57 per cent + 11 per cent), followed by buses (27 per cent), cycling (25 per cent), walking (15 per cent), trains (8 per cent) and boats (1 per cent) [29]. The buses in the Stavanger area are a combination of “feeder” routes with high frequency and many stops, and express routes in the rush hours between main mobility hubs and the industrial areas.

There is a rapid change amongst the inhabitants in Rogaland to transfer from private cars to other means of transport. In the one-year period from 2018 to 2019 the reduction in people who claimed they did not see any reason to replace their usage of private cars with other means of transport was 18 per cent, while the increase in people considering to get rid of a private car was 28 per cent in the same period [29].

The chosen route for the TrAM project is a multi-stop, circuit route from Stavanger to Hommersåk. This route is partly operating as a commuter route between Hommersåk and Stavanger, as well as between populated islands and Stavanger city. The fast-ferry has a high frequency, operating 15 trips every day, but also short distances allowing for a fully electric energy supply. For the commuters travelling on this route, it is important to have good connectivity with land-based mobility modes to extend the access to work locations around Stavanger. The TrAM vessel will operate the route with the same speed and frequency as today's traditional diesel-driven fast-ferries but is expected to improve customer satisfaction both through noise reduction and reduced GHG-emissions.

With the introduction of the fully electric TrAM vessel, Kolumbus will be closer to its targets of zero-emission mobility services. Kolumbus intends to use the competence gained from this project to further electrify their fast-ferry routes and to be able to fully meet the zero-emission targets by 2024.

C. Methodological Approach

In the course of the TrAM project, Fraunhofer IAO has been working together with the mobility provider Kolumbus to identify and evaluate service propositions that can optimize intermodal mobility in the Rogaland County and thus, increase user acceptance and demand. In the first phase of the cooperation, the partners followed a five-step method that ranged from the description of the mobility services' status quo, through the development of a vision for the project's scope to the selection of potential services. Fig. 3 illustrates the objective of each step in the method.

As a first step, Kolumbus provided a description of the current spectrum of mobility services they operate in Rogaland County. Besides having a vast network of city buses

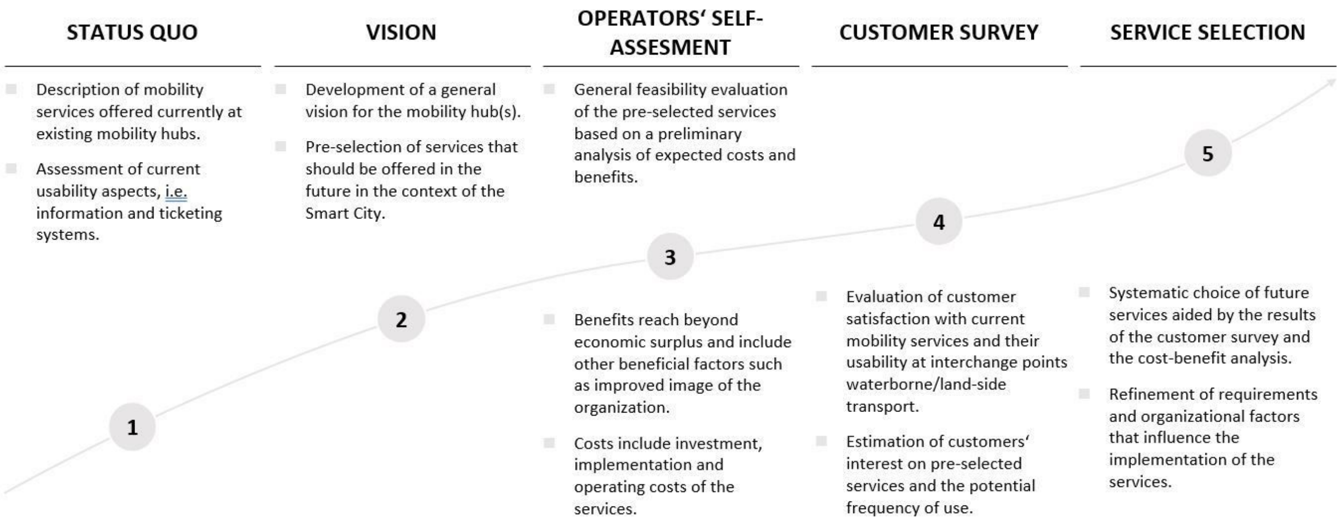
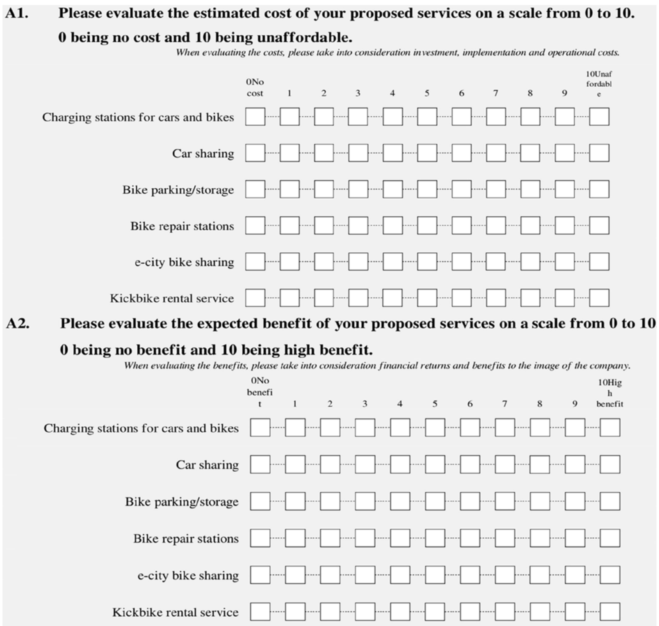


Fig. 2. Method for the preselection and evaluation of services for a smart mobility hub.

ferries connecting the mainland with the fjords around Stavanger, Kolumbus has also established innovative on-demand and sharing mobility concepts, such as the Home-Work-Home solution, an on-demand shuttle called HentMeg (Pick Me Up) and carpooling services. A city e-bike system was re-launched with new e-bikes during the first half of 2020 amid the Covid-19 lockdown that has received a very positive acceptance from users. In a second step, a general vision for the mobility hub was presented, accompanied by a rough description of pre-services that are believed to expand the modal choice for customers or improve the quality of intermodal journeys in and around Stavanger. The municipality has announced its plans to make changes in the area of Fiskepiren, the current port of Stavanger, to improve accessibility towards and out of the city. Some of the plans include the construction of an underwater tunnel that can help reducing car transport via ferry, the improvement of the connection between the port and Stavanger's train station, the modification of parking space dedicated to bicycles, the amplification of walking space to allow for more amenities and, definitely, the construction of the charging infrastructure for electric vessels. Kolumbus is considering increasing its mobility sharing offerings by implementing: (1) car and (2) city e-bike sharing, (3) providing charging stations for these electric vehicles, (4) providing bicycle parking, (5) bicycle repair stations and a (6) kick-bike rental service. The implementation of such plans requires a good basis for cooperation and exchange among different stakeholders. Besides the municipality and the county's authorities, port owners, parking owners, energy providers and subcontracted mobility providers need to carry out a consultation and evaluation process.

In the context of the TrAM project, a general evaluation of potential costs and expected benefits of the six preselected services was carried out in the third step of the methodology. As shown in Fig. 4, this assessment enabled a quick qualitative screening of feasible and promising services that may be worth prioritizing. The results were transferred to a matrix showing the cost/benefit position of all six services in four quadrants, allowing a fast visualization of the most interesting services. For reasons of confidentiality, that illustration is not included in this article.

The fourth step of the methodology included a customer survey, which goals were to gain an insight into the level of satisfaction of passengers regarding waterborne and landside interfaces and estimate the potential use and acceptance of future mobility services. That allowed the partners to collect data regarding the most commonly used landside transport modes at each pier along the selected ferry route for TrAM and evaluate the level of customer satisfaction at the interchange points with regard to, e.g. frequency, waiting time, distance to next mode, signage and wayfinding. The evaluation was made separately by embarking and disembarking piers, and it was possible to have separated evaluations for the busiest piers. In this way, the assessment of the users' evaluation is more precise. Moreover, the survey included a section that evaluated general usability criteria, such as the acceptance of the


A1. Please evaluate the estimated cost of your proposed services on a scale from 0 to 10. 0 being no cost and 10 being unaffordable.

When evaluating the costs, please take into consideration investment, implementation and operational costs.

	0 No cost	1	2	3	4	5	6	7	8	9	10 Unaffordable
Charging stations for cars and bikes	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Car sharing	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Bike parking/storage	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Bike repair stations	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
e-city bike sharing	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Kickbike rental service	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

A2. Please evaluate the expected benefit of your proposed services on a scale from 0 to 10 0 being no benefit and 10 being high benefit.

When evaluating the benefits, please take into consideration financial returns and benefits to the image of the company.

	0 No benefit	1	2	3	4	5	6	7	8	9	10 High benefit
Charging stations for cars and bikes	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Car sharing	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Bike parking/storage	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Bike repair stations	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
e-city bike sharing	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Kickbike rental service	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Fig. 3. Cost/Benefit analysis of mobility services.

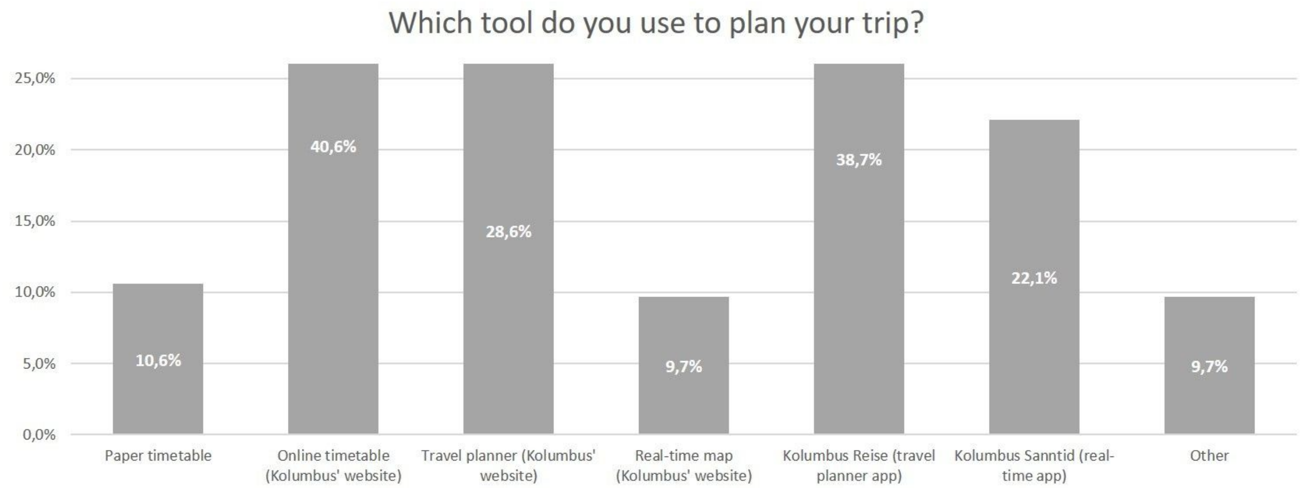


Fig. 4. Assessment of customer satisfaction regarding usability aspects as part of Kolumbus' intermodality survey.

different information, journey planning and ticketing systems. An example is shown on Fig. 5. The customers' evaluation of the attractiveness and potential frequency of future services' use allowed a comparison with the service ranking that derived from the fourth step in the method.

The Kolumbus survey had 217 completed records over an execution period of four weeks. From that total, 143 surveys made as a paper-based survey on board of the boats and 74 of the surveys were made on an online-based survey. The choice of both online and paper-based surveys aimed to reach users without affinity or access to internet or digital services. The sample was selected by interviewing passengers on board the ferries that cover the Stavanger- Hommersåk route as an attempt to gain a representative evaluation of the usability at the ferry stops of relevance within the project's scope. The users could conveniently respond to the survey during their travel time. This sample was considered representative for the time of the year that the survey was conducted, in yearly spring. The delimitations of the project scope and budget constraints were the major factors that determined the design of the survey to target only ferry users instead of users and no-users and the period of the survey. Despite of limitations, the results are relevant for the intended work, presenting an accurate picture of the users' perceptions regarding current and future services.

Finally, in a fifth step, all the evaluations carried out in the prior stages of the method from both the mobility provider and customers were consolidated. The objective was to assess whether those services that were evaluated as the most potentially attractive to current customers fit the mobility provider's expectations and estimations. Overall, services related to micro mobility promotion, i.e. last-mile solutions, showed a very positive ranking among both customers and the mobility provider. In this case, a service offering of "Bike parking and storage" raised the highest interest among the survey respondents and has been assessed as the one service with the most favorable cost/benefit ratio. This service is followed by "Bike repair stations", also known as bike kitchens, which can be a complementary service to the parking and storage, even though its cost/benefit ratio was not given a remarkably high score. Additionally, a "Kickbike rental" service was assessed as the respondents' third most interesting service and considered a solution with a fair cost/benefit ratio by the mobility operator.

V. Conclusions and Outlook

The work carried out during the TrAM project has provided an opportunity to not only reassess and reshape development and production processes in the shipbuilding industry, but also the processes with which innovative and environmentally friendly vessels can be integrated effectively into a comprehensive mobility system. It has become clear that user expectations on today's and future mobility go beyond the boundaries of what one single mobility mode can offer. More important appears to be the seamless integration of different modes and services that offers at least as much flexibility, accessibility and comfort as a private passenger car, at competitive prices and without compromising, but rather contributing to the achievement of sustainability objectives.

Societal preconditions, such as sustainability awareness among the population, can play a key role in the acceptance of new technologies. Norway, with its leading position in electric car penetration [30] and vessel hybridization and electrification projects [10], can be appraised as an appropriate candidate to test the integration of electrified passenger vessels into a comprehensive mobility system.

The Covid-19 pandemic in 2020 and 2021 has put humankind, industries and cities to the test. In the context of mobility and the Smart City, mobility providers and authorities have resiliently confronted the consequences of a practically global shutdown of economies and social activities by ensuring safe mobility options for key workers and systems. Important lessons have been learned in that time, and they are likely to influence the way mobility concepts and hubs are designed in the future.

The TrAM consortium is currently working on the physical demonstrators' fine planning, which will operate in the Stavanger and London's preselected routes and replace older fleet that run on fossil fuels. Simultaneously, collaboration formats to promote an adequate exchange between project partners and external stakeholders to continue planning the mobility hub Fiskepiren are being evaluated for the case study in Stavanger. These include, but are not limited to, the harbor's administration, owners of the parking buildings at and around the harbor, the municipality's traffic agency and architects in charge of the new hub's planning. The project, which will be culminated in 2022, will actively contribute to making zero-emission and resource-efficient waterborne transport in Europe a reality.

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Emergent and Unexpected Sources of Value from Radio Astronomy Projects

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***Abstract*—Construction projects are under increasing pressure from local communities to deliver Societal Value (SV), defined as integrated social and environmental value. Societal Value delivery requires the co-creation of value outcomes with environmental and community stakeholders, in addition to the functional benefits of the project. The aim of this research is to advance understanding of the conceptualisation and practise of Societal Value in capital projects. This paper will summarise existing research and key concepts in the delivery of Societal Value, applying examples from both existing and planned radio astronomy projects such as the Very Large Array (VLA, USA) and Next-Generation Very Large Array (ngVLA, USA), Square Kilometre Array (SKA, South Africa and Australia), Arecibo (NAIC, Puerto Rico), Ghana Radio Telescope Observatory, and Atacama Large Millimeter / submillimeter Array (ALMA, Chile). Such projects are built in rural areas, bringing services, infrastructure, jobs, education, and astrotourism to surrounding communities. Answering these research questions can lead to the development of a societal value framework for construction projects, including metrics and an audit methodology, for use by organisations and governments in practising project assurance.**

Keywords—societal value, sustainability, radio astronomy, rural communities, assurance, construction

I. Introduction

As science progresses, so too does the discussion about the value and impact of scientific projects. Traditional metrics (such as technical products, benefits to government, new scientific discoveries, science, technology, engineering, and mathematics (STEM) teaching, training, and learning) remain essential. Additional metrics are becoming common, often focusing on societal desirability, value, and ethics [1]. While much of the conversation about science focuses on the merits of intellectual pursuits and investment, attention is now being given to the physical impact of scientific installations (science construction).

This research aims to advance understanding of the conceptualisation and practise of societal value (a principle of sustainability) on construction projects, with the ultimate goal of developing an audit framework for societal value. Societal value expectations pose a dilemma for project managers. In this perspective, beneficial outcomes require an integration of ethics (doing right behaviours), with social (managing enterprises' responsibilities to society) and environmental (managing impact on natural environment) sustainability [2].

Existing frameworks such as Triple Bottom Line and, more recently, Sustainable Development Goals (SDGs) [3] have been adopted in the UK and Europe on construction projects as measurement frameworks, in an attempt to balance the short- and long-term benefits of projects. However, these approaches have been criticised as reductionist methods that implicitly focus on readily quantifiable financial benefits over environmental or social value benefits that are difficult to quantify. The SDGs are viewed as overly complicated, with 196 possible metrics and inherent conflict among the development goals. Adoption of these frameworks on construction projects also provides additional challenges, as the capacity to deliver beneficial outcomes (as defined by Triple Bottom Line or SDG) may be distributed among temporally- and geographically-dispersed participants, with varying and possibly conflicting stakeholder perspectives. Existing frameworks may not adequately represent these inherent complexities and trade-offs in capital projects. Finally, external shocks such as COVID-19 may change project stakeholders' perceptions of their societal role, which may encourage them to take a more broad perspective of societal value, exceeding existing frameworks. There is, therefore, a need to advance understanding of the conceptualisation and practise of societal value in capital projects and come to a consensus regarding the scope of societal value.

Using examples from both existing and planned radio astronomy (RA) major projects, this paper seeks to examine the following research question: What are the challenges in conceptualising and measuring the societal value of construction projects?

II. Background

Since antiquity, astronomers have sought landscapes suited to the viewing of the sky without interference. As the field of astronomy has evolved, so have the location requirements for high-quality astronomical observations. These include atmospheric conditions (cold and dry with a thin atmosphere and good air quality), low light pollution (dark skies preservation) and low electromagnetic interference (radio-quiet zones) which requires increasingly large swaths of land, often with a secured buffer zone. For this reason, telescope and radio astronomy facilities are often sited in remote places, typically distant from major cities. However, this does not mean the regions are unpopulated. In addition to native flora and fauna, such rural territory is often rich in indigenous peoples' history and culture, serving an extant human population.

Characteristics of ground-based radio astronomy (RA) observatory facilities typically include long-term community commitments and land use agreements, with the installation of not just research-intensive equipment but also significant civil infrastructure, facilities for research and offices, staff and visiting scientist accommodations, maintenance, fire safety and security, data centres, training facilities, and visitor centres. Some radio astronomy telescope facilities are small; others are on the scale of mega-projects, valued at billions of US dollars. Major facilities are often designed to operate for 20 to 25 years and then be decommissioned, but usually remain in operation decades beyond their planned obsolescence date.

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In many countries, RA's growth is nationally transformative and life-changing to the local community in which facilities are established. The construction of radio astronomy observatories has both short- and long-term impacts on the local population, first from building activities over the course of several years and then the physical presence of facilities and infrastructure. Also, such facilities attract both short- and long-term highly educated and sophisticated populations and families that, in turn, themselves have short-term (months to years) and long-term (decades) population booms and ripple effects on the local area and community. Radio astronomy supports an incredible diversity of careers and the golden age of radio astronomy is now, with technology on the cutting edge of capability, facilitating multi-national cooperation and considerable investment. These characteristics make radio astronomy observatories a natural fit for the study of societal value in construction.

III. Literature Review

While the term "value" refers to a preferential judgement by stakeholders of a given project's output, processes or outcomes (e.g., benefits), "values" are the determinants of any social behaviour including attitude, ideology, beliefs, and justifications. They are linked, as the latter can shape perceptions of the former. Early research in project management did not expressly address the concept of value. The later emergence of "modern" project management (that is, the use of dedicated tools and techniques) introduced the idea of delivering financial value from projects. Current research embraces three paradigms: Functional, Perceived and Narrative.

The functional value conceptualisation is captured in the "value for money" (VFM) approach, defined as delivery of cost-effective, reliable, and timely services at agreed prices and to agreed quality, as specified in the contract [4]. This approach attempts to use quantifiable (financial) metrics and the related notion of exchange to capture trade-offs between project value dimensions [5]. Functional value seeks to identify optimal solutions based on a predefined set of quantifiable criteria for domains for a narrow subset of stakeholders, primarily the customer and supplier. Overall, the approach is to minimise uncertainty and reduce to the present the temporal horizon over which value estimation is performed (for example, by calculating Net Present Value (NPV) or Return on Investment (ROI)).

While functional value can be defined using externally verifiable metrics, perceived value is not clearly defined in project management literature and practice. Perceived or perceptual value conceptualisations acknowledge that value is multi-dimensional, and goes beyond a single unitary function, unlike functional value. First, perceived project value is multifaceted as financial, technical, and long-term value can be sought from a single project [6]. Second, individual perceived project value types are evaluated differently by stakeholders. A comprehensive understanding of project value thus must consider different stakeholders' perspectives (i.e., what value is and for whom) and specific contexts (e.g., project types) [7]. The perceived value conceptualisation also acknowledges that contradictory types of value may be obtained by stakeholders [6]. Perceived value is also influenced by temporal and geographic context, enabling or constraining the value creation process. Perceived value is co-created and is emergent from stakeholder interaction [8]. Stakeholder management (as conceptualised and practised) tends to place the project firm or organisation at the core, financially-linked stakeholders closer, and still others at the periphery. In construction projects, this enables considering a range of value types from the perspective of a relational dyad (contractor/client, designer/planner, etc.) since interaction with a smaller subset of closely linked actors shapes value expectations and outcomes. Within this stakeholder network, individual entities, especially those at the periphery, may pursue influence strategies to increase the visibility and salience of their claims. Perceived value incorporates various value metrics which, in addition to financial value, can include relational elements such as quality of relationships, leadership, learning, creativity, knowledge, technology transfer, and trust [8].

In the narrative paradigm, value is conceptualised as a linguistically-expressed social construct [9]. These narratives and stories express not only value but also the values and beliefs of individuals. The process of value creation occurs via stakeholder discourse involving a wider range of stakeholders, in contrast to the numerical perspective of the functional approach and dyadic co-creation in the perceived perspective [9]. The range of potential value identified goes beyond previous conceptualisations to identify complex societal benefits that include sustainability, societal value, quality of life, and wellbeing. Despite the development of both the perceived and narrative perspectives, there is still an implicit belief in the unidirectional flow of value from organisation to stakeholder. Further, broadening project management goals to incorporate stakeholder concerns sees the emergence of contradictions/tensions in value along with value destruction [10]. Table I provides an illustration of the value created and destroyed. While the emergence of the narrative perspective seeks to explicitly address these issues, little empirical research has been done using this approach.

TABLE I. Value Created and Destroyed

Value Paradigm	Value Created	Value Destroyed
Functional	Financial Self-sustaining economy	Loss of income Loss of revenue (Tax/Business) Loss of services Property damage Productivity reduction
Perceived	Intra-stakeholder relationships	Negative impact on stakeholder routines
Narrative	Quality of life Wellbeing Social value Societal enhancement	Reduced quality of life

(Adapted from [10] and [11])

IV. Research Method

To date, value research in the first two (functional and perceived) paradigms has been conducted with the perspective that entities under examination are fixed with varying attributes [12]. Based on this assumption, a phenomenon is described using a small number of variables (such as financial value, cost, quality, or stakeholder satisfaction). These approaches dominate research in the social sciences, and have particular strengths in comparing entities or relationships among variables. Process approaches, by contrast, assume that both the entities and their attributes are evolving. By directly examining the complex relationships between events and outcomes [13], process approaches explicitly assume that entities are linked.

Developing theoretical understanding from the analysis required a combined narrative and visual mapping strategy [14]. The interview data were coded to identify the various categories of value, which were then compared between and across interviews to identify overarching themes. The team then used themes to create narratives or descriptions of value characteristics. These narratives were analysed to create visual maps [15] in the form of tables and diagrams to identify value conceptualisations.

The research approach combined insights gained from over twenty personal in-depth interviews with professionals working on radio astronomy projects and broader impacts research in the United States, Puerto Rico, United Kingdom, Ghana, South Africa, Australia, and Chile. The interviewees were purposively sampled for their specific responsibilities and expertise in RA projects. The duration of their involvement ranged from four years to several decades. In this research, their identities were kept anonymous, and interviewees are here referred to as "I", followed by their interview number. Interviews were transcribed entirely and coded at the sentence level to identify value conceptualisations and associations among them. This approach provided a diversity of responses that supported the development of an understanding of the activities and associations of value conceptualisations, along with the context in which they were embedded [16].

V. Results

Interviews were conducted with staff at RA observatories in various phases of planning, construction, and operations. For established facilities, some of the identified benefits were already realised. Others were just beginning to exhibit value at the early stage of operations, and still others were planned but not yet realised. Even so, societal value from RA observatories could readily be grouped into several categories, with many similarities.

A. Infrastructure improvements

Modern radio astronomy sites typically include an antenna or group of antennas, and buildings to support the antennas and data, such as offices, data centre, visitor centre, maintenance warehouse, temporary accommodation, and more. Of those observatories participating in this research, sites varied in size, ranging from five acres to 3,500 acres to distribution across entire continents. Some areas included a buffer zone for protection from radio signals. and were often fenced. The radio astronomy observatories in this study were constructed in remote locations which required a considerable number of infrastructure improvements needed at the new facilities sites and also to link the site to the nearest town(s).

These projects catalysed institutional changes to physical and social infrastructure [17] within the surrounding towns. In terms of physical infrastructure, these projects built new roads and improved existing ones, and installed new power and sewer lines, signage, railways, fencing, and high-speed communication fibre, benefiting both the observatory and the local community. These benefits could be conceptualised using a value-for-money (VFM) approach. Long-and short-term visitors and staff necessitated new short- and long-term housing and also influenced physical improvements to schools, libraries, hospitals and urgent care facilities, community centres and other buildings, and transportation. These improvements could be quantified using construction cost and other economic indices.

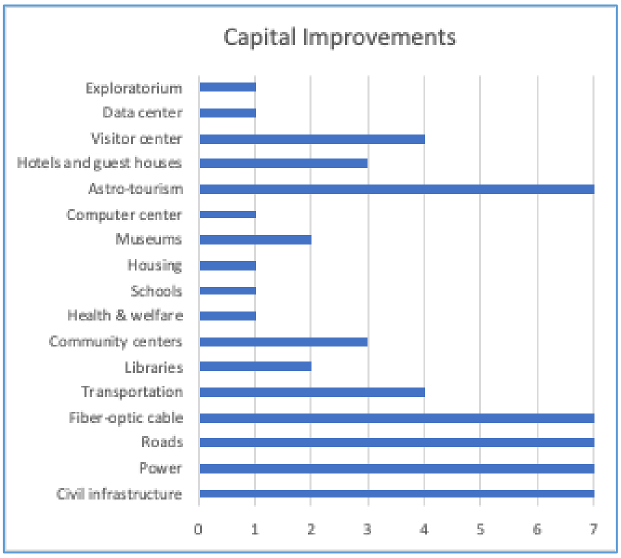

Fig. 1. Infrastructure improvements

On the institutional side, the radio astronomy projects created or expanded support structures that were linked to not only physical infrastructure (such as road and power line maintenance) but also to a broad provision of public goods such as policing, fire and emergency services, food security, and telemedicine, augmenting the standard-of-service provided in these domains. There was also an emergent social infrastructure, linked to opportunities for interaction between the research community and local residents, as well as prospects for collaboration among public and private entities that likely would not have existed without the physical investment.

B. Job and business creation

This perceived value dimension was linked to infrastructure provision, as well as to social and economic developments generally as a result of the overall radio astronomy capital investment. Thousands of jobs have been created through radio astronomy observatories. Some job creation was immediate during the period of construction and available jobs, in turn, created vocational trade-focused training opportunities in carpentry, plumbing, bricklaying, welding, electrical and mechanical. The outcome of this process was the development of a skilled local workforce that then spawned small-business creation and employment in the region. Once regular facilities and research operations began, additional jobs were created, and local workforce and businesses developed, to support on-site operational activity and local growth in the aforementioned vocations plus such necessities as parts and materials supply, materials recycling, food supply, information technology, instrumentation, mechanics, maintenance, tooling/machining, housekeeping, management, and administration. In several instances, the scale of training was such that some surrounding towns became known as centres of excellence for electrical and mechanical trades, and a police academy. Other businesses were also created to support business activity, such as graphic design and conference management; some of these businesses have grown to support more than just the local area. Population growth in towns near radio astronomy observatories resulted in additional job creation and economic growth.

Radio astronomy observatories have a tendency to become beloved iconic structures. Over time, direct and indirect human capital development and job creation occurred, linked to spin-off industries created as a result of the radio astronomy influx but also well suited to the remote nature of the facilities. Astrotourism, ecotourism, and leisure are three such industries, with local growth including but not limited to artisanal crafts, art, hotels, guest houses, restaurants, tour guides, museums, cultural centres, sports/adventure outposts, wild game parks, glamping, and retail. Astrotourism alone has created thousands of jobs, globally. These businesses, and those mentioned previously, provided services not just to the original local community but also to the increasingly sophisticated community that emerged around the radio astronomy facility comprised of imported scientists and support staff (and their families), visitors, and tourists. To support entrepreneurship and business creation, courses in business management, computers, and finance were provided at local schools, libraries, and community centres, and computer centres (cyber labs) were created for public use. Together, these contributed to economic growth and local spending, as shown below (Fig. 2), and could be quantified as the number of jobs and businesses created, and financial value of goods and services imported and exported.

C. *Environmental impact*

The telescopes often had a direct impact on the rural environment at and surrounding the installation of physical infrastructure. Since these installations required limited electromagnetic interference, the area around radio astronomy antennas required a relatively pristine environmental state. To protect the environment from human intrusion, some sites installed fencing while others had the area designated as a nature reserve (one particular nature reserve was 130,000 hectares in size). Increasingly large radio astronomy sites enabled university research and land management practices that were beneficial for the environment, such as photovoltaic power, the removal of invasive trees, wildlife introduction, materials recycling and reuse, and bio-control methods such as the rearing of beetles. Radio astronomy technology itself contributed to positive environmental impact; in several instances, satellite / GPS data gathered as part of earth-based research enabled local officers to identify illegal land use, mining, and poachers who targeted rare or valuable animals. In this way, species and natural resources were protected, increasing longevity and ensuring biodiversity.

D. *Research opportunities*

In addition to the formal physical and social infrastructure created by radio astronomy observatories, over the long-term a research and science infrastructure developed that enabled intellectual and scientific contributions, as shown below (Fig. 3). Directly, the radio astronomy facilities housed and built skills in astronomy and astrophysics, mechanical engineering, software development, and systems engineering, and supported citizen science. Complementary research areas also developed, with increasing sophistication over time, specialised to the location. These included engineering skills not just linked to the telescope itself but to the data science and machine learning skills required to manage and interpret the considerable data generated by the radio telescopes. Similarly, technology and science hubs developed in other specialty areas (in addition to the aforementioned environmental research); other fields were supported such as interpreting geographical data (oceanographic and atmospheric data, seismic information, and land surveying) to further research in fishing, agriculture, and climate change. High altitude locations enabled medical research. With the facilities built on rural, often indigenous land, research hubs also developed to specifically support the study of heritage, including indigenous astronomy, paleontology, archaeology, and cultural research.

E. *Education*

Education provided an example of the evolving nature of value derived from radio astronomy projects. Initial impacts were immediately visible within the area of science (STEM) education, at the K-12 level and in community programming and adult learning, part of the radio astronomy projects' strategic plan for education outreach. Over time, local high school students proceeded to university and, as the number of local science graduates increased, these individuals went on to further study at the masters and doctoral levels. In several instances, the surge in graduate students exceeded the number of available PhD supervisors and teaching assistants. Some of the university graduates ultimately returned home and became local educators in their own right, creating a decades-long cycle of STEM education in the local community. This could be measured in terms of number of publications, targeted interactions, students participating and graduated, grants

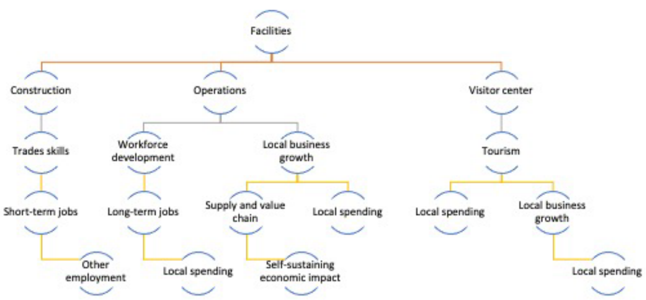

Fig. 2. Job creation at radio astronomy observatories

Fig. 3. Research opportunities created by radio astronomy observatories

given, public attendance, teachers funded, students funded for university, and test score improvements. Globally, thousands more students are currently progressing through this global K-12 to higher education to career pipeline.

The increasing volume and sophistication of human capital resulted in the further growth of science-based businesses and an increasing number of highly educated individuals, as shown below (Fig. 4), sometimes to the point where they exceeded the local absorptive capacity of jobs within the field of education. This then led to partnerships with industry, forging local relationships and creating local, national, and international internships, jobs, and career paths in such fields as big data, aeronautics, deep space, telecommunications, power, renewable energy, infrastructure, and medical imaging.

F. Emergency response

Staff at radio astronomy facilities were typically embedded in the local community and behaved as part of that community, often highly valued. During times of strife, their contributions did not go unnoticed, with science, project management, and engineering expertise transferable to solving immediate problems. During 2020's COVID-19 pandemic, contributions from the radio astronomy community at the local and national level included the development of contact tracing apps, biological data analytics, telemedicine, and the production of ventilators.

VI. Discussion

Radio astronomy observatories are an unusual combination of capital-, land-, and knowledge-intensive projects. Therefore, they generate a wide variety of value types, both directly and indirectly, and the interaction of these value components creates ever more complex evolving outcomes that exhibit tensions and paradoxes. While the value for money (VFM) conceptualisation can easily measure causality or benefits, other value types are more complex and direct measurement is difficult. Indeed, the cause-effect mechanism is sometimes not direct, with many variables, and thus can be difficult to measure. Perceived value dimensions, such as changes in the local labour market, advancing the field of science, and economic impacts, are not necessarily reducible to parts, making causation difficult to validate.

There is limited training in the area of impact assessment where the focus was on delivering VFM dimensions. Since these installations are in place for long time, a number of emergent impacts have occurred which were not necessarily predictable from the conceptualisation of the project. These are difficult to measure by their very nature, and since there was a lack of longitudinal studies it is fairly difficult to formally quantify these impacts at this time. The adoption of a narrative approach, based on the analysis of interviews in this study, suggests that value emergence follows a particular pattern, from the immediate value of rural services and infrastructure installed during facilities construction, to immediate to long-term value achieved during facilities operations, to value realised within the community in the future (longitudinal, measured in decades), as shown below (Fig. 5).

In addition to identification, the societal expectations of value can be expected to change over time as the observatory and the host community co-evolve. For example, the initial installation attracted radio astronomy researchers, staff, and tourists. Over time, some communities developed additional attractions based on the preservation of the biosphere, building a more complex astrotourism product that incorporates such elements as technology, agriculture, sports, and ecotourism.

A. Tensions and Paradoxes: STEM

As discussed earlier in more detail, while significant value was provided through education, over the course of a decade or more the local education market could not support all the new university graduates, and industry relationships were not yet created that could absorb these individuals at the rate at which they graduated. This improved over time, as relationships with industry were created and strengthened.

Since these facilities operate in a number of institutional contexts, there were domains in which science may not necessarily have been seen as a public good, but as a politicised tool to achieve particular economic and social outcomes. Various funding institutions supported the agenda of providing support to marginalised groups in the community, specifically in Africa with support of black economic empowerment initiatives which provided training and preferential business access to particular communities. Again, given the multilevel conceptualisation of value and conflict among stakeholders, these preferential schemes may have created some tension.

B. Tensions and Paradoxes: Value Destruction and Re-creation

Sometimes, immediate impact was not positive; construction of the facilities came with consequences. Conflict over land acquisition was not uncommon, as were

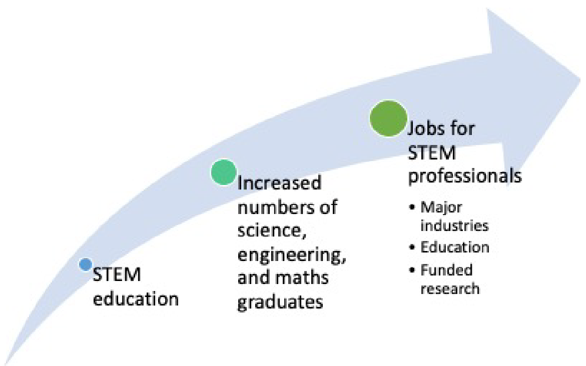

Fig. 4. STEM impact by radio astronomy observatories

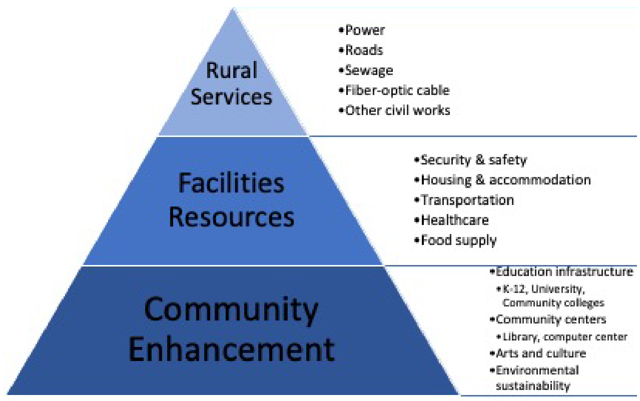

Fig. 5. Categories of infrastructure impacted by radio astronomy observatories

concerns about historic and culturally significant sites. In one particular instance, the radio quiet zone required for radio astronomy necessitated reducing the local community's wireless (cellphone, WiFi, and radio) signal pollution; voice and data connectivity was restored by installing an area-wide low frequency communications network. Ultimately, this resulted in reliable communication technology provided to traditionally rural and underserved communities and improved emergency-service communications. In another instance, protection of the antennas required limiting sheep grazing in the area, affecting the agricultural community. Although value destruction did occur in these instances and more, it was often offset by an order of magnitude in value created in the same category. For example, where sheep grazing was restricted and local farm jobs lost, local businesses were created to provide centralised feed lots, with training provided in agriculture, trades, and business management, and jobs, businesses, and career paths created.

VII. Conclusion and Next Steps

Radio astronomy science provides a portfolio of societal value to the local community: commercial products, scientific products, and national image. One challenge in conceptualisation and evaluating societal value of facilities construction and operations is the longitudinal nature of value. Impacts are both short- and long-term, and the time frame for value capture often does not occur immediately. Indeed, measurable and demonstratable value might not appear for several years, or even decades [18]. While radio astronomy antennas are often designed for a 25-year useful life, they tend to well exceed that timeframe, often remaining useable 35 to 55 years after construction. This means organisations that wish to measure the value of long-term facilities, and the changing dynamics of that value, need to plan to conduct periodic retrospective assessments and require funding for multi-decade studies. This process could be supported by computational text analysis of project documentation to enable the identification of insights from stakeholder discussions.

Perceived value of capital projects can vary depending on the perspective of the stakeholder conducting the evaluation. A narrative perspective extends this further as multiple stakeholders both co-create and co-assess value. The value types identified here for radio astronomy observatories should be studied for other major capital project types. There is a need to define value criteria to be measured, specifically for construction projects, creating a uniform consistent global language for comparison across contexts; practices in some countries may be advanced, whereas other countries are at differing levels of practice for societal value assessment. These new approaches need to explicitly capture tensions and paradoxes which may be missed in approaches that seek to simply measure associations among variables. Future strategies should recognise value destruction, as it enables stakeholders to develop trust by presenting a complete picture of costs and benefits.

Further, examination of RA-specific dimensions (such as Astrotourism) may require additional study as a distinct value type. In addition to individual regional benefits, Astrotourism (like other tourism experiences) is a networked phenomenon incorporating multiple locations. Societal value assessment approaches will need to explicitly recognise this value network and encourage the adoption of communication, knowledge exchange, and value co-creation strategies that integrate the input of multiple sites.

Acknowledgment

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A Smooth and Accepted Transition to the Future of Cities Based on the Standard ISO 37120, Artificial Intelligence, and Gamification Constructors

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***Abstract*— A community and a city in terms of energy are composed of residential, commercial, industrial, and transportation sectors. Besides, standards as ISO 37120 provide indicators that determine if the community is having a sustainable and quality of life. The energy indicator is used in this paper to analyze the level of energy consumption. Another element involved in a city is the user who lives in that place; there is an interaction between the community, buildings, users, and the software and hardware technology. Consequently, social interaction in users plays a primary role in understanding and knowing the user's patterns and profile them and how they interact in the building, the community, and the city. Thus, creating a smart community or smart city goes beyond that only use one methodology, so this paper proposes to combine gamification, machine learning, and ISO standard to create a strategy that could promote in a better manner the transition to smart communities and cities. Therefore, this paper analyzes the Energy indicator of the ISO standard applied to Tecnologico de Monterrey, Mexico City Campus (Tec CCM) in a three-level structure: smart building, smart community, and smart city.**

Keywords*— *Smart City, Smart Community, Gamification, Educational Innovation, Higher Education, ANFIS, Multi-sensor system, HMI, ISO 37120, Energy indicator, Smart Building, Tailored Interfaces, Smart University

I. Introduction

A community and a city in terms of energy are composed of residential, commercial, industrial, and transportation sectors. Moreover, four energy sectors in the U.S. energy consumption are residential, commercial, industrial, and transportation. Residential buildings represent 21.69%, commercial sector an 18.22%, and a 27.84% transportation sector. Thus, communities belong to that 67.75% of the total U.S energy consumption in the last year [1]. Therefore, the communities and cities' essential task is to reduce energy consumption without being obtrusive or losing the quality of life in the communities by transforming the community into a smart community and then into a smart city.

On the other hand, the measure of sustainability in cities and communities is complicated due to economic, political, or topographical conditions in a city. Hence, standards as ISO 37120 help in tackling these problems by providing a set of indicators that determine if the community is having a sustainable and quality of life [2]–[4].

The ISO (the International Organization for Standardization) allows the evaluation to adjust the system according to the metrics. Sustainable cities and communities - Indicators for city services and quality of life: ISO 37120 incorporates indicators to monitor city performance progress. These markers help cities assess their performance management of services and quality of life over time, learn from each other by comparing them across a wide variety of performance measures, and aid policy development. However, a strategy that engages and motivates the users to reduce energy must accept adapting a new sustainable way of living.

London [5], Oslo [6], Copenhagen [7], and Villach in Austria [8] have launched smart community initiatives where there is a continuous interaction between the citizen and the communities (government, agency, company, and institutions) and user-centered designs by encouraging the digital engagement of citizens and communities. Other projects consist in introducing civic gaming elements as Mexico City's *Laboratorio para la Ciudad* or *Human Experience Lab* in Singapore [9] There is an interaction between the building, the user, and the software and hardware technology within the smart building through the smart appliances or devices considered socially connected products. In [10], the authors consider that if a product modifies the end-user behavior by observing, registering, and analyzing her/him consumption patterns, then it is a product that should be considered a social product. Besides, this product can adapt online or offline its characteristics to improve its implementation and acceptability in the business [11]–[13].

Consequently, users' social interaction plays a primary role in understanding and knowing the user's patterns and profile them [14], [15]. A manner to shape occupants' attitudes is by sending motives through gamification tactics [10], [13]–[17]. Gamification, in this context, enhances services with game techniques to boost overall content creation [16], [18].

A. *Gamification in a Smart City*

Gamification uses game elements and game design methods in real-life contexts [19]–[22]. In [23], they exemplify game elements in a smart city like water, energy,

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waste management, health, education, food safety, leisure, government indicators. In [24], they employed the concept of Human Smart City, referring to governments' need to involve civilians by being open with them, encouraging the co-design of technical and social innovation processes. Besides, some of these gamified applications promote the reduction of CO2 emissions, the careful choice of transportation, the use of the bicycle, recycling, noise pollution awareness, promoting sustainable communities, healthy climate, and energy conservation. Thus, gamification simplifies the complexity of reality and daily life by employing rules and quantifying citizens' performances through game elements as bars, badges, leaderboards, or points [9].

Strategies for energy reduction on campus have been proposed in several papers by improving thermal insulation, lighting, and CO_2 ventilation control, an efficient HVAC system, among others [9], [23]–[28]. In previous research [16], it was proposed an adaptation for the Octalysis

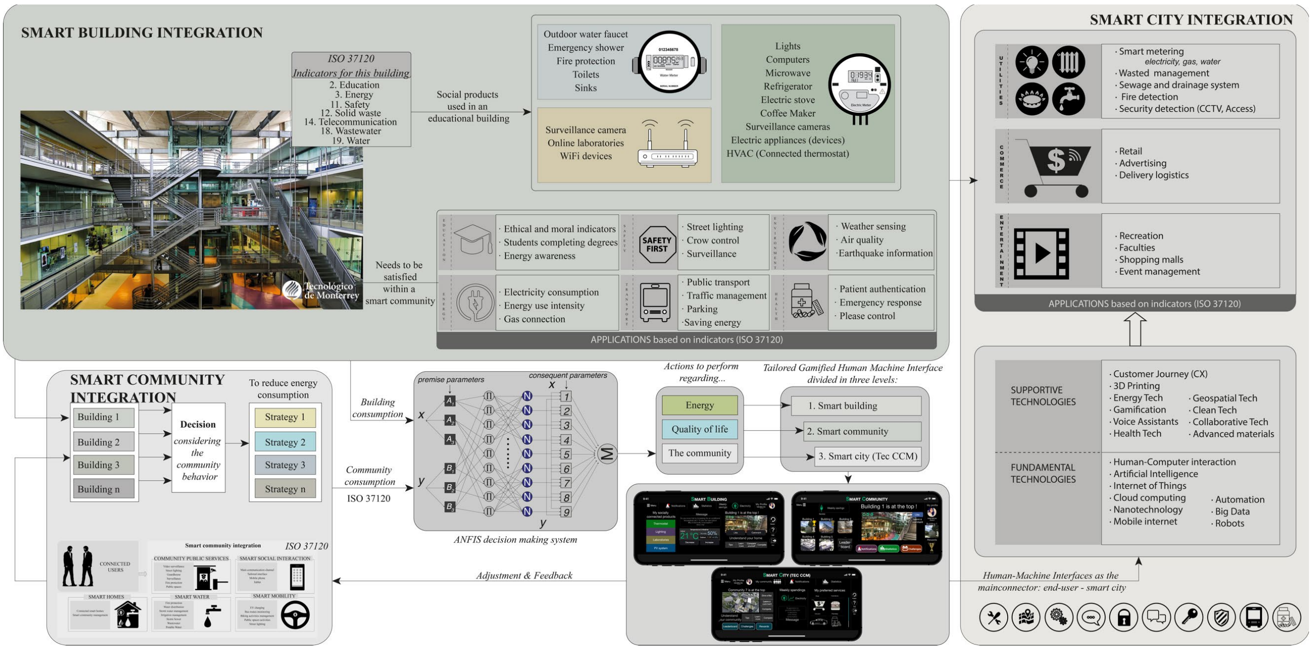


Fig. 1. General proposal for data fusion on HMI at smart buildings, community, and city.

framework. This adaptation includes the game design elements offered in [29], the Hexad gamified user, role player, and energy end-user segment and target group proposed in [30]–[35]. Table I presents the extrinsic and intrinsic motivations regarding energy applications [36].

TABLE I. GAMIFICATION MOTIVATIONS USED FOR ENERGY APPLICATIONS

Extrinsic motivation	Intrinsic motivation
Offers, coupons	Notifications
Bill discounts	Messages
Challenges	Tips
Levels	Energy community
Dashboard	Collaboration
Statistics	Control over peers
Degree of control	Social comparison
Points, badges, leaderboard	Competition

Thus, creating a smart community or smart city goes beyond that only use one methodology, so this paper proposes to combine gamification, machine learning, and ISO standard to create a strategy that could promote in a better manner the transition to smart communities and cities. The first approach is by proposing the energy indicator to promote energy reductions in the building, community, and city. Hence, a university can be considered as an example of a smart city. Thus, this paper analyzes the Energy indicator of the ISO standard in Tecnologico de Monterrey, Mexico City Campus (Tec CCM).

II. PROPOSAL

Fig. 1 depicts the general proposal for this research. This proposal uses a Multi-sensor system to know more about the community's needs, specifically for promoting pro-environmental attitudes in the community to reduce energy consumption and improve their quality of life by considering the energy indicator of ISO 37120. The adaptive neural network fuzzy inference system (ANFIS) analyzes and evaluates the building's information and buildings' community to propose actions that improve the quality of life and promote solutions to essential factors in the community energy reduction.

A personalized interface is then tailored at three levels: activities for the smart building, the smart community, and the smart city. The interface displays gamification elements as messages or tips regarding the users' interests to promote a significant interaction between the city and the community and provides information about their favorite services at the smart city level. The communication between interfaces and the end-user is from a tailored Human Machine Interface (HMI) within a gamification structure that includes feedback and adjustments based on the user profile and behavior to teach, motivate, and engage the end-user perform specific goals, as energy reduction. The type of gamification structure used in this proposal is divided into two: extrinsic and intrinsic. When it comes to extrinsic motivation, people are inspired because they desire what they can't get, and acquiring it infers outer appreciation. For intrinsic motivation, the activity is satisfying by itself [31].

A. *Multi-sensor Data and ANFIS*

The Multi-sensor data fusion theory bases its theory on animals' and humans' fundamental activities. Multiple sensors aim to improve their ability to survive as they need to detect external threats [37], [38], [15]. Thus, they have to perform some functions. Sometimes, conventional analytical mathematical modeling algorithms in occasions have problems to deal with hazy or ambiguous information. Thus, applying linguistic rules (IF-THEN), through fuzzy logic systems, have the strength and ability to think as individuals, without using accurate and full information. However, a problem arises when transferring human knowledge to a fuzzy logic system and harmonizing the fuzzy logic system. In that regard, a combination of artificial neural networks with fuzzy systems has been proposed.

On the other hand, artificial neural networks can learn and adapt from the background, thus complementing fuzzy systems using artificial neural networks. One of the essential methods is ANFIS [39], which automatically generates fuzzy IF-THEN rule bases and fuzzy membership functions. ANFIS considers adaptive networks, a superset of feed-forward artificial neural networks with supervised learning capabilities. [39], [40].

B. *Smart City Integration*

This integration considers and analyzes the information that comes from the smart community. Considers the nineteen indicators of ISO 37120 to measure the sustainable city and community levels in each indicator. Table II depicts the nineteen indicators for a sustainable city and community. Thus, new development and improvement of infrastructure, healthcare, and security cities should be powerful than nations as we are all connected in a network life. Thus, standard ISO 37120 plays an essential role as an indicator of the communities' quality of life.

University Campus as a Smart City: A great example of a smart city is a university, as they have nineteen indicators. For instance, due to an earthquake in 2017, many buildings were destroyed included some buildings of Tecnologico de Monterrey, Mexico City Campus (Tec CCM). Thus, the new masterplan considered the inclusion of urban parks and plazas, the mitigation of annual flooding with bioclimatic considerations as naturally ventilated buildings, pergola for heat gain reduction, and reduction of carbon footprint. Besides, it considers renewable sources as photovoltaic arrays [41]. Fig. 2 depicts the masterplan design with the indicators considered in each building and public space.

TABLE II. INDICATORS IN ISO 37120 STANDARD

Indicators			
1. Economy	2. Education	3. Energy	4. Environment and climate change
5. Finance	6. Governance	7. Health	8. Housing
9. Population and social conditions	10. Recreation	11. Safety	12. Solid waste
13. Sport and culture	14. Telecommunication		15. Transportation
16. Urban/local agriculture and food security	17. Urban planning	18. Wastewater	19. Water

In 2015, Tec CCM developed the Sustainable Campus project to participate in four areas: ecological campus management, applied research, climate and environmental education, and community and business projects. The energy facility recommended having electrical energy savings by switching the lighting into saving lamps, replacing high consumption equipment for low consumption equipment, boosting the woodland canopy to release luminaires, improving outdoor lighting, disseminating energy awareness campaigns, and placing solar-powered luminaires [42]. Those electrical energy savings objectives reached solar-powered luminaires' installation and began continuous energy awareness campaigns. It has been proved that those campaigns help promote electrical energy reduction; for instance, 5% to 15% of energy cost savings is usually reached with scarce to no investment [43]–[45].

Therefore, this paper proposes the Tec CCM as a study case of the smart city. It is accessible for the authors to implement dashboards like the one proposed by [8], [46] but focusing on the third indicator, energy. A gamified structure through an ANFIS decision-making system with data comes from the thermostat setpoint and lighting consumption. Thus, this proposal implements the ISO 37120 and analyzes public buildings' final energy consumption per year in G.J./m2 or kWh/m2.

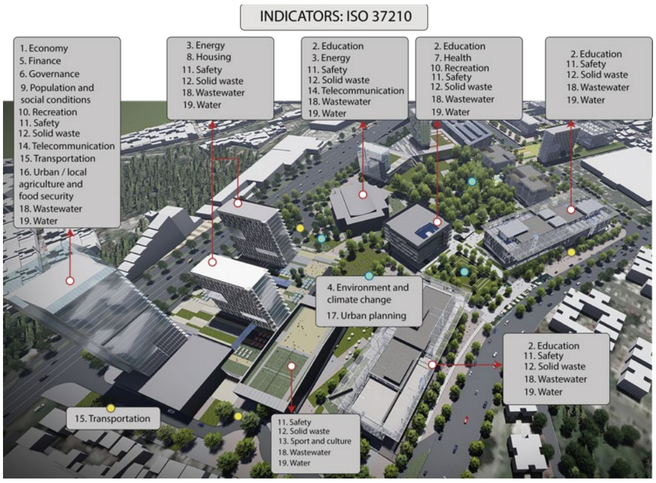


Fig. 2. Tecnologico de Monterrey, Mexico City Campus masterplan with ISO 37120 indicators.

Energy measures how much electricity is currently being consumed and needed to handle the generation, consumption, and electricity conservation adequately. Besides, in an educational facility, 72% of the total electric consumption come from the cooling, lighting, and office equipment [47]. That embodies an opening area to be optimized; however, it is not easy to renovate or retrofit buildings as they are not considered in the budget. Incorporating gamification in a system to target energy reduction as a goal is not as complicated as it may seem. For instance, providing a Human Machine Interface that monitors the classrooms or the office areas can help tackle energy savings. This gamified interface provides information regarding the benefits of using wisely the setpoint, as 1 °C could save 6% of the electricity consumed in a place [48].

As a university involves different types of users with different socio-cultural aspects, universities represent a challenge in reducing energy; however, providing a gamification structure could allow students and professors to be involved in energy reduction strategies. An example is sending tips or messages to the students and suggesting them to turn off the air conditioner (AC) before leaving the classroom or the office to reduce energy consumption. If the classroom is not crowded and all approve it, turn off the air conditioning if not needed or turn it on when needed, which may be another option to mitigate the energy consumption. Research indicates that when a group of members competes with other groups, specific goals can be achieved.

Another example could be performing tournaments during a semester; hence all the students who belong to specific classes participate. At the end of every month, it is compared to which group consumed less energy. Being in those types of dynamics had proven that users get engaged as they are motivated by extrinsic outcomes. Therefore, as a beginning, applying the gamification extrinsic motivations in a mobile phone could help tackle those energy reductions.

The management area has the credentials to determine what type of information is displayed to other community members. The other members of the community, as students and professors, have the faculty to propose any change, share their tips on how to save more energy or improve the quality of life at Campus. The way to promote a gamification structure is by promoting this collaboration, sending messages, reading the tips for saving energy, and earning points and badges so they can change those points or badges for an offer or coupon inside the Campus, for instance, at the foodservice.

C. Smart Community Integration and ISO 37120 indicators

The complete systems and ANFIS collect the data to make decisions that cover social needs and energy reduction through the Energy indicator from ISO 37120. This analysis is performed by applications that gather information about the buildings. At this point, the HMIs and big data analytics bring new information to identify, track, and forecast energy behavior patterns [49].

Applying this into a university context relies on integrating all the community involved in each building group through gamification motivations. This can be achieved by performing challenges or social sharing, so the community is motivated to reduce energy consumption. An achievable goal is to reduce the AC system's energy user by increasing the thermostat's setpoint for cooling during summer periods.

A smart community structure within a campus could be grouped into faculties by educational level (high school and university), administrative and business area, cultural buildings, and research facility.

At this level, the professor has access to the AC setpoint. The students only have the credential to track all the changes and suggest changes; if their suggestions are performed, they will receive points to tackle a gamification structure. Besides, they can share their tips for saving energy or build an energy community. Another aspect to mention is that based on a schedule is the professor's level of access, for instance, during their teaching classes; otherwise, they become only an eyewitness and have the same level of participation as students. In this case, only the management has the full credentials.

D. Smart Building

During this layer, each community member should be motivated and taught how to understand the benefits of reducing energy consumption in the classroom.

A significant determinant that can help achieve or reduce energy consumption during summer periods is the human factor. Consequently, the Universal Thermal Climate Index (UTCI) is a one-dimensional quantity that exposes the human physiological response to the current thermal condition to classify it as thermal stress [50]. An individual can possess no thermal stress within an air temperature spectrum from 9 ºC to 26 ºC. Usually, the thermostat at commercial buildings or schools has a setpoint of 22ºC or below; however, if the thermostat setpoint could increase at least 1ºC, it may save about 6% of the electricity [48].

Therefore, the AC's setpoint in a classroom should be at least 22 ºC or above, if the group of students accepts it so the professor will change it. However, to succeed that setpoint, first, it is essential to understand that the end-user can achieve this thermal adaptation by achieving three categories of thermal adaptation [51]:

- Behavioral adjustment (personal, technological, and cultural responses).
- Physiological adaptation (genetic and acclimatization)
- The psychological dimension of thermal adaptation [42].

Regarding the aspect of security, depending on the community member is the access they have to the system. For instance, in a classroom, a teacher has the credentials to move the AC setpoint, whereas the students have the credentials to monitor the changes in real-time to receive feedback. Speaking of the command chain, the students are at the lowest level, while the management area has the highest level to perform orders and take action.

E. Socially Connected Products Integration

A social product, by definition, is the one that promotes energy consumption awareness. The building takes advantage of the socially connected products and devices to interact with the building. Some applications consider population (demographics), utilities, safety, health, housing, and transportation in interaction with the smart community and the smart city.

III. Results

Fig. 3 displays a three-level HMI considering extrinsic gamified motivations presented in Table I. An online set of stimuli based on challenges and rewards is displayed and how much energy is spending and consider the level of consumption based on the ISO indicator.

Fig. 4 displays the type of HMI for every level of the smart city. Fig. 4 (a) displays the interface for a smart building, being in this case, the CEDETEC building in the point of view of the professor. This interface emphasizes the community side as an option to collaborate with others. Besides, it emphasizes the AC system; a message is displayed to motivate and remember to each team member that they can save energy by increasing the setpoint during cooling periods. For instance, the teacher is the team leader in each team, so the professor sends the action to increase the setpoint; then, the student receive a message asking if they accept to increase the setpoint by 1ºC (Fig. 4 (b)). Likewise, a P.V. system is included in the section of "My socially connected products" to generate interest to the user and see what is needed to install a P.V. system. Fig. 4 (c) displays the smart community integration, where the end-user can visualize which building is winning. This interface intends to promote competitions and challenges to motivate each team. As a visual reward, it is displayed in a bigger size, which building is winning. Fig. 4 (d) displays the Smart City integration for the Tec CCM; this gamified displays in general terms how much energy is saving the city and provides the end-user with options of their preferred services. The interfaces are focused on showing the rewards elements; although the extrinsic motivation is not interested in challenges, this button is added to promote social interaction subtly.

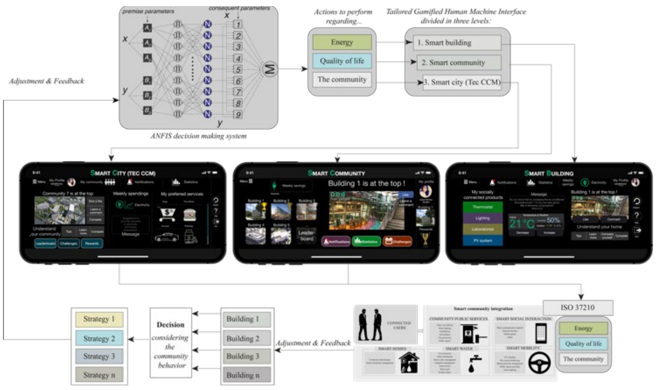


Fig. 3. The general structure for the tailored gamified interfaces and the analysis of the ISO 37120 indicators.

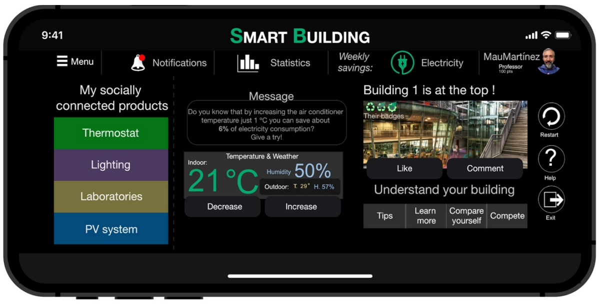
IV. Discussion

This paper proposes implementing a gamification structure in three levels to promote energy reduction by considering the ISO 37120 indicator 3: Energy. Although there have been approaches for monitoring ISO indicators as the Smart City Monitor implemented in Villach City, Austria, it lacks a gamification structure that motivates the end-user to reduce energy consumption.

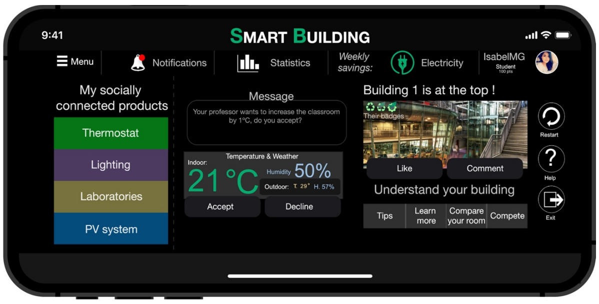
Using decision-making systems as ANFIS through multisensory data provides the data to analyze and propose a gamified application in motivation and competition. Besides, Fig. 3 proposes a general structure for the tailored interfaces by each level: smart building, smart community, and smart city using Tecnologico de Monterrey, Mexico City Camps as a study case. However, these interfaces could be optimized by profile the type of end-user and provide tailored gamified interfaces based on their personality instead of more general gamification motivations.

On the other hand, within a building, there are devices and appliances as the thermostats in classrooms that, by considering the individual's interaction with a gamified application, turns the device into a social product. This proposal only considers indicator 3; however, the systems could adapt and include more indicators to achieve a sustainable quality of life. Although this proposal considers a university as a study case, this provides an insight into how a smart city, smart community, and smart building behave.

The literature shows gamification approaches within a smart city context, which includes the use of multiple applications to promote energy reduction or energy awareness [9], [23]–[28]. However, these approaches lack end-user inclusion because it is difficult for the end-user to use multiple applications to monitor their energy reduction. That lack relies on usability problems, as the end-user is not engaged in using those applications [16], [52]–[54]. In that sense, this proposal aims to collapse all these services into a three-layer interface, so the user engages in a single application. Therefore, a gamification structure is displayed.



(a) Smart Building interface from the teacher's perspective.



(b) Smart Building interface from the student's perspective.

(c) Smart Community interface (for the teacher and the student).

(d) Smart City interface (for the teacher and the student).

Fig. 4. Three-level interface proposal for the Tec CCM: (a) Smart Building from the teacher's perspective, (b) Smart Building from the student's perspective, (c) Smart Community from both perspectives, and (d) Smart City from both perspectives.

Moreover, this application's challenge is to link all these services and that the utility facilities accept them. In the case of a university, it is not so complicated since the managers can bring together all the services in a single application.

The gamification structure's success relies on the energy community, the tips they receive, the suggestions they make, and as a result of their participation, a rewarding structure based on points, levels, badges are performed. Hence, by gaining badges, they can exchange them for products as coffee, or a cookie, or even an extra point for a topic class.

V. Conclusion

In this paper, an ANFIS structure through a multi-sensor system improves the quality of life by taking into account the ISO 37120 energy indicator. A gamification structure triggered by outcome motivations within an HMI for a smart campus is displayed. This strategy considers each building's energy consumption and the ISO indicator with data collected from the thermostats and other electrical devices.

This proposal aims to profile and know better each building energy patterns and the interaction of the buildings in the community and the whole campus to propose an application that improves the quality of life without affecting the university community's interaction and promotes energy reduction.

This proposal set the opportunity to create an environment where socially connected products, connected buildings, and connected communities can interact within the university to promote energy reduction.

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Achieving Life in Smart Cities: Chances and Challenges for a Holistic Care Platform

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***Abstract*—The paper presents the first results of a project that aims to promote cooperation within a Smart City by developing a holistic care platform. In the context under consideration here, a holistic care platform is to be understood as a platform that contains all interesting information for all persons in need of assistance and their relatives and additionally supports them in their everyday life with functions such as booking services and advisory services. By building up a network of professional as well as informal service providers and people, the exchange of information is to be increased and a more efficient and targeted use of resources in the health sector is to be made possible. Since there are already some care platforms or platforms with a relation to care, a competitor analysis was carried out as a first step. Existing platforms were examined and compared with each other. Also, a qualitative analysis was carried out in which stakeholders were asked about their assessments of a holistic care platform. The results of both analyses show the chances and potentials but also the challenges for the development of a holistic care platform. For example, the competitor analysis showed that existing platform solutions can only cover part of the needs of people in need of care. This results in a potential for a holistic platform that can also offer consulting and complementary services in addition to care services. The analyses serve as a basis for the further development and design of the platform. The aim is to create a clear added value compared to existing solutions, both for persons in need of assistance and providers on the platform.**

Keywords*—*smart city, care platform, user-oriented development, qualitative analysis, demand-oriented development, networking

I. Introduction

Urbanization is increasing worldwide. In 1950, only 29.6% of the world's population lived in cities. In 2000, the percentage of the urban population was already 46.7%. For the year 2030, a share of 60.4% is expected [1]. With a simultaneous increase in the total population, cities will have to develop rapidly to meet this growth. Fig. 1 shows the development of global population urbanization since 1950.

Especially in the last 20 years, smart cities have become increasingly important in urban development. The availability and quality of knowledge communication and the social infrastructure are crucial for the competitiveness of cities [2].

The Smart City concept describes a complex ecosystem based on technological innovations with the potential to improve urban quality of life, functionality, and sustainability by networking people, data, and processes [3]. It is therefore not only a concept for bringing technological progress to cities, but also for networking people with each other. The human factor is essential for a smart city. It is therefore important to consider social interaction when talking about a Smart City.

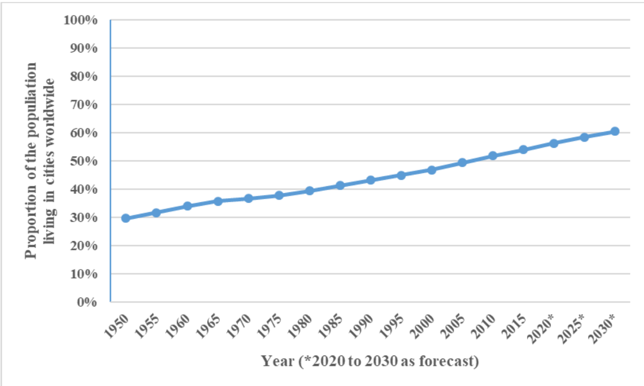

Fig. 1 Proportion of the population living in cities worldwide from 1950 to 2010 and forecast to 2030 (according to [1]).

In terms of technological progress, it is important to examine how social coexistence in a Smart City can be improved through technological solutions. Since this area is very far-reaching, it makes sense to look at one sub-area first. In the following, this paper deals with people who are dependent on assistance due to health or physical limitations. Due to their limitations, these persons are often less mobile, which means that their social life with other people is also subject to special challenges.

Because of the growing need for home health care [4], it is advisable to investigate the possibilities of accommodating this development through technological innovations. One approach is a digital, holistic care platform that provides the person in need of assistance with intuitive access to all necessary services and products, thus improving the quality of life of this person through care in his or her own home. The platform does not have to be limited to the mere procurement and delivery of services and products, but can also offer additional services, such as consulting services. Also

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conceivable is the support of persons with assistance needs in maintaining and building up social contacts.

An innovative care platform is being developed as part of the Smart Care Service project[1]. To analyze the market and general conditions, the project included a competitor analysis of existing solutions and surveys of various stakeholders. Based on the results of these methods, opportunities and challenges for a holistic care platform will be identified in the course of this elaboration.

A previously conducted literature review has provided a good overview of studies in the field of holistic care platforms. Other studies address the research field, including one that builds in the area of open innovation and examines the adoption of an open health platform by patients, caregivers, physicians, family members, and the interested public [5]. Besides, a study shows that multiple levels of integration improve the flexibility of home care systems through a portal-based home care platform that integrates multiple assistive devices and their online services. [6]. A recent study shows that holistic management of specific diseases can also be a useful tool for those involved in the disease. [7]

II. Methods

A. Competitor Analysis

One of the first steps in identifying market and general conditions is to analyze existing solutions from other providers. These vendors represent potential competitors and are therefore compared and examined within the framework of a competitor analysis [8]. The strengths and weaknesses of the respective providers are identified and it is examined where there are starting points for offering the user additional added value [9]. Fig. 2 shows the systematic structure of the applied competitor analysis. First, the processes that need to be examined are identified. Then criteria are defined. In the third step, the platforms to be analyzed are examined. Subsequently, extensive research on these platforms is carried out to gain information. In the last step, the collected information is analyzed and potentials are derived [10].

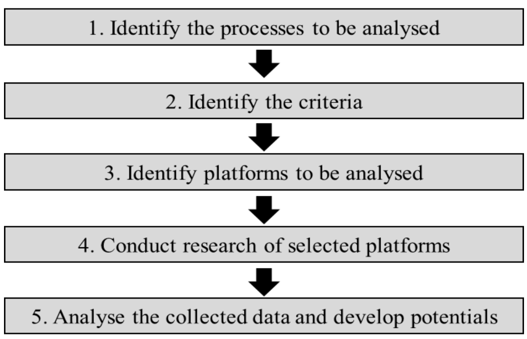

Fig. 2 Procedure of the Competitor Analysis (according to [6], [7]).

Based on 52 criteria, twelve platforms in the German-speaking countries were examined and compared. The criteria were combined into seven categories. These are General Information, Intermediation Offer, Offer in Addition to the Intermediation, Marketing, Quality Assurance, Funding, and Special Features. The information was mainly collected on the platforms themselves. The properties of the criteria were recorded for each platform in an Excel spreadsheet. Mainly values like *Yes* or *No* were used. Occasionally, however, individual values were also set [7].

B. Stakeholder Analysis

Within the scope of a stakeholder analysis, different stakeholders from the areas of care services, care and social counseling, health and nursing care insurance companies, housing consulting, voluntary organizations, financial service providers, seniors' representatives, and mail-order pharmacies were qualitatively surveyed. The analysis aimed to talk to different actors in the care and health care sector to include different perspectives in the study. The purpose was to determine whether, from the respondents' perspective, a need for a holistic care platform exists and what opportunities and challenges they identify in this regard.

For this purpose, a total of 15 people with many years of experience in their respective fields of activity were interviewed between June and November 2020. Methodologically, structured expert interviews were conducted [11]. For the selection of the experts, criteria were defined in advance that they should comply with. Besides, the experts should have many years of professional experience and represent a variety of sectors. Due to the different areas in which the interviewed persons work, it is possible to include different perspectives in the observation. The interview guide was developed using the SPSS method according to Helfferich (2014) [11]. However, the guide should only serve as a basis for interviews. Most of the interviews took place face to face on the premises of the interviewees at their request. After a welcome address and explanation of the background to the survey, all experts were prepared to sign a data protection declaration, specially prepared for the stakeholder survey. This authorized the interviewers to record the interview using a sound recorder so that it could later be transcribed in detail. Furthermore, the sound recording may not be passed on to third parties and must be destroyed after the analysis is completed. Besides, stakeholders were assured that the results would only be published in anonymized and aggregated form. After the interviews had been conducted, they were transcribed, anonymized, and evaluated using the MAXQDA software. For this purpose, a coding guideline was deductively developed in a first step and then inductively extended or finalized. This procedure corresponds methodically to the content analysis according to Gläser and Laudel [12].

III. Results

This chapter presents the results of the competitor analysis and the expert interviews about the potential and challenges of a holistic care platform.

A. Chances for a Holistic Care Platform

In the following, the results of the analyses carried out are presented regarding the opportunities and potential of a holistic care platform. The interviewed experts assessed the potential of a holistic care platform. The shortage of skilled workers in the care sector is a major problem so that new concepts are needed to achieve more efficient use of resources in the health sector. From the point of view of the respondents, a care platform would offer the possibility of bringing together people in need of assistance with corresponding professional care and household-related service providers in the vicinity in a timely and flexible manner and create more transparency in the care sector. Evaluation systems could also be used to counteract dubious offers on the care market and thus support users in choosing a suitable service provider for them. There could also be a chance that trained nurses who are not currently working in the care sector could make their work available via the platform, as this would enable them to decide independently how many hours they want to work and on which days of the week. According to this, the attractiveness of the nursing professions could be promoted. Besides, there is a chance that people in need of assistance and their relatives can network with each other in a city. This could promote exchange and cooperation in a city and make neighborhood assistance possible. It is precisely this aspect that, in the view of the interviewees, can counteract loneliness in old age. Besides, the quality of life could be improved by staying in one's environment for a longer period and participating in society through a care platform. A further potential of a holistic care platform could be the reduction of information asymmetries of users and providers by better preparing and understandably presenting the information.

The results of the competitor analysis also show the potential for improvement of current platforms in the care sector. The analysis reveals that the portals examined can only cover part of the needs of people in need of care. A holistic care platform that combines care services, support services, training, consulting services, other services such as food delivery or hairdressing, as well as product, offers such as care aids, medication, and AAL system components could have great opportunities to establish itself on the market for care platforms in the long term. There is still a lot of potentials, especially around consultancy. This includes advice on procedures for caregiving relatives, on conversion measures for barrier-free living, on AAL systems, and in the psychological field. The use of artificial intelligence and machine learning in counseling could also provide new impulses. Furthermore, the targeted use of videos and images in the counseling sector was not yet well established on the platforms investigated, so that there is still room for expansion in this area. The possibility of using the platform via an app could offer further advantages. An app could also be interesting for caregiving relatives, as services and products can be ordered more easily while on the move. The more practical application could attract the attention of more providers and users. However, so far only 25% of the portals surveyed use an app. Another opportunity for a care platform could be the implementation of automatic billing processes between people in need of care, service providers, and health insurance companies. Also, there is great potential in expanding the target group to include younger people in need of care and people with assistance needs, and in designing the platform to suit this target group. So far, this has only been implemented by a few platforms. The qualitative analysis also revealed that, from the interviewees' point of view, the existing care platforms have not yet exhausted their potential and that there are still useful additions in many areas. The interviewees, therefore, welcomed the idea of developing a holistic care platform that specifically addresses the needs of people with assistance requirements.

B. Challenges for a Holistic Care Platform

Within the framework of the qualitative analysis, the experts were asked what challenges they see for the development of a holistic care platform. It was repeatedly mentioned that the platform should be developed with the involvement of potential users and providers so that real added value is achieved compared to existing platforms. Since there are currently a large number of different care platforms on the market, the platform must be specifically differentiated from existing solutions and be more strongly oriented towards the needs of the target group. Also, the interviewees reported that many people in need of care are currently not as technologically inclined as younger age groups. The use of the platform by higher age groups and the presentation of the added value they can achieve through the platform must, therefore, also be seen as challenging. Furthermore, targeted channels for addressing them must be developed.

The platform should also be intuitively understandable, comprehensible, transparent and target group-specific. Especially if younger people in need of care or assistance are to be addressed via the platform, this could pose a challenge. In addition to easily understandable formulations and larger font, the implementation of several languages should also be considered. However, providing information on how to apply for care services or forms in different languages could prove to be particularly difficult. In most cases, it is still common practice to establish personal contacts with service providers, counseling centers, etc. Processing via a platform could, therefore, be too anonymous for some people and thus not be accepted by some. It is important to be aware that a platform does not replace social contacts, but should promote them and act as a useful supplement.

In particular, the handling of contractual and accounting matters via the platform was considered desirable but challenging. There are currently different accounting procedures and systems between health insurance companies, which can also be different from place to place within a health insurance company. Compatibility with existing systems used by the providers in their everyday lives would also be desirable from the providers' point of view, so as not to increase their workload with the platform. Besides, data maintenance poses a challenge. This concerns not only the data on individual providers represented on the platform, such as contact details, opening hours, etc. but also the information on applying for care services, subsidies, forms, etc.

Compliance with the currently valid data protection regulations and other legal regulations, for example about product recommendations, etc., was also not considered easy. If not only companies but also the self-employed and volunteers can offer services on the platform, the question of quality assurance of the providers must be clarified. Correspondingly, the binding character of the providers and demands should be ensured.

A well-functioning care platform also requires a large number of providers who make their services available via the platform. To accomplish this, a lot of work has to be invested in the development of cooperations, networks, and the promotion of the platform. There is currently a surplus of demand in the care sector so that providers do not need to look for demanders at present. Another challenge is transparency. On the one hand, it would help people in need of assistance if service providers become more transparent, especially about their pricing structure. On the other hand, it would have to be prevented that only prices are compared and that price transparency leads to dumping prices and the promotion of undeclared work. A solution has to be found to this problem.

In addition to the challenges already explained, all respondents identified financing as one of the greatest challenges in the development of a care platform. The question of who is willing to pay for the platform and what business models could look like in this context is, therefore, a central issue. The results of the competitor analysis also provide only limited solutions to this problem.

IV. Conclusion

The results of the competitor analysis and the stakeholder analysis provide a good insight into the opportunities and challenges for a holistic care platform. The interviewees were convinced of the idea of a holistic care platform and listed numerous advantages of such a platform in the interviews. The mentioned potentials are related to individual persons and service providers as well as to the promotion of togetherness within a Smart City. This aspect in particular was repeatedly emphasized positively. This also reflects the findings of other studies that identify a need for networking opportunities in a Smart City and also point out that people should not be marginalized because of their age, gender, or certain restrictions [13–16]. The results of the competitor analysis also show that a care platform is considered to have great potential. Currently, there are a large number of different care platforms in Germany that are trying to establish themselves on the market. So far, however, it appears that none of the existing care platforms has yet been able to develop its full potential. The platforms examined to offer many particularly individualized services, but each of them only covers part of the needs of people in need of care. There is, therefore, great potential for an innovative care platform in the bundling of different services and products to meet the overall needs of users. However, the development of a holistic care platform is, as the analyses show, associated with numerous challenges. In addition to the demand-oriented development of a care platform, the development of suitable financing and pricing models represents a major challenge.

Based on the results of the competitor analysis and the stakeholder analysis, a holistic care platform will be developed that offers persons in need of assistance and their relatives as well as the providers on the platform real added value over existing solutions.

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Practical Approach for the Development of Digital Guidelines for Smart Cities

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***Abstract*—Due to emerging urban challenges, cities are currently under great pressure to change. A popular response to these challenges is the concept of a Smart City. Urban space is undergoing a digital transformation process. As in industry, this transformation not only brings opportunities, but also many risks for a city. The neglect of stakeholders and financially unsustainable implementations are only exemplary risks that cities must take into account. To pursue a sustainable implementation of Smart City initiatives, a holistic approach is required.**

A holistic Smart City development requires strategic management. Uncoordinated activities can lead to important synergy effects not being used and resources and capacities being wasted. In this paper, a practical approach is outlined for the development of digital guidelines for the transformation process towards a Smart City. The procedure is divided into the definition of responsibilities, an internal and external analysis, the development of a structuring framework and the design of the digital guidelines. In principle, approaches from the strategic management of companies can be adopted, but must be adapted to the concrete challenges of cities. This concerns in particular the structuring framework of the digital guideline. Special attention should be paid to this again in the context of the city strategy. It is particularly important to pursue a hybrid approach and so to involve not only the administration but also the citizens. This will strengthen the acceptance of the digital guidelines.

Keywords—smart city, digital strategy, digital guidelines, performance dimensions, digital transformation

I. Introduction

Urban space is facing a multitude of challenges. Urbanization, demographic change, climate change and overloaded infrastructures are just some of the overriding issues that currently challenge cities. The pressure for change within the city has different causes, but all stakeholders have a common goal in tackling the problems: to ensure a socially, economically and ecologically sustainable urban society [1]. In the discussion on how to cope with urban challenges, the "Smart City" approach has become the leitmotif [2]. In this approach, information and communication technologies are used to improve the quality of life in a city and to meet urban challenges. The growing use of digital technologies is a necessary development. For example, resources can be used more efficiently to mitigate climate change [3]. Cities are developing into intelligent and networked spaces. And just as industry is being challenged by fundamental technological change [4], the city is also facing major transformational tasks [5]. Competencies and findings from digitization in the industrial environment (keyword: Industry 4.0) help cities to develop more innovatively and efficiently [6].

However, the digitization of urban space not only brings opportunities, but also risks. For example, the population may feel disturbed and monitored in the area of their private sphere [7]. Residents fear the reality of the transparent citizen [8]. In addition, there may be a risk of making the critical infrastructure vulnerable to external attacks. Hacking into the digital infrastructure can disrupt relevant structures of a city over large areas [8]. The development of sustainable Smart City solutions is a cost-intensive process, especially at the beginning, which therefore also involves financial risks for a city [9]. However, these expenses can be refinanced through long-term cost savings and business models [9]. Unfortunately, holistic and comprehensive Smart City visions, strategies and architectures are only partially available today. There is a lack of approaches for implementing a sustainable and liveable city that can quickly spread solutions to a wide audience [5] [10].

In the course of this work a practical approach is presented, which supports cities in the development of strategic frameworks. Industry faces similar challenges as cities. The concepts already established here, for example from [4], serve as a starting point for the development of strategic guidelines for a Smart City. For this purpose, the challenges that this development process entails are outlined in more detail in section two. Building on this, section three presents the developed procedure. This work concludes with a brief discussion in section four and a conclusion in the fifth section.

II. Analysis of the Problem

Digitization means a far-reaching change and it is a trend that is very hard to reverse. Digital technologies permeate all structures, processes, systems and also cultural coexistence [4]. Many cities are currently engaged in implementing ad-hoc decisions and projects. They neglect conceptual approaches [6]. In order to give Smart City projects a long-term orientation and ensure the sustainable development of a city, a deeper examination of the Smart City phenomenon is required [6].

A city is a complex ecosystem that addresses many different stakeholders. The close intertwining of social, economic and ecological factors can lead to the situation that different motivations exist within a city [25]. Solutions in one area can have negative consequences for another area [5]. Strategic management is needed to address stakeholders not only through isolated, one-dimensional pilot projects, but

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also to address holistic Smart City development [11]. Uncoordinated activities can lead to important synergy effects not being exploited and resources and capacities being wasted [4]. Due to a very individual starting point of a city it is essential to evaluate the respective situation. Every city has its own historical development and, connected to this, individual requirements and needs [12]. Initiatives and projects can be planned on the basis of this assessment.

The development of a Smart City strategy is a major challenge for cities. The digital transformation is characterized by fast and dynamic processes and demands a variety of new skills from a city. The development of an intelligent city requires new structures that bring together and support the implementation in terms of organization, content and projects [12]. In addition to the technical complexity and technical innovations that confront a city in the course of transformation, a city must also adapt to social innovations [13]. Urban transparency and dialogue with citizens play an important role and therefore social change management is required [13]. In addition to technical and social change management, the development of a Smart City also requires program management [13]. This allows the complexity of this process to be managed in a structured way. The current structures of city administration are designed to manage the existing rather than change. In addition, there is a lack of experience in interagency program management. Current administrative structures are not capable of rapid transformation management to a Smart City [13]. New structures and responsibilities are therefore needed. Despite a steadily growing interest in Smart Cities and intensive science, there is no consensus on how to proceed successfully when developing a Smart City strategy and guidelines [14].

In developing Smart City guidelines and vision, the actors involved are faced with major, sometimes contradictory decisions as shown in Fig. 1. These conflict pairs can be structured according [14] in four dichtonomies. These show the differing strategic principles that cities are currently pursuing. The *first dichtonomy* adresses the driver of the digital transformation and describes the interplay between demand and supply in the development of a strategy. Here, the technology-driven thrust (technology-led) is contrasted with a holistic, socio-technical approach (holisitc strategy). However, only the introduction of technologies in urban space cannot serve the complexity of cities [14]. This run the risk of long-term dependency on technology and neglects social aspects when building a Smart City [6].

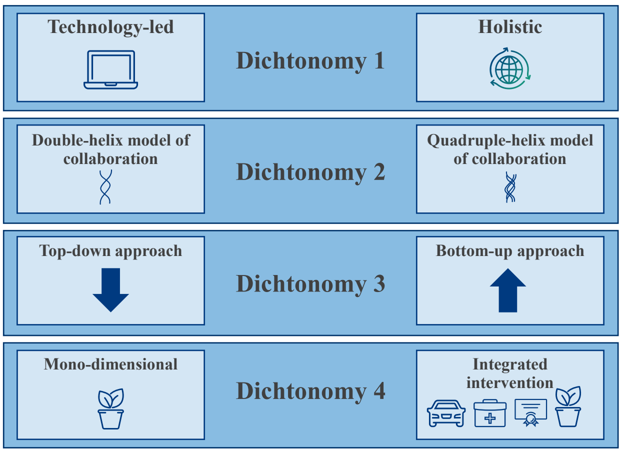

Fig. 1. Dichtonomies for developing a Smart City followed by [14].

The *second dichtonomy* addresses the circle of stakeholders in strategy development. In this way, a strategy can be developed in the form of a closed cooperation model by the solution provider and the city administration. Here [14] speak of a Double-helix model of collaboration. The Triple-helix model represents an intermediate stage to the full stakeholder circle [15]. Here, a network of research, industry and administration is chosen [15], which however neglects the citizens [14]. Based on this, some cities (see Amsterdam) also pursue the Quadruple-helix model of collaboration and involve not only the first-mentioned stakeholders but also business and science as well as citizens in the strategy process [16]. The city of Amsterdam interprets the population as the final users of the strategy and therefore involves them intensively in Smart City initiatives [16].

The *third dichtonomy* describes two different approaches to strategy development and thus the comparison of the top-down and bottom-up approach [14]. Top-down smart cities are coordinated by the administration, which also provides the vision and strategic framework [17]. This has the advantage that the activities always take into account the overall system [12]. Bottom-up Smart Cities give citizens an active role for change [17]. Thus, strategy and vision are significantly coordinated by the population [14] to ensure a citizen-centered approach [11]. A combination of top-down and bottom-up is called a hybrid approach [12]. Here, the advantages of both approaches converge and both user orientation and the overall picture are taken into account [12].

The *fourth dichtonomy* addresses the dimensions of a Smart City. A city can be viewed one-dimensionally or multi-dimensionally and so can its strategy. A one-dimensional strategy focuses on the resource efficiency of a city and aims for a resource-saving future [14]. Since a city does not only have to consider environmental aspects, multidimensional approaches have also developed that take different goals into account. A city is characterized by a multitude of interest groups. A possible and established framework to structure these groups is provided by [18]. Here a city is structured according to its characteristics. This results in six areas that describe a Smart City: Economy, People, Governance, Mobility, Environment and Living. A strategy then focuses not only on the Dimension Environment, but serves a number of other stakeholders [14]. It is clear that many contradictions have developed in the strategic approaches to a Smart City and that uncertainties have also arisen [14]. The different decision options also result in different paths that a city takes on the way to a Smart City [7] as shown in Fig. 2.

[7] identified five different paths that cities have already chosen. Each of these paths follows different perspectives. The *Experimental Path* (1), describes the approach of a real laboratory and focuses on experimentation. This approach is chosen in many cities. In the form of pilot projects, new technologies are tested to improve the quality of life for the population [19]. Here, a technology-driven approach is chosen in combination with a bottom-up approach [7]. This approach, however, neglects the scalability and cost-effectiveness of a solution, which poses major challenges for policymakers [19]. The question of financing is the biggest obstacle to the scalability of smaller Smart City initiatives [19]. Other cities, on the other hand, follow a *Ubiquitous Path* (2). This approach is also known as the "Korean Experience", since it is the approach taken by many Korean cities [7]. This technology-driven and centralized, top-down approach

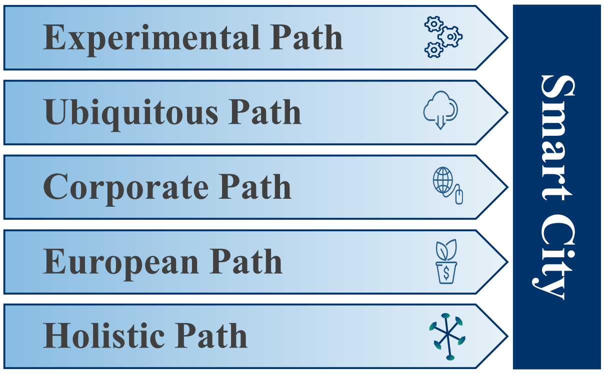

Fig. 2 Paths for developing a Smart City followed by [7].

focuses on market power in the development of a Smart City with the aim of placing ubiquitous technologies in urban space [7]. Here, the interests of industry are served at the expense of the interests of citizens in the form of a triple-helix model of collaboration [7]. Another path, the *Corporate Path* (3), works closely with solution providers and consulting firms that provide platforms and digital solutions to urban society. This path is supported by IBM, for example [7]. Here, a centralized top-down approach is adopted in a double-helix model for the implementation of Smart City initiatives. The fourth path described [7] is the so-called *European Path* (4). This describes the procedure of building a city as a highly intelligent system to address the energy sector. This path is largely shaped by the influence of the EU. The EU has provided impulses to build Smart Cities in order to reduce emissions and reduce the environmental impact in urban areas [16]. This path is the only one that takes only one dimension of the urban landscape into account [7]. The fifth possible path is the *Holistic Path* (5). This path does not only follow the path of an intelligent or digital city, but also summarizes the wholehearted approach [7]. On this path, human, social, cultural, environmental, economic and technological aspects are in harmony [7]. This path is based on a quadruple-helix model of collaboration, which is controlled bottom-up and takes all dimensions of a city into account [7].

This variety of options, choices and fields of tension illustrate the uncertainty and challenges that cities can have when building a strategy [14]. In this paper we focus the following fields of action that cities have with the development of digital guidelines for smart cities.

- *A Smart City needs clear responsibilities:* Since this process requires new skills and different areas of a city work together in a new form, there is a need for higher-level responsibilities to orchestrate all activities.
- *A city is a holistic, socio-economic and technical entity [11]*: To ensure a socio-technical perspective, Smart City approaches should be developed on the base of specific needs and targets and not on focusing what technology can deliver.
- *A Smart City needs hybrid management*: the development process should be managed and understood of both: top-down and bottom-up to address all needs and to take all actors along.
- *A Smart City is multidimensional:* A city consists of different interest groups and should therefore serve the multitude of interest groups when structuring a Smart City.
- *Each city is unique*: Since each city has gone through its own historical development process, the respective initial situation must be taken into account.
- *A Smart City needs Structural and strategic management:* Since cities can chose between so many options to develop their Smart City concept a structural action plan with strategic principles (like targets) is relevant.

In the course of this work we have chosen a pragmatic approach to provide cities with an efficient and structured tool to design their Smart City Strategy and Vision. In doing so, we have oriented ourselves on approaches that are already used in industry (see [4]).

III. Related Work

In the literature, there are several approaches that can help to develop digital guidelines for a Smart City. Holistic approaches aggregate several relevant elements of the transformation process. The work of [10] provides a structured approach and a detailed method box for the conception and planning of Smart City activities. Both the objectives and concrete project ideas are addressed. The procedure also pursues a hybrid approach. However, the development of the strategy and goals is controlled top-down. It is not until the implementation ideas are put into practice that citizens are involved from the bottom up. Thus, the targets are not developed in a hybrid way, which in our view is essential for a consensual commitment of the city.

The work of [11] describes strategic approaches to building a Smart City. It describes the process from vision to the planning of the technical infrastructure to participation possibilities [11]. However, the multidimensionality of a city is neglected here. In addition, the individual components are only described in a superordinate manner and do not have sufficient depth of detail to apply this approach.

In the work of [20], strategic management is defined as a necessary foundation and basis for Smart Cities. The strategic elements of this work address the inventory and consideration of the initial situation of a city in great detail. The multidimensionality of a city is also taken into account in the analysis. For the identification of strategic options, however, the multidimensionality is neglected.

[1] describe in their guide an all-encompassing approach for Smart City Transformation. Their approach assumes that cities can be transferred to the six dimensions according to [18]. Thus, the uniqueness of a city is neglected here. The approaches described here and other approaches were examined for possible applicability and incorporated in our approach.

IV. Process for the Development

In this paper, a pragmatic approach is presented to develop strategic guidelines for the development towards a Smart City. Digitization strategies initially emerge in the context of new information and communication systems from business and management [21]. This process is based on thoughts and preliminary work that are already used in industry. Thus, it was oriented on approaches that are used for the development of corporate strategies [4]. Furthermore, preliminary work from the smart city context was also taken into account in the development of this process [1], [10]. The approach was implemented in cooperation with a medium-sized city (about 148,000 inhabitants). The resulting strategy paper was subsequently approved in the form of a council resolution. The approach is divided into four phases (see Fig. 3): the definition of responsibilities, the internal and external analysis, the structuring framework of the digital guidelines as well as the way the digital guidelines are developed.

A. Definition of Responsibilities

Building a Smart City requires a number of structures that bring together, drive, manage and control the process in terms of organization, project and content [12]. An established approach to implement these structures is a staff section, which is usually located close to the mayor [12]. This is where the actual steering and control, i.e. the governance of the Smart City and its projects, lies [12]. First of all, it is necessary to define the areas of responsibility and the division of tasks between the staff unit and the actors of the urban community [10]. Clear responsibilities and communication channels in Smart City projects are an essential core of successful transformation [1]. A pragmatic approach can be taken to clearly delineate the areas of responsibility of the staff section. By using the Value Proposition Canvas (as seen in Fig. 4), the future customer profile of the staff section can be defined. On the other hand, the corresponding value proposition can be developed. Results of a workshop by filling out this canvas should be a clear value proposition of the staff position and the associated areas of responsibility [22].

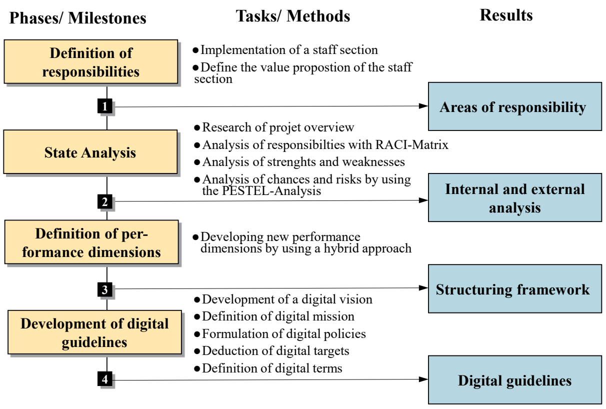

Fig. 3. Phases of the practical approach for the development of digital guidelines.

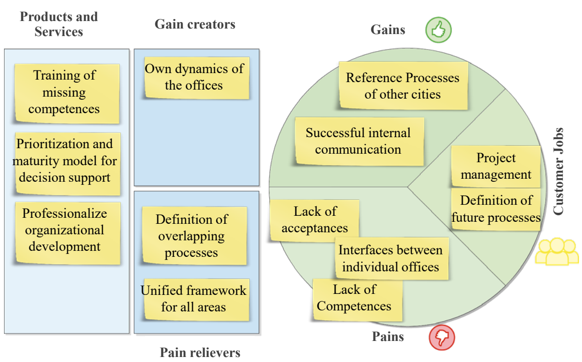

Fig. 4. Exemplary extract from the Value Proposition Canvas in the Style of [22].

B. State Analysis

Both internal and external perspectives are taken into account in the state analysis [20]. In the internal analysis, the city's performance is determined on the basis of predefined performance dimensions. These performance dimensions are the dimensions structured according to [18]: Economy, People, Governance, Mobility, Environment and Living. This gives a framework for the internal analysis [20], since these fields of action represent a balanced basic model [12]. In the first step, a detached research on current digitization activities and projects in the city is compiled in the form of an overview list. These results can be supplemented by a workshop with, for example, the staff section and then assigned to the individual areas of life. In addition to the pure project inventory, the corresponding responsible persons and offices are also assigned to the individual areas of life. The RACI matrix can be used to differentiate the degree of responsibility. The gradations "Responsible", "Accountable", "Consulted" and "Informed" [1] are used to specify responsibilities in the current project environment in detail. This mapping of projects and responsible persons is used primarily for internal structuring and for identifying white spots. In addition, the strengths and weaknesses of the city are identified in the internal analysis. The strengths and weaknesses analysis can be extended beyond the mapping. From this, important fields of action for future strategic steps can be derived [1].

In the course of the external analysis, the opportunities and risks in the environment of a city are considered [20]. Since a Smart City Transformation is not isolated but rather dependent on the environment and stakeholders, external analysis also plays a central role [1]. Thus, opportunities and risks for urban development are assessed with the involvement of various stakeholders from both internal and external units. In the environmental analysis, the external influencing factors can be analyzed in the form of the PESTEL analysis, which originates from [23]. According to the following categories, trends and developments are identified that need to be considered within the strategy [1]: Political, Economic, Social, Technological, Environmental and Legal.

C. Definition of Performance Dimensions

Due to an individual history, each city has its own needs and individual requirements [12]. Thus, each city also goes through an individual transformation process. The performance dimensions defined by [18] therefore cannot be fully transferred to every city. In the context of the state analysis, it becomes clear that different performance dimensions are weighted differently in each city and that the dimensions cannot be considered separately. Thus, the structure of performance dimensions rather serves to set priorities for strategic activities [12]. In order to take into account the ideas and needs of all actors and domains for the further orientation of urban development, the structuring framework is redefined both top-down and bottom-up in the form of a hybrid approach, thus deriving city-specific performance dimensions. This creates an overall view of all domains and respective needs [10]. The existing project landscape and responsibilities are assigned to the newly established dimensions. These dimensions now serve as a structuring framework for the digital guidelines to be developed.

D. Development of Digital Guidelines

When designing the future of a city, it is important to consider all dimensions and stakeholders and to address the corresponding needs and demands. Therefore, the following description of the development of the digital guidelines is to be understood as a multidimensional process. Each performance dimension of the city is considered according to the following steps. In this paper, the performance dimension of *mobility* serves as an example to illustrate the applicability of the approach to the topic Smart City

According to [4], digital guidelines consist of five different elements. A superordinate *digital vision* is developed, which represents a concrete, feasible and at the same time distransferred vision (5-8 years) of the future of the area of life [4]. A broadly supported vision helps to resolve conflicts in later phases and provides initial pointers for the selection of projects [1]. The vision must be resilient enough to balance complex and contradictory needs. It must be developed by a large number of city stakeholders with different backgrounds, perspectives and interests in an active participation process [11]. An exemplary vision could be as follows: *The future of the cities traffic lies in multimodal traffic concepts that seamlessly link different means of transport. An intelligent traffic flow control system ensures fluent traffic and less waiting time.*

The *digital mission* describes the elementary reasons for the digital transformation of the city and answers the question why the city is initiating the digital transformation [4]. In the context of *mobility* one digital mission is to reduce high traffic volumes. *Digital policies* represent the city's core values in the context of digitization. In this way, guiding maxims are established [4]. An important basic value in the overall context of Smart City is data security. Therefore, basic values such as this one should be addressed in the course of the digital guidelines: Digital data is subject to the same evaluations, the same understanding of the state and the same understanding of basic rights as analog data. The fulfilment of the requirements for data economy, secure data storage, data transparency, data sovereignty or data security is one of the decisive factors for acceptance.

Digital targets are derived from the digital vision and mission. The digital targets are used to substantiate the strategic orientation of the digital transformation [4]. However, before the goals are defined, it is advisable to assess the motivation of the city [10]. According to [10], a city can follow the problem-oriented or the hero approach. Problem-oriented cities are largely guided by good practices in order to implement proven solutions [10]. In the Hero approach, cities pursue pilot goals in order to seek out the state of the art [10]. Based on regional specifics, it is not possible to define model goals at this point. Rather, it is more relevant to bring the most important stakeholders to the table and jointly adopt goals [10]. The SMART principle should be used as a quality criterion for defining goals (Specific, Measurable, Achievable, Relevant and Time-bound). The goals are divided into short, medium and long-term goals [10]. To illustrate the definition of a target in the performance dimension of *mobility*: The collection of all parking data (4200 parking lots; on- and off-street) in the city center in real time until 2022.

In order to establish a city-wide, uniform understanding, elementary *digital terms* are formulated [4]. These digital terms can be processed in the form of a glossary. It is important that a uniform understanding of the term is established in urban society. As example: *Citizen Account - The collection of digital master data of a citizen in an account, which should simplify the communication with the administration* [24].

The digital guidelines serve both internal and external communication of the transformation process. The vision, mission, policies and targets are written per performance dimension in the context of digital transformation. To illustrate the digital target image, these guidelines can be formulated in scenarios. In addition to just write the scenarios down, it should also be recorded graphically. This increases the identification potential of the digital target image.

V. Discussion

The procedure developed here describes an overarching process and presents a rough direction for implementing a smart city strategy. Less attention is paid to the level of detail of the individual components. For example, it is not clearly defined here how intensively the citizens are included in the formulation of the goals and visions. The depth and feasibility of each process is to be judged very individually. This strongly depends on the size and structure of each city. In this case, the procedure was applied in a medium-sized city. Here, short paths make it possible to address the individual steps pragmatically in workshops and series of interviews. This could be difficult in larger cities. Here, it can quickly happen that relevant stakeholders are neglected in this process.

Also, this approach does not define whether the Smart City Strategy is a document that will be integrated into the previous strategy documents or whether it will be considered separately. This should be considered in more detail in a further process. Another step which should be considered in a further process is the transfer of the results from this procedure into a concrete action plan for cities. This procedure helps cities to develop a holistic understanding of the individual smart city process. However, the concrete implementation is neglected.

VI. Conclusion

This contribution shows a pragmatic procedure for establishing a digital guideline for a city. Approaches from the strategic management of companies can be adopted, but must be adapted to the concrete challenges of cities. The main challenge is to structure the guideline regarding the ideas and wishes of all stakeholders. And to determine which stakeholders shall be involved as they are not clearly defined in all areas of a city. Due to this, communication is very important in order not to encounter resistance but ideas regarding the topic of digitization. Clear pictures must be shown and stakeholders must be supported in contributing their ideas, even if they are not experts in the field of digitization at all. Only in this way all stakeholders will feel that they are being taken into account in the transformation process and will support the transformation.

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Collaboration for Innovation Between Universities and Smart Cities

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Abstract—**Cities are facing regularly changing societal and infrastructural needs because of multiple reasons like a growing population, new ways of life and new societal needs, climate change, or digitalization. Often, changing needs and boundary conditions show a much higher dynamic than city administrations can cope with. The development of long-term strategies and concepts for smart cities and their implementation can, thus, be facilitated by integrating knowledge and competences available at innovative research institutions, like universities. Recent studies suggest that universities may take a leading role in supporting smart city projects. Nevertheless, a clear procedural approach of the knowledge transfer between universities and smart cities has not been described or tested, yet. To address this research gap, this paper will present a reference model, which can be used as a guideline. Traditionally, the role of universities is described by its missions to teach, to conduct research and to share new findings with its stakeholders. While concepts like the 'Quintuple Helix' and 'Third Mission' try to describe the role of universities as key players in innovation projects, only few studies describe their role specifically for smart city projects. Therefore, this article will propose a structured, procedural approach for collaboration and knowledge transfer between universities and smart cities with an adaptive reference model. Due to its flexible architecture, the adaptive reference model facilitates efficient and effective knowledge transfer between universities and external partners, in this case with the stakeholders involved in smart city projects.**

Keywords—collaboration, knowledge transfer, smart city projects, reference model, innovation

I. Introduction

During the last century, a clear trend emerged, that more and more people would move from rural areas into cities. In 2008 the UN stated that more than half of the world population was now living in urban areas [1]. It is also expected that this percentage will see further growth until it reaches about 70% in 2050. Especially in Asia, metropolitan areas have emerged that exceed their city limits and are home to 20 million or more people. The biggest one is currently the Tokyo metropolitan area with almost 38 million inhabitants [2]. Due to this influx of people cities and urban areas now face a multitude of problems that have to be addressed in the near future. For example, cities will have to ensure sufficient access to natural resources like fresh water, air and green areas. People also require an affordable housing solution as well as industrial and commercial areas that provide jobs. Cities also have to establish an appropriate transportation concept to enable easy movement within the city and avoid traffic jams. Despite all these challenges and many more, cities have also to ensure that they still offer the expected public services like police, firefighters and universities. Due to the diverse nature off all these different problems and the rapid development in technology it is often not possible for cities to find smart solutions to all these problems on their own. But this may be solved if cities can utilize the broad knowledge of different fields and modern technology, which is available at universities. Currently multiple cities try to implement smart aspects within their societal and infrastructural framework. For instance, Singapore is one of the pioneers in intelligent urban planning and tries to incorporate many different solutions to optimize the life in the city [3]. To put their "Smart City Agenda" into practice, intensive knowledge transfer with the society, economy and universities is conducted. However, not every city has similar resources and capabilities as a modern metropolis like Singapore. Thus, this paper presents an adaptive reference model, which serves as flexible template that will facilitate the transformation to a smart city for many cities by integrating the opportunity of collaborations between cities and universities. Therefore, the following research questions arise:

RQ1: *What are the specific influencing factors on the transfer between smart cities and universities?*

RQ2: *How can the collaboration between smart cities and universities be displayed in a structured manner?*

This article will first briefly explain the applied research methodology and then introduce the adaptive reference model. An evaluation of the model concludes this contribution.

II. Research Design

To ensure the quality of the research, a comprehensive research method is needed. Two general approaches are described by HEVNER [4]. The "behavioral science" focuses on the construction of a hypothesis and its empirical validation. Complementary to this, the "design science" focuses on the creation of IT artefacts and their evaluation. This research method is very close to methods use in engineering but has its special focus on IT artifacts. In the

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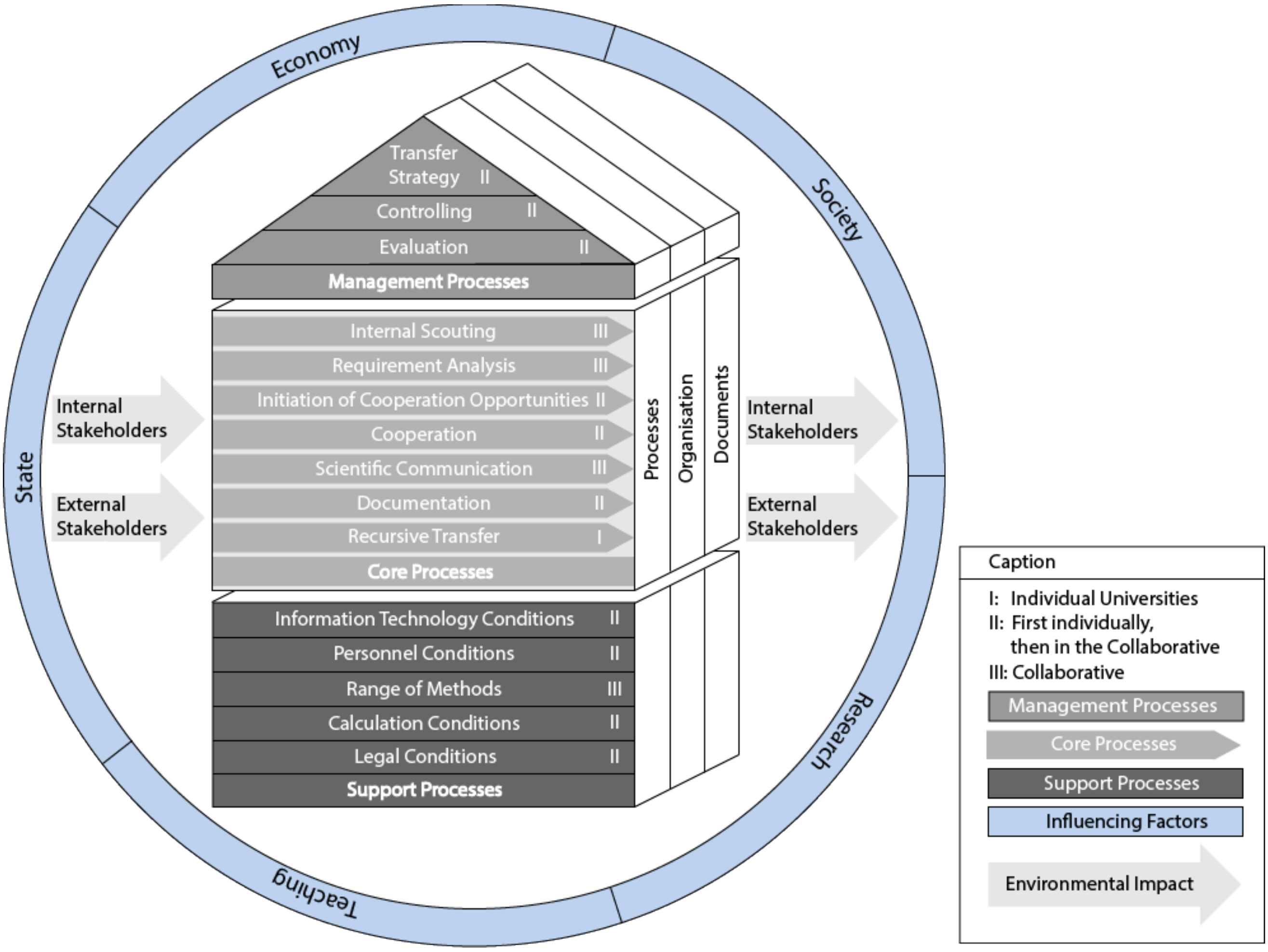

Fig. 1 Reference model for collaboration and transfer [5].

context of this research, the proposed adaptive reference model represents the IT artefact. In accordance with the guidelines of HEVNER et al., the relevance for the research is given by the need to transfer the knowledge of universities to public entities, in order to realize smart city projects. The necessary evaluation is given in the context project TRIO, which focuses on knowledge transfer between organizations like universities and external partners. TRIO is a cross-university initiative of six collaborating universities in Germany. In January 2018 these universities have initiated a joint alliance. In a series of interviews, experts from different departments of the collaborating universities were asked to provide feedback on the reference model and how their opinion was. To disseminate information about the reference model, it will be published in this conference as well as in an accompanying doctoral thesis. In order to ensure the scientific rigorousness and to support the research as a search process guidelines, a literature search based on the principles of VOM BROCKE was conducted [6].

III. Reference Model for Collaboraition and Transfer

Various concepts try to describe smart cities with respect to a growing knowledge economy. These approaches try to integrate the physical, IT, social and business infrastructures to a sustainable urban space. The transfer of knowledge in collaboration projects indicates that knowledge is shared between cooperating partners to generate new knowledge and create a strategic imperative [7]. But especially in the context of smart city projects, often a lot of different stakeholders are involved and modern technologies are required, due to the high complexity involved in smart city projects and the required knowledge transfer, an adaptive reference model was created according to the proposed structure by MEISE [8] (cf. **RQ2**). This reference model is an artefact of the Design Science process and aims to enable knowledge transfer between universities and external partners, in this case with smart cities (see Fig. 1). The goal of this approach is to include all transfer processes, partners, relevant tools, documents and necessary organizational structures in one adaptive reference model. This should enable a wide variety of different smart city projects to be able to use the structure provided by the reference model. The structural design of the reference model resembles a house, which simplifies the interpretation of the target user groups [8]. Target users of this reference model are researchers, representatives of smart city projects and companies who conduct research in collaborative projects. The university-internal users of this model are employees in technology and knowledge transfer departments, research funding departments, finance and legal departments. Especially the simple graphical design of BPMN supports the usability even from partners that are not familiar with reference models.

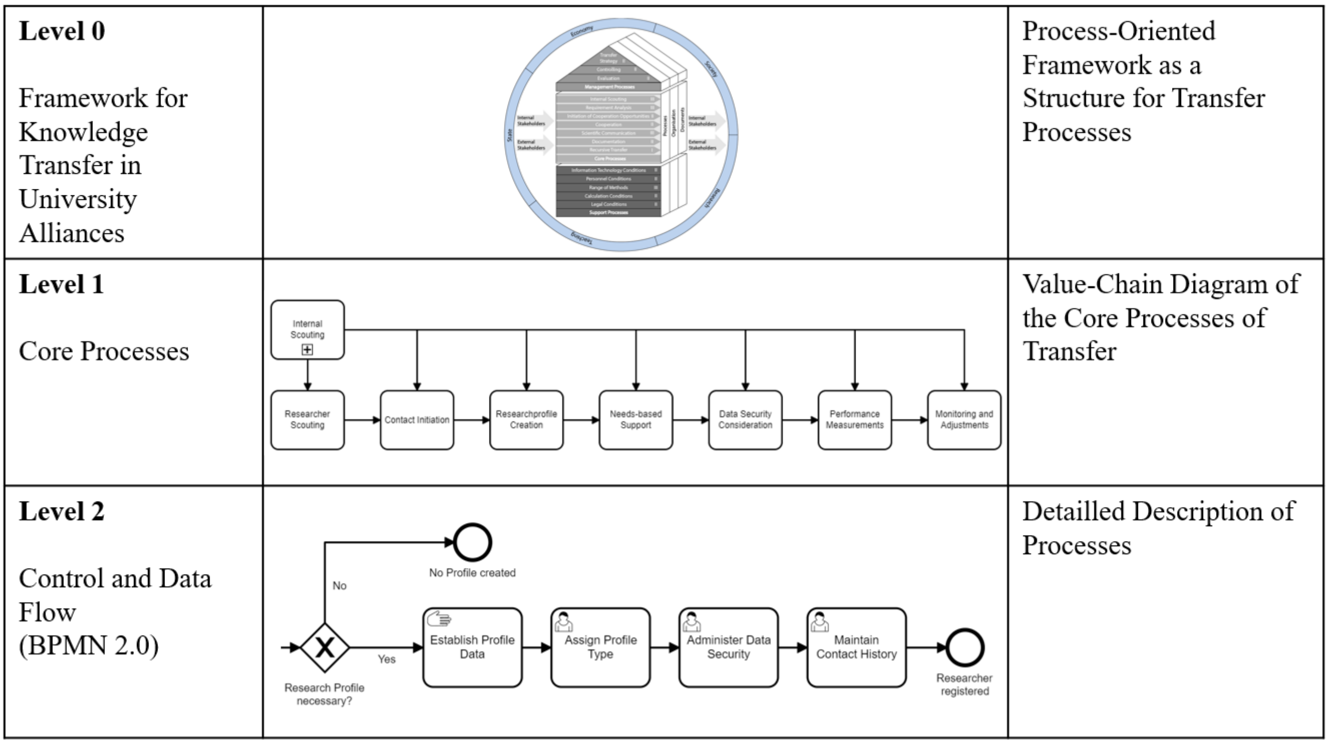

Fig. 2 Levels of the reference model for collaboration and transfer [14].

The reference model consists of specification-content and a specification-view (processes, organization and information). The specification-content summarizes the single processes of knowledge transfer between a university and external partners, like stakeholders involved in smart city projects. The organization and information-view propose opportunities for collaboration concerning the organizational design of a project and the flow of information within transfer projects. Processes first need to be modelled and defined and then in a second step assigned to a responsible organization (or department within a university), which is displayed in the organizational view [9]. The flow of documents and information, which are needed to carry out the transfer processes, is described in the document view.

The structural design of the model separates knowledge transfer into management processes, core processes and support processes. Management processes determine the strategic alignment of transfer and therefore shape all other processes. Here for example the transfer strategy of the smart city development will be determined. Often, governments still lack knowledge in how to build smart cities and therefore depend on data and knowledge from research [10]. The transfer strategy for smart city projects can define which areas to focus on (e.g. urban planning or public safety) and therefore shapes the knowledge which needs to be transferred. The management processes also define the controlling and evaluation of the transfer projects. This includes providing a reliable set of key performance indicators (KPIs), which allows the evaluation and assessment of transfer projects [11].

The support processes contribute only indirectly to value creation and the realization of transfer projects. Here, for example, required personal or IT-infrastructure for a transfer project is provided. Smart city projects are often accompanied by extremely bureaucratic processes [11]. The reference model can therefore supply the project partners with all necessary process support and required documents to simplify the realization of transfer projects. For example, in a collaborative smart city project all project partners receive an overview which processes and documents are needed (e.g. examples for project proposals or project contracts can be provided through the model) in the planning phase of the project.

Core processes contain the added value and thus contribute to a considerable extent to the fulfilment of the requirements of the customer. The reference model for collaboration and transfer consist of seven core processes (see Fig. 1).

- Internal Scouting: these processes describe the finding of a suitable research partner in universities.
- Requirement Analysis: the demands and requirements of the smart city project partners are defined and analyzed by these processes.
- Initiation of Cooperation Opportunities: these processes present possibilities in how smart cities and universities can collaborate (e.g. different types of research projects).
- Cooperation: when the suitable form of cooperation is chosen, these processes support the project partners in the realization of the transfer project.
- Scientific Communication: to disseminate information about the research and transfer findings, these processes describe the various possibilities in scientific communications.
- Documentation: to ensure that the findings of such project are not forgotten, a structured documentation is needed, which is described by these processes.

- Recursive Transfer: finally, the findings can also shape and influence teaching contents within the universities and therefore prepare the students for their future. Research and teaching at universities are closely related and influence each other. Excellent research requires well-educated graduates. State of the art teaching considers new research results in order to ensure its up-to-date teaching contents. The reference model proposed here is relevant for many study programs in the context of smart cities, engineering, economics, and politics.

The processes of the reference model are described in three levels (see Fig. 2). Level 0 resembles a process-oriented structure of all transfer processes. The core processes of transfer are described and classified in value-chain diagrams on Level 1. A detailed description of the core processes is given on Level 2, where the control and data flow of these processes is modelled using the Business Process Model and Notation (BPMN 2.0) modelling language and implemented in a new adaptive and digital modelling framework (see example of partial process in level 2 in Fig. 2). Subsequently, the reference model allows each member of a transfer project to work according to their own processes which are derived from the reference model.

As the establishment of smart cities may involve more than one university and multiple other project participants, the importance of a clearly communicated project management approach cannot be underrated. Obviously, universities are competitors for funding and research projects, but in order to answer the diverse requirements, which smart city projects may involve, collaboration is often needed. To allow for the collaboration of more than one university in a transfer project, the reference model describes three different types of processes (see in Fig. 1 the roman numeral I-III). These characterize which processes in the reference model need to be carried out by single universities or by all universities collaboratively.

Transfer and the adoption of new technologies and knowledge is a complex process [12]. Factors, which may influence the transfer between universities and smart cities are presented in a circle around the reference model (cf. **RQ1**). They consist on this top level of the model of five different sectors, which contain detailed factors at a deeper level. The factors "teaching" and "research" form together with "Transfer" the third mission of universities, which acts as a means for a greater collaboration between universities, the economy and the society [13]. Universities therefore have to interact deeply with their surrounding environment and are no longer seen as "ivory towers" in which research is done without any interaction with the society [14]. The influencing factor "society" exits, among other factors, also of the factor "culture of the collaborating partners". Cultural differences among universities and smart cities can increase difficulties in technology and knowledge transfer activities [15]. Communication and an open mindset are therefore crucial to successfully carry out a smart city project [16]. This can be supported by structured processes and tools but needs also all participants to take efforts to collaborate in such diverse situations with different cultures, languages and multiple stakeholders. Although the freedom of research exists as a supreme standard, the state and also the economy can exert influence on the transfer and research of universities through for example the allocation of funds [17]. Universities still often only exert research, when there is funding incorporated, which makes them somehow depended on the state and the economy. The industry (here in the factor economy) is providing the hard- and software for smart cities and is therefore, together with the universities, the main solution provider for smart city projects.

IV. Conclusion and Outlook

In this paper the two research questions RQ1 and RQ2 have been answered. The first research question dealt with the influencing factors on transfer between smart cities and universities. By examining the third mission of universities, these factors could be examined. The created artifact, the adaptive reference model for collaboration and transfer, takes these influencing factors into account and gives a neutral representation of how the collaboration between smart cities and universities could be presented in a structured manner (cf. RQ2).

The evaluation of the reference model for collaboration and transfer is conducted in the project TRIO. By carrying out expert interviews with transfer project participants the model was tested and evaluated. All experts were from different departments in the collaborating universities (e.g. technology and knowledge transfer offices, research funding departments, finance and legal departments). The possession of privileged information about research and transfer and a position with responsibility and experience in knowledge transfer project were the prerequisites in the selection of experts [18]. The interviews were conducted in five different German universities in a partly structured manner according to [19], to allow for a generation of interpretive knowledge. With the usage of an interview guide with open questions, the experts were able to provide additional information on this topic. Therefore, open questions like the following were asked "*What structures are in your point of view needed to pursue knowledge transfer within a smart city project?*".

Currently multiple cities try to implement smart aspects within their societal and infrastructural framework. For instance, Singapore is one of the pioneers in intelligent urban planning and tries to incorporate many different solutions to optimize the life in the city. To put their "Smart City Agenda" into practice, intensive knowledge transfer with the society, economy and universities is conducted. However, not every city has similar resources and capabilities as a modern metropolis like Singapore. Smaller cities, like for example Athens in Greece are also pursuing their smart city endeavors and are therefore collaborating with i.a. universities to solve their city problems [20].

Future work includes the integration of the reference model into an online tool. This may support the adaptive approach of the model and show which kind of project should be carried out and then provide the necessary processes and documents.

This will be achieved by setting the reference model up with adaptive parameters. They represent the different influences on a smart city project. These parameters will then be used to define which parts of the reference model will be relevant for the specific project. For example, some parts of the reference model can be relevant for a project which involves multiple universities, while other may only be relevant if one or more partners from the economy are involved. These different parts will be attached with a specific logic (e.g. Boolean terms or utility analysis). This logic will then evaluate the parameters provided by the user and depending on the outcome of the logic, select the relevant parts of the reference model. In this way the user is provided with a simple way of tailoring the reference model to a specific project, even without in-depth knowledge about modeling or the process itself. This enables also smaller cities to have a guiding framework for their smart city projects despite an initial lack of knowledge and fewer available resources.

There is still lots of uncertainty in how smart cities and universities can collaborate for innovation and replication [11]. Thus, this paper presents an adaptive reference model, which serves as flexible template that will facilitate the transformation to a smart city for many cities by integrating the opportunity of collaborations between cities and universities.

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Case Study of University Ecosystem Development

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***Abstract*— The high educational institute's automation systems for the student and staff management was described and compared in the article; also, was explained why HEIs are forced to develop their own systems to automate the work with the student information, to support the educational process, with the possibility to generate reports and obtain statistical information. Next, the case study of university ecosystem development was considered in the article. The flexible information system named University Student Management system was developed which allows importing data from existing software, to conveniently process data on the higher education applicant's information changes, to control the processing of student orders in The Unified State Electronic Database on Education, to quickly receive all types of statistical reports.**

Keywords— information and communications technology, student management system, automatization, integration, digital ecosystem

I. Introduction

Development of the digital ecosystem of the High educational institute (HEI) involves technologies organization implementation for interactions between a great variety of university departments and offices. One of the greatest challenges is monitoring the university student information.

The importance of the process of analyzing and controlling the data about the students is necessitated, because the university should develop project indicators of the plan of admission and graduation in accordance with external and internal regulations annually at the beginning of the calendar year, based on the analysis of the flow of students and admission of higher education students. Also, at any time, university employees should be able to obtain information about each student, form of study and type of funding, course of study, etc. To determine this data, university staff must monitor all orders about each student's learning process, starting with enrollment. To provide correct information, HEI must have an information system, which will allow capturing student information during the study at each specific time interval, with the possibility of obtaining statistics for previous periods and at any date specified in the request for receiving information.

To organize this process, the Ukrainian government introduced in 2012 year the Unified State Electronic Database on Education (USEDE), which is an automated system for collecting, registering, processing, storing and protecting educational information [1]. An HEI is a user in this system, without the right to upgrade or modify the software, so unfortunately it is not possible to get statistical reports on different types of queries from USEDE, although the information for each student is stored.

In view of the above, HEIs are forced to develop their own systems to automate the work with the student information, to support the educational process, with a possibility to generate reports and obtain statistical information.

II. State of the Art

The literature on HEI's ecosystems agrees that the ecosystems build on combinations of cultural, financial, human, institutional and political factors within an institute. Key success factors in the process of sustainable university ecosystem establishing include, for example, a strategic view by the management, long-term commitment on all levels, sponsors and collaborators within and outside the university, appropriate organizational infrastructure and substantial financial resources [2]. The architecture of a university ecosystem consists of multiple structures, each consisting of actor and software elements, therefore the software structure of the university ecosystem is important. The inner part of the HEI's ecosystem is an integrated student information system that manages the entire student life cycle including admissions, and also courses, employee and document management, etc. This system should be flexible and give an ability to incorporate different elements and the interaction and interoperability of the HEI's elements.

There are an increasingly large volume and variety of data being generated in HEIs, which leads to problems with their storage and processing. From the end of the XX century scientists working on exploring this problem and looking for solutions [3]. Leading universities of the world are engaged in the process of digital transformation, an essential process for increasing efficiency and collaboration, and reducing costs and errors in the management of at-scale training systems. For example, the "Riconnessioni" project was promoted in agreement with the Ministry of Education of Italy, which is experimenting with new learning models, taking advantage of opportunities that emerged from perceptions stemming from concerns and systemic issues [4]. An open-source portal framework was developed and customized for university purposes in Romania after several failures in implementing commercial applications. It is usefully applied by using the concept of single sign-on and helps students and teachers to keep a better connection with the university, to be better informed and, at the same time, to provide feedback to the university [5]. In Indonesia, a quantitative method through continuous analysis of simulation was used for the research of

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prospective students as a unit of analysis for predicting their implications for service systems process performance [6].

The next step after the digital transformation of the HEI's information is creating ecosystems as co-innovation networks, in which actors from organizations concerned with the functions of knowledge production, wealth creation and norm control interact with each other in forming interdependent relations [7]. These co-innovation networks should have a reliable data source about students and staff, which is the most important HEIs functioning component. There are many publications about the HEI's automation systems for the student and staff management, the analysis and forecast of the higher education applicants count, and others [8] – [18]. A comparison of the most popular systems is shown in Table I.

TABLE I. COMPARISON OF THE MOST POPULAR STUDENT MANAGEMENT SYSTEMS

Indicators	**Iolite-School Management System [8]**	**The All-in-One School Automation System [9]**	**Student Admission Management System [10]**	**Campus 365 [11]**
Admission Management	Not implemented	Student Admission Module	Application tracking system, admission management	Paperless Admission, On-line Application Forms and Fee Payment
Reports	Student, Staff, Library, School, Exam and Fees Reports	Custom Report in Professional Version	It is possible to get custom reports as per the requirement of the Institution	Student & Behaviour Analytics
Curriculum Management	Not implemented	Not implemented	Assignments with deadlines, an online multiple choice quiz	Courses and class timetables management system
Student Desk	Students and Academics Details	Student Information Module	Student Portal	Personal and academic information Dashboard
Educational institution	Schools	Schools, colleges, universities	Schools, colleges	Schools, colleges, universities
HR Management	Partially implemented	Human Resources Module	Staff management module	Human Resource module
Integrations	Not implemented	Video conference, Tally, Google Apps, Payment Gateway, Moodle	SMS, Paypal, Moodle, HESA Integration	SMS, Email, Google Apps, payment systems, Google Analytics
Import data	Not available	Not available	Not available	Import an existing course schedule
Language Support	English, Hindi, Gujarati	English	English	English
Source Code	Not available	Available only in Enterprise Version	Not available	Not available
Payment	Fee-paying	Fee-paying (also for hosting)	Fee-paying	Fee-paying

The biggest disadvantage of the reviewed systems is high cost, the average cost is \$ 0.14 for 1 student per month [11] - [12]. So, it will be more than \$1000 per month, which is unacceptable for most Ukrainian universities' current budget. Also, most of the considered systems have a lack of access to the source code. This prevents the implementation necessary for each specific institution of specific functions. One more challenge is the lack of integration possibility with existing systems in the institute (neither via Application Programming Interface (API) methods, neither via import from files). Because of this, for using any of the specialized solutions all information about current students, staff, courses, etc. must be entered manually.

Also, most commercial offers are representing in English, which is a complex task for a majority of the staff. That is why a few Ukrainian systems for similar goals were reviewed [13]-[18]. Almost every Ukrainian HEI conducts research and develops complexes of economic and mathematical models for analyzing and forecasting the HEI's student information to provide reporting and improve the tools for supporting effective management decisions. At the same time, automation is usually done either in the form of specialized solutions or in attempts to develop a universal solution. In the first case, the tasks arising from the lack of linkages between different HEI units and data integration within HEI and across national databases. In the second case, the issues are:

- inability of automatic transfer of existing arrays of information to the new system;
- inability to add new functionality independently;
- inability to take into account the features of HEI;
- lack of integration with USEDE.

III. PROBLEM STATEMENT

Due to the issues with universal solutions, the task of implementing the University Student Management system within the framework of HEI "Zaporizhzhia Polytechnic" National University, which allows automating the work with the students' information, was occurred. This system should be possible to support the educational process, generate reports and obtain statistical information, which takes into account the other educational institutions' achievements in this field and allow integration with USEDE using the API.

First of all, there was necessary to estimate the amount of data that needs to be stored and processed. Let's take as n_x – count of students enrolled in HEI in a given period of time (each student must store his personal information, gender, date of birth, etc.), and as n_y – count of orders that capture and approve the student's movement within the university, beginning with enrollment and ending with expulsion from the university. This data should also include the case of transfer to another form of study, change of funding, renewal, deduction, etc. During his studies at HEI, the student can perform many such changes, which requires storing some data amount for each student in an orderly form (the date of commencement of the order, course, form and type of study, and other data depending on the order type). The n_y minimum value for a successful student, who is receiving a bachelor's degree, is 5 (enrollment, 3 transfer to the course and study completion), for the master's degree $n_y = 3$. In the case of changes in the form of study, type of funding, provision of academic leave, deductions and renewals, the value n_y is almost unlimited.

Accordingly, information storage on the current composition of the student contingent is required $X = \langle x, y \rangle$, where X – is a data tuple set with personal data x and data tuples with data about study y, where $y = \{y_0, \ldots, y_{n_y}\}$.

HEI, in which the system was planned to be implemented, is the "Zaporizhzhia Polytechnic" National University. Accordingly, data tuples count that must be stored to estimate the current student composition is approximately 46 000 (to obtain this value, was assumed that count of students who have orders greater than 5 for a bachelor's degree and 3 for a master's degree is approximately equal to count of students who have not completed their studies and, accordingly, have fewer orders count).

In addition to the current student composition, in order to make a response to the statistics queries, it is necessary to store student's data for the past years (at least for the last 10 years). The undergraduate student composition is updated annually by 25% (fourth year students finish their studies, first year students come to university), master's students – by 50% (there are only 2 courses in the magistracy). Accordingly, count of student records for past years is equal $n_{old} = c_{years} \times (0.25 \times n_{xb} + 0.5 \times n_{xm})$, where c_{years} – count of years for which statistics are stored, n_{xb} – count of bachelor students, n_{xm} – count of master students.

According to these calculations for HEI "Zaporizhzhia Polytechnic" it was determined that the total count of bachelor students (current contingent and contingent of the previous 10 years) is equal to 28 000 and magistrates 12 000 ($n_x = 40000$). Data tuples count that you need to store to evaluate the status of the current student contingent and the current contingent of previous years will be equal to 200 000. Such records count requires detailed planning of the data structure and the methods for storing and processing this data.

The most important task was to create a model that will integrate the requirement of all target groups (students, dean office, admission office, training department, student personnel department, bookkeeping, curricula management department). This model was implemented in the university digital ecosystem for storage and manipulation of the information about the current status of each student. Representatives from each target group should have the possibility to obtain comprehensive information about student contingent at any date in the required context.

The process of system development has consisted of the following steps:

- carrying out the analysis of the subject area, identifying the main processes of accounting the student information, possible types of orders for changing student statuses, performing their analysis;
- development and optimization of information models of the student information management system which was allowed to create data structure and system functions for accounting automation;
- system design and program implementation for the "Zaporizhzhia Polytechnic" National University, which solves the task of accounting higher education applicant's information and integrates with USEDE, as a state-level contingent accounting system.

SWOT analysis of the developed University Student Management system is presented in Table 2. As shown by the SWOT analysis, the benefits of University Student Management system are the possibility to integrate existing data into the system, the possibility to carry out automatic verification by comparing the data from University Student Management system and USEDE, a convenient interface and the ability to store information slice for each reporting period.

TABLE II. SWOT ANALYSIS OF DEVELOPED UNIVERSITY STUDENT MANAGEMENT SYSTEM

Strengths	**Weaknesses**
– the ability to automatically download existing data to the system; – the ability to verify the data by comparing the developed system data and USEDE data; – no need for large hardware or additional software, except for the Microsoft Access 2019 office suite; – user-friendly interface; – the ability to store sections of information for each reporting period.	– the necessity for continuous support of the system (especially in case of changes in reporting forms); – long term of development; – the necessity to change sustainable processes; – the necessity for retraining of staff.
Opportunities	**Threats**
– the ability to add new functionality independently; – the possibility of developing additional modules; – the possibility of integration with various existing systems.	– staff turnover; – changes to USEDE access methods; – changes in the legislation of Ukraine.

The main threats are the changes to USEDE access methods and changes in the legislation of Ukraine (for example, changes in reporting forms). Therefore, the necessity arises for continuous support and changes sustainable processes.

Access to the developed system is organized using encrypted and reliable data protocols (for example, connection with USEDE occurs via SOAP (Simple Object Access Protocol) available only in the university web with data protection). To protect students' data, each user needs an individual couple of login and password to get access to the university digital ecosystem.

For now, the system users are employees of the education department and dean's office, who know all details about the student's education process. To reduce the threat of staff turnover a lot of checks and verification were implemented in the University Student Management system to ensure data security.

IV. CASE STUDY

Let's describe the development process of the University Student Management system in the "Zaporizhzhia Polytechnic" National University, which allows automating the work with the students' information, support the educational process, generate reports and obtain statistical information, integrate with USEDE using the API.

Development of the ecosystems consists 5 steps:

- to build a conceptual information model for entity "student", who is attached to the "study groups" and other structural units of the university;
- to create a database for storing information that will meet the requirements of the model;
- to develop an intuitive interface for entering, editing, and analyzing data by the university's department employees;
- to create interfaces and functionality to integrate with USEDE and generate different student statistical reports;
- to protect students' data to avoid data incidents, which can include inappropriate access to personal data, loss or damage to the integrity of personal data.

Within the first step, a conceptual model with main entities and attributes was created and shown in Fig. 1. Based on this conceptual model a relational database was implemented.

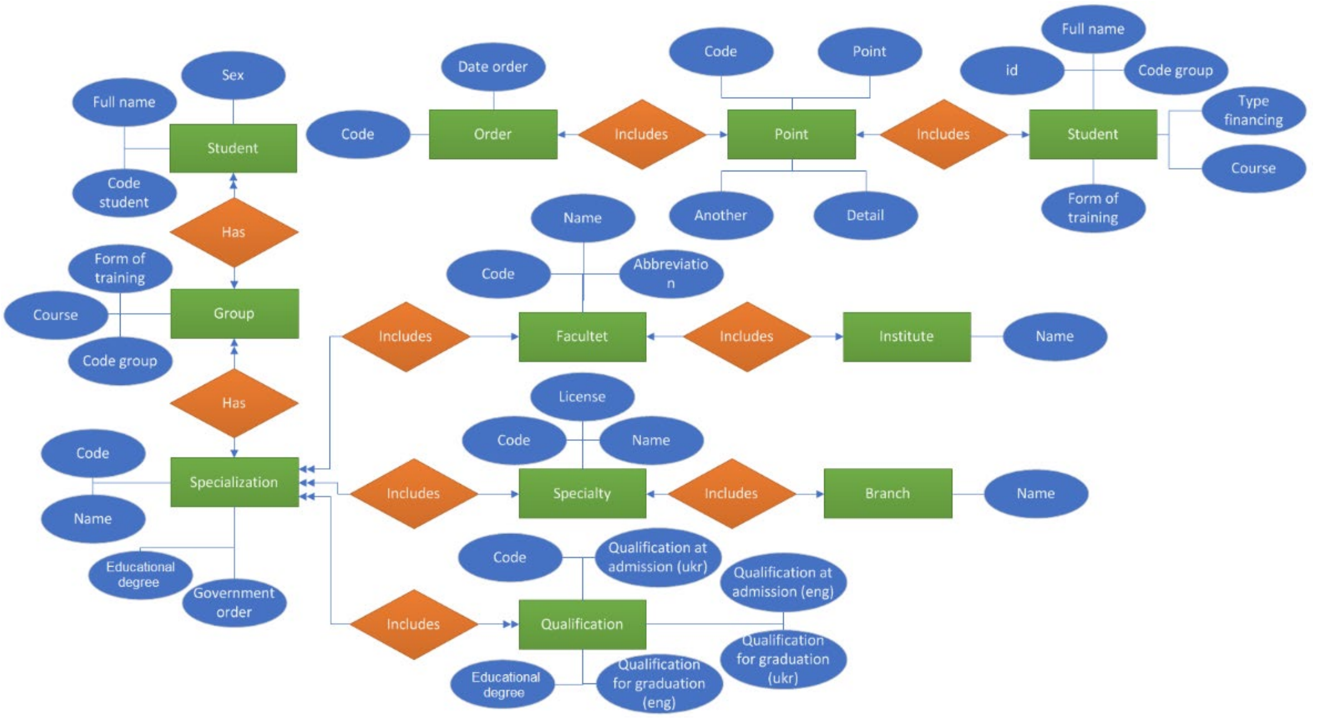

Fig. 1. The database conceptual model.

The biggest issue was the information duplication and necessity to capture all student information changes in multiple automated systems (USEDE and different university unit's application systems). In order to reduce errors, it was decided to carry out monthly data checks for data differences on the developed system and USEDE.

This requires all USEDE data to be retrieved, the only way is to get it via the USEDE API. In the second USEDE edition there is access to API methods, but the documentation for API using is usually lagging in time and does not contain all the necessary information. Thus, there is necessary to analyze the actions of the web interface with the API (Fig. 2) with the further implementation of this interaction using VBA.

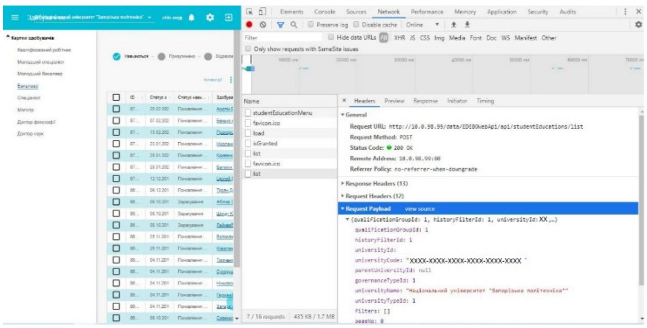
Fig. 2. Request to the USEDE API via the web interface.

Downloading data about HEI's students using this API is as follows.

```
    Dim Request As New Dictionary
    Request.Add "qualificationGroupId", 1
    Request.Add "historyFilterId", 1
    Request.Add "universityId", XX
    Request.Add "universityCode", "XXXX-XXXX-
XXXX-XXXXX-XXXX-XXXX"
    Request.Add "parentUniversityId", Null
    Request.Add "governanceTypeId", 1
    Request.Add "pageSize", 10000
    Request.Add "menuItemCode",
"ENT_NZ1_Orders"

    Json = edbo_send_api(
"http://10.0.98.99/data/EDEBOWebApi/api/student
Educations/list", Request)
```

Data obtained from USEDE is uploaded to the appropriate University Student Management system tables for further verification.

Developed University Student Management system allows users:

- to create a digital-student interface with storing all information about student and him education history;
- to create a student-oriented digital ecosystem in university (with interface for different university departments with restricted access);
- to automatize the formation of statistical reports and control of compliance with licensed volumes and volumes of state order;
- to import data from existing student information management systems;
- to conveniently process data about higher education applicants;
- to control the processing of student orders in the USEDE.

The main achievement of the implemented system is reducing the human factor in the information processing of the student information by observing and correcting the actions of the user. Also, the ability to provide data to HEIs workers within the university has emerged through the separation of data and the interface part of the system.

V. CONCLUSIONS

The developed system is a flexible source tool for the integration of a large variety of university applications, like student admission, student and study management, digital library, eLearning (via integration with the Moodle learning system). During the development process, the following principles were applied:

- information duplication minimization between university systems;
- if information for any reason is duplicated in different databases, a constant automatic data reconciliation is implemented to eliminate inconsistencies;
- data protection;
- data processing via API to separate data and interface layers;
- ranking of user's access depending on the functions performed;
- data entry control;
- permanent creation of encrypted copies of archived and current data;
- automation of the maximum number of data processing processes.

The benefits of the developed University Student Management system are the possibility to integrate existing data into the system, the possibility to carry out automatic verification by comparing the data from University Student Management system and USEDE, a convenient interface and the ability to store information slice for each reporting period. The manual and time-consuming reporting process now is almost fully automatic and takes an average of a few minutes for each type of report (instead of hours or days before). It gives error-free guarantees, which was impossible with manual reports creation. There is a plan for further developing the described system, improving its integration with USEDE, developing additional modules for other departments and deans, as well as integration with various systems to improve navigation on HEI [19], verification systems and remote learning systems [20].

As for relevance for education, the University Student Management system was developed for HEIs of Ukraine and makes the possibility to create a "digital student interface", which allows identifying any person, current state of his education (and history of changes in personal and educational information). It allows a better connection with the university, makes any student be better informed and provides feedback to the university, with a view to improving its services. Also, in the future, there is a plan to associate the developed system with education plans and to give access to this system to all students of the university, which allows them to get all information about all disciplines they should learn.

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International Interinstitutional Coordination of Vocational Education and Training of Programmers for Industry 4.0 Needs

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***Abstract*—To meet the challenges stated in the document about of Industry 4.0 [1] there is a need to also carry out various changes in the system of education, including the system of vocational education and training. One of the areas in which the changes should be considerably significant is training of future technical workers and programmers for the labour market of Industry 4.0. These changes are influenced by the development factors of world globalization and interinstitutional cooperation. Today, systems of education in the European Union countries use a lot of mobility and projects focused on international cooperation. In this global environment secondary vocational schools, industrial practice, higher education institutions and research centres are facing a necessity to establish a joint communication platform for a common exchange of information, experiences, good practices, incentives and ideas to create and manage a complex education framework for the relevant technical staff workers. In the paper the authors describe and analyse an example of such kind of international interinstitutional cooperation.**

Keywords—Industry 4.0, labour market requirements, training of qualified labour forces, vocational education and training, PLC and IoT systems

I. Introduction

Application of automation, robotic and cybernetic systems in industrial practice is becoming a key element of technological development, economic growth and countries competitiveness in a global economy. The strategic document of the Government of the Federal Republic of Germany, entitled Industry 4.0, [1] contains recommendations for focusing research activities and applications of progressive elements of information technology in industrial automation. This document contributed to starting up the imaginary fourth industrial revolution. An important impetus for its creation was actually the effort to increase the competitiveness of German and European industry in a global context - especially in comparison to technologies of Asian and US economies. The course of the German economy significantly influences also the Slovak economy. Mechanical engineering production, represented mainly by car manufacturers, has a strong presence in the Slovak industry. Successful application of content themes of the document Industry 4.0 in industrial practice thus also becomes a task of national importance for Slovakia.

The new digital economy requires an integrated approach to the educational process with new goals, structures and content [2]. To innovate education towards challenges of the digital economy and Industry 4.0 it is becoming increasingly important in the context of students achieving a higher level of development in professional competences of the twenty-first century [3] – [6]. It is the personnel with the ability to carry out professional activities in the digital space, who are important as the necessary human resources for the country's innovative economy.

To meet the challenges resulting from the document of Industry 4.0 [1] there is a need to carry out various changes also in the system of education, including the system of vocational education and training [7]. But for teachers of technical-oriented subjects the current challenges are very disruptive. One of the areas in which the changes should be considerably significant is in the training of future technical workers and programmers for the labour market of Industry 4.0. This change is influenced by the development factors of world globalization and interinstitutional cooperation [8]. Today, systems of education in the European Union countries use a lot of mobility and projects focused on international cooperation. In this international environment secondary vocational schools, industrial practice, higher education institutions and research centres are facing a necessity to establish a joint communication platform for a common exchange of information, experiences, good practices, incentives and ideas to create and manage a complex educational framework for the relevant technical staff workers. Hereinafter we present a methodology to carry out such kind of cooperation, an example of the use of the proposed cooperation in practice and an analysis of the results which have been achieved.

II. State of the Art

The term digital economy is related to new advanced digital and computing technologies and their spread into all social areas and human activities. Origin of this term has been dated in Japan, in the midst of Japan`s recession of the 1990s [9]. In general, the concept of a digital economy is defined as an economy that focuses on digital technologies and covers all business, economic, industrial, social, cultural, educational etc. activities. As its main components used to be stated e-business infrastructure (i.e. hardware, software, telecom, networks, human capital), e-business (i.e. ways in which processes are conducted over computer-mediated networks) and w-commerce (i.e. transfer of goods, mostly in online form) [10]. Nowadays, the term of digital economy is used, together with the terms web economy or internet economy) as a collective naming covering all economic transactions that occur via the internet.

Speaking about Industry 4.0, two differences should be mentioned in comparison to the phenomenon of digital economy. At first, the focus is "only" on the industrial part of the society existence and operation, and secondly this term is related specifically mainly to automation and data exchange in manufacturing technologies, including cyber-physical

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systems, internet of thing (IoT), cloud computing, cognitive computing and creating smart factories [1], [11] – [13]. Transition to Industry 4.0 is subject to manufacturing sector to become digitalized with built-in sensing devices virtually in all manufacturing components, products and equipment [14], [15]. One of the important characteristics of the 4th industrial revolution is a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres.

Digital transformation, whether it is that related to digital economy or related to Industry 4.0, leads to necessary massive changes in the skills needed for work and life. On the one hand, education and training institutions at all levels are expected to provide every citizen with the knowledge, skills and attitudes as well as the lifelong learning opportunities required for living and working in an increasingly technology-driven environment. On the other hand, teachers are forced to seek innovative solutions to replace traditional teaching materials, methods and tools to fit into the world of digital technology [16]. On the one hand, all citizens need to have 21st century digital skills and competence, and on the other hand, there is a lack of adequately prepared working forces to cover the more and more increasing demand for qualified graduates with specialized IT skills in the labour market.

Based on the results of the research study on implications of the Industry 4.0 revolution Spöttl et al. [17] created four scenarios for the provision of the technical and vocational education and training (TVET) appropriate to the Industry 4.0 conditions and its labour market needs. According to the first scenario, the phenomenon of Industry 4.0 does not need or result in significant changes in the TVET provision, at least in a short time period. This scenario supports the development of broad basic qualifications with a separation of mechanical, electronic and IT-based tasks. This scenario is accompanied with a high risk of that due to the transition to Industry 4.0 reality the profiles of the graduates will not meet even the small-scale changes. According to the second scenario the structure of the TVET provision will remain unchanged, but the content of the TVET will have to be adjusted to the requirements posed by the Industry4.0 (stronger process orientation, skills in handling of networked equipment, ICT skills and stronger attention to skills for handling CPS). The third scenario expects a combination of existing occupations and qualifications, e.g. mechatronics can become a rather broad occupation strongly related to other occupations. This requires to shift the curriculum design and provision of TVET to the work process-based approach. Similar trends can be expected in ICT sector occupations. This means that according to this scenario occupational profiles and qualifications will be more extensive and complex what will result in overloading the training and reducing possibilities to provide in-depth training for the development of particular competencies and skills. Finally, the fourth scenario is based on the precondition that there will be a significant development of separate highly specialised qualifications oriented to the requirements and needs of Industry4.0. This precondition implies a very important role for the initial TVET and higher education in the supply of these qualifications and presumes reduced possibilities to provide such qualifications in the continuing TVET.

To contribute to solving the educational challenges we are facing in the context of the mentioned transition either to the digital economy or industry 4.0, in 2016 UNESCO has prepared for its member states a strategy for technical and vocational education and training (TVET) for the period 2016 – 2021 [18]. The year 2021 is the final year of the implementation period for which the strategy was prepared. In this year an evaluation of the achieved results should be conducted. Within the evaluation also the Recommendation concerning TVET [19] should be taken into account.

Following the strategy for technical and vocational education and training, the member states of UNESCO should be able to enhance the relevance of their TVET systems and equip the youth with the skills required for employment, decent work, entrepreneurship and lifelong learning. Additionally to that they should be able also to contribute to the implementation of the 2030 Agenda for Sustainable Development as a whole [20]. Within the strategy the main attention is paid to three areas, which are fostering youth employment and entrepreneurship, promoting equity and gender equality and facilitating the transition to green economies and sustainable societies. In our opinion two of the most important items of the strategy are the call for creating effective institutions and partnerships between agents and institutions involved in TVET at different, e.g. national and local, levels, and the call for designing effective strategies regarding the use of skills to achieve the expected development outcomes in the priority areas. The international interinstitutional coordination of vocational education and training of programmers for Industry 4.0 proposed by us presented hereinafter complies to both of these strategies. Moreover, the proposed cooperation of the involved different kinds of partners reflects in some aspects also the model of combined academic and vocational education used by some Chinese universities.

Chinese higher vocational education driven by the support of neoliberal ideology has undergone a restructuring in different aspects. These aspects have been related mainly to human resources supply, higher education system expansion and skill-centred knowledge emphasising towards more high-level skilled manpower rather than to academic knowledge [21]. Development of higher vocational education in China embodies a global trend of vocationalism that values skills and skilled workers, which is opposite, in some ways, to the Confucian tradition in Chinese education that values theoretical knowledge related to good governance [22].

Two years ago, in 2019, there was announced the Implementation plan on National Vocational Education Reform in China [23], through which China is seeking to reform its entire vocational education framework, including occupational standards, assessment and evaluation mechanisms, teacher training and recruitment, and industry engagement. A very dominant intention of the reform is to better equip the labour force to meet the demands of the economy now and into the future. As to its structure the reform contains 7 priority objectives, three of which can be perceived as the coincidence with the structure of the model of by us proposed international interinstitutional cooperation, and these are to promote the integration of vocational schools with industry, to establish a vocational education system that is supported by various bodies and to improve policies to safeguard the benefits of skilled professionals (the other four priorities are to improve the National Vocational Education System, to establish national standards for vocational education, to strengthen the quality supervision and evaluation of vocational education and effectively to implement the reform).

III. Methodological Aspects of the Proposed Cooperation

The educational process at secondary vocational schools in Slovakia can be concluded either by obtaining the certificate of apprenticeship or by passing the state school leaving examination that is divided into theoretical and practical parts. Besides the traditional form, the practical part can be carried out via participation in a long-term project (1-2 years) that must be confirmed by a special educational-vocational committee. Students participate in such projects under the guidance of their teachers and vocational tutors and during the final examination they introduce the outcomes of their scientific and technological work. They describe the whole set of procedures that have led to the achievement plus they explain the technological and organizational aspects of their work. This is followed by a discussion where the student is interrogated by the committee members. The practical part of the state school examine that is done in this way undoubtedly has many positive results. One such practical advantage is the students´ adequate preparation for solving the real problems in their future work experience regarding e.g. project management, setting the work time schedule, dealing with critical situations, communication with specialists, searching for suitable information sources, implementation of theoretical knowledge in real practice and also the presentation of outcomes in front of vocational committee. Simply put, the student experiences situations that imitate the real vocational environment. Besides the mentioned advantages, there is also one important handicap of this approach. It is the financial and material burden of this type of examination. In many cases, the project activity requires materials and devices that a school cannot provide or cannot afford. One possible solution is that students use their own financial sources, but this alternative is extremely rare.

Our model of project cooperation was based on the inter-institutional mutual connection of a secondary vocational school, academic research environment and partners from industrial practice (Fig. 1). The secondary vocational school offered the space needed for execution of the state school final exam and hosted the event both organizationally and institutionally. It also chose the students that would be able to deal with these quite complicated technological tasks. Partners from industry (private sector) guaranteed all material and financial expenses within the project under the condition - that students would participate in research and application tasks from industrial practice in which that partner is directly interested. Academic institutes who have a long-time tradition of cooperating with private partners in the framework of research and solutions for industrial automation decided to guarantee the vocational guidance, training and support of students. The content of all project assignments was discussed within the mentioned tripartite structure. The private partner drafted the content frame of projects, academic workers and secondary school teachers defined exact assignments of particular tasks and guided the technical aspect. In the process of topic selection there was also taking into account the interests of students themselves.

Fig. 1 shows a scheme of the described model of the proposed cooperation. All three participating partners are connected with green arrows. They represent the created communication channels that were deployed in the process of defining the content of project tasks and consequently during

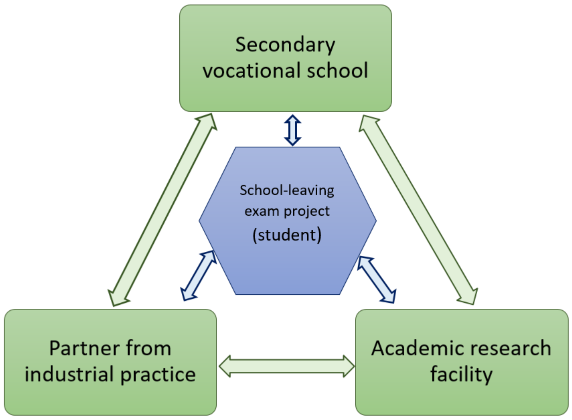

Fig. 1. Model of the proposed international interinstitutional cooperation.

the discussions regarding organizational, teaching and technical issues.

Bidirectional green arrows also emphasize mutual influence of particular institutions. Secondary school provided the possibility to get to know and prepare the future students or workers for a university or industrial partner. On the other hand, it gained material provision, vocational advisory and feedback on its educational activities regarding real needs of industrial practice. The university gained material provision for its research activities plus the possibility of participating in real industrial projects. During whole project the academic workers had a chance to better get to know and select their potential future students.

Blue arrows show the relation of particular institutions towards the school final exam tasks. Influence of particular institutions seems to be more than obvious. It is really interesting to see how all participating partners were enriched by this cooperation. The secondary school raised its prestige thanks to the interesting and financially attractive project tasks and as a bonus the increased interest in study at this school. University unburdened its research capacities because some partial tasks were delegated to students. Industrial partner widened its platform for the solutions in the field of implementation and research. Attraction and advantages for all participating sides are an important factor for sustainable existence of this type of cooperation.

IV. Results and Their Disscussion

Project tasks in the frame of the practical part of the school final exams were executed by students of the Secondary Polytechnic School in Zlaté Moravce (Slovakia). EATON Slovakia s.r.o. represented the private sector as a partner from industrial practice. The Department of Technology and Information Technologies at Constantine the Philosopher University in Nitra (Slovakia) participated as an academic research centre. To show the overall level of expertise, technical execution and the content of particular tasks, we now briefly describe one of them. It was called Interoperability of PLC and IoT Systems.

A. PLC systems

PLC (Programmable Logic Controller) systems serve to control technological processes in the field of automation. It is a set of electronic computer controlling units that evaluate in real time the state of regulated system via sensors of physical parameters. Based on the required entry parameters and the logic of central controlling program they evaluate obtained parameters and send commands to the action members which influence behaviour of regulated system. PLC systems are the dominant and most frequently used controlling units in contemporary industrial automation and robotics.

B. *IoT systems*

IoT (Internet of Things) systems serve as electronic controlling systems with a function of remote control via computer net (the Internet). In contrast to PLC systems, they are primarily used for control of everyday things/devices (TV set, washing machine, door locks, windows etc.). The term Smart is an integrated part of IoT systems. Things and devices with IoT systems are really becoming smart. Nowadays we can see smart technologies in TV sets, wristwatches, cars, households, but also in whole cities and so on. IoT systems have a huge potential to shift the automation from the industrial environment into the world of common ordinary people.

C. *Interoperability of the systems*

This term refers to the ability to communicate and share data between different information and controlling systems. Interoperability works at two application levels. The first one is the hardware compatibility of devices made by different producers. The second level is the software compatibility for sharing data between different types of systems (e.g. PLC and IoT). Nowadays, the importance of interoperability is underlined by a fact that it has become one of the fundamental requirements in a document called Industry 4.0.

D. *Project assignment for the school leaving examination*

The aim of a project work was to verify the communication frame for PLC/HMI systems by EATON company with IoT systems at hardware platform called Arduino, PC system Windows and mobile devices Android. The communication frame is based on the programmable library of functions that can be used in PLC systems, IoT, PC-Windows and Mobile-Android. This library enables mutual communication between applications and also sharing data of devices galore. The library was created in the frame of research activities of EATON and KTIT UKF in Nitra. This project represented an ideal environment for testing this library by an independent third side (students of secondary vocational school from Zlaté Moravce). These independent views, opinions and inspirations regarding the implementation of our application in real practice were very important for us. To be frank, they were not expected in the beginning, still they are a surprising and pleasant benefit that arose from our cooperation.

Secondary school leaver was asked to create a model of Smart building (Fig. 2) that would have electronic door locks, fire and other dangerous gases sensors. The door locks should be opened or closed via RFID card. The mentioned sensors, door locks, RFID card scanners and fire signalization were supplied with IoT elements. The whole system was centrally controlled via PLC/HMI system by EATON. HMI EATON panel, Android mobile device or PC stored the data regarding history of open/closed doors, activity of sensors and signalization, database of available RFID cards and their accessibility to particular doors.

Students had to design and create a model of building based on PLC/IoT hardware platform. They also had to create communication applications for particular systems that shared data through the created communication library. Finally, they had to evaluate their experience with the deployment of created programmable library. The primary goal was not to create a complicated Smart building with large number of door locks, sensors and signaling systems. We concentrated especially on the wide application platform in the field of deploying the communication library.

Fig. 2. Student (in the front) working on the school final exam tasks under vocational guidance of an academical employee (behind).

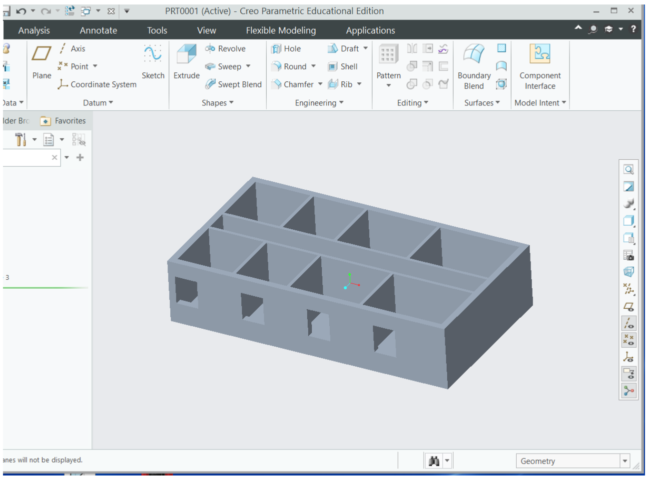

Fig. 3. Design of the model of the Smart Building model for 3D printer.

Fig. 4. Programming application for PLC/HMI Eaton XV1xx.

In total in the pilot run of the proposed cooperation 4 students were involved to elaborate their project tasks. The students defended the projects in front of the graduation examination commission, which evaluated the achieved results as excellent.

However, benefits resulting from the proposed cooperation are not exclusively on the side of the secondary vocational school and its students. In general, the benefits have been mutual. Beneficial for the secondary vocational school and its students has been the opportunity given to the students to try out a job in their field already during their studies and to experience the real connection of the acquired theory with practise. This finally results in improvement of professionalism and training of future experts for automation and programming of PLC systems. The benefit for the involved higher education institution has been the opportunity given to its academic community (university staff) to connect more effectively its teaching and research activities with now-a-days industrial practice needs (due to a lot off stimuli and ideas resulted from the activities on the project task solving). Additionally to that, another benefit for the higher education institution was the possibility of free access to different kinds of technical manuals and facilities offered by the partner from the industrial practice to ensure adequate conditions for the solved project tasks (offered to the HEI, in premises of which to these facilities also the secondary students had enabled access).

The benefit for the industry partner was clearly obvious. As the project tasks were based on the issue which this partner (in our case the multinational company Eaton Corporation Inc.) needed to solve to meet its business partners requirements, prompt outputs of the solved projects have contributed to a higher status of the company among the company`s customers and business partners, to its higher reputation on the market, and at last but not the least they have had impact also on the economic results of the company (in terms of the financial impact of the solved project output research results on the economy of the company, financial contribution of the project results is undoubtedly much higher than the costs allocated by the company for the technical support of the carried out presented cooperation).

V. Conclusion

An important indicator on the reflection of tuning educational processes more towards the requirements of industrial practice is the reintroduction in Slovakia of the system of dual vocational education and training at secondary vocational schools [24], [25]. The system of dual vocational education and training is a combination of knowledge with skills and practical knowledge [26] giving students an opportunity to try out a job in their field during school. The proposed model of the (international) interinstitutional cooperation should not been considered as a substitution to the system of dual vocational education and training. However, it can serve besides it as a supporting element of an appropriate preparation of qualified labour forces for the labour market for Industry 4.0 conditions. The primary benefit of the proposed cooperation between the three stakeholders is the possibility given to the secondary school students to experience contacts with the professional practice for which they are trained. This can be perceived as the first contact of the students with their potential employer during which they have a chance to participate in professional internships for several weeks so that they can understand the complexity, content and tasks of their future occupation. A not to be neglected benefit is the motivation aspect of the carried-out cooperation, from which, on the other hand the higher education institution can profit. Under the motivation aspect we mean an increased interest of the secondary students to continue in their further studies in the relevant study programs offered in the higher education institution. In this context the presented model of the interinstitutional cooperation may be perceived as a very efficient tool to recruit secondary students, or even to recruit the best of the secondary students to apply for study at the concerned higher education institution.

Acknowledgment

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Opportunities and Limits in Designing an Individual Hybrid Process Model for Project Management

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***Abstract*—Project consultants and project managers are still facing the challenge that there is no mechanism that helps to design a specific, individual process model. With a lot of experience, a feeling for the needs of an organization and a good overview of the different agile, traditional or hybrid models, there is a chance that an effective process model for project management can be developed. But how can less experienced project managers be supported? Supporting models are oriented towards industrial organizations. This paper shows what to look for when using these models in Smart City projects. Furthermore, a semi-automatic and adaptive reference model for the construction of a hybrid project management procedure model is presented which is based on the so-called SIMOC method. An evaluation will show what the benefits are already today and what the next steps will be to continuously improve the recommendations the model provides.**

***Keywords*—Hybrid project management, SIMOC, SIPOC, process model, method**

I. Introduction

There are handbooks and case descriptions for the implementation of Smart City projects, but they do not provide a standard for the related project management. [1] identified the project context as a major influence factor on the selection of project practices (methods) and the resulting success of Smart City projects. Therefore, it is a great advantage to know how to identify a suitable process model and/or to know how an individual process model consisting of individually selected methods can be designed for a specific context. Such a process model is called "individual" because it is designed for an equally individual project context, which may be different in different organizations, but may also vary from project to project within an organization. In section III-A and in section IV-B parameters for determining the context are presented. The challenge of designing an individual process model for project management can be approached on three different levels of detail. The parameters to consider on each level are discussed in this paper. The algorithm that is used in the semi-automatic and adaptive reference model for the design of a hybrid project management procedure as well as the SIMOC method it is based on, are presented in this paper as well.

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In addition, the preconditions for applying these parameters in Smart City projects are described and discussed at the end of the article.

II. Research Design

The factors to be considered in the selection or design of a process model are called "parameters" in the recent literature. An already started keyword search was aborted because it became apparent that different terms were used for these "parameters" in the past. Therefore valuable sources were overlooked in a keyword search. For this reason, a reverse search was performed based on the available literature [2].

The development of the SIMOC method and its partial automation [3] followed the "Process for the determination of influence variables in the development of an adaptive reference model" [4]. It represents a project management related extension of the process for the development of reference models according to [5]. For the incremental development of SIMOC and the associated IT artifact (the semi-automatic and adaptive reference model), the guidelines for good design science research according to [6] are followed. One of these guidelines states that partial and final results must be evaluated. Therefore the first results of the evaluation are discussed in this paper.

III. Context-based selection or designing of a project management procedure model on three different levels of detail

A. Choosing a suitable project philosophy

The least specific recommendation for the selection of a suitable process model is offered by the parameters identified during the literature search described in chapter II. A recommendation shows a tendency on whether a project is more traditional or agile. These parameters are listed in table I. Each parameter is assigned an agile and a traditional alignment. The sources are ordered chronologically from left to right. This shows which parameters have been added over the years. To be able to understand the topical focus of the individual researchers, the parameters are categorized in the first column.

The table can be used to weigh up for each parameter whether the agile or more traditional expression applies. This is a qualitative consideration, because no absolute values are

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TABLE I
PARAMETERS FOR THE SELECTION OF A PROJECT PHILOSOPHY

Category	Parameter	Agile	Traditional	Shenhar et al. 1996 [7]	Boehm et al. 2003 [8]	Leffingwell 2011 [9]	Habermann 2013 [10]	Spundak 2014 [11]	Wysocky 2014 [12]	Stacey et al. 2016 [13]	Brehm et al. 2017 [14]	Paukner et al. 2018 [2]
Requirements	Novelty of the requirements	New	Old	x				x				
Requirements	Awareness and availability of all requirements (scope) at the beginning of the project	No	Yes	x		x	x	x		x		
Requirements	Dynamics, number of changes (also priorities)	Low	High		x		x	x			x	x
Requirements	Sum of requirements over total project duration	Volatile	Fixed				x					
Budget	Budget	Fixed	Open			x						
Duration	Project duration	Fixed	Open			x						
Customer	Customer, user, end user (availability)	Good	Bad				x	x				
Customer	Delivery of project results (customer expectations)	Early incrementally	Late fully				x					
Management	Openness for agile processes in organization	High	Low					x				
Management	Handling of requirements changes after project start	Normal thing, regularly	Disruption				x					
Team	Degree of qualification	High	Low		x						x	x
Team	Culture, Degree of freedom (employées)	High	Low		x						x	x
Team	Team distribution	Central	Decentral					x			x	x
Team	Interaction of Business- and IT-Experts (e.g. developers)	Intense	Low				x					
Team	Dedication (Projects per team member)	1	>1								x	
Team/Product	System criticality/ risk potential	Low	High		x			x			x	x
Product	Complexity (Product and its development)	High	Low	x			x					x
Product	Solution (Technical and methodological)	Not clear	Clear	x			x		x	x		
Product	Length of product life cycle	Short	Long								x	
Product/Project	Target	Not clear	Clear						x			
Project	Project size	Small	Big		x			x			x	x
Project	Documentation	Implicit knowledge	Formal					x				

available for the agile and the traditional expression. At the end the number of parameters per philosophy is compared. The philosophy with the most denominations is considered the preferred one for the project.
The main advantage of this rough decision is that the method is very easy to apply and a tendency for a suitable project philosophy can be identified quickly.
The disadvantage is the vagueness of the method. For example, there is no absolute minimum number of parameters defined, which must be agile or traditional in order to get a clear recommendation for one of the two philosophies. Likewise, the question can not be answered clearly, at how many characteristics a hybrid process model (combining for example agile and traditional methods) should be used. Furthermore, this procedure does not include the weighting of parameters. A further disadvantage is that even if there is a clear tendency towards an agile, traditional or hybrid process model, no definite process model is recommended.

B. Choosing a specific process model

Since a tendency regarding a suitable project management philosophy might not be precise enough for some users, the choice of a specific process model can be aimed for from the beginning on. In a research for frameworks for the development of Smart Cities, models can indeed be found, but these offer no or only superficial information on the use of project management. With the ”Smart Environment Metamodel (SEM)” framework [15], for example, there is a proposal for modeling smart cities from the functional and the data view. The SMELTS framework [16] is used to describe the main pillars on which a Smart City project is based. SMELTS stands for ”social, management, economy, legal, technology and sustainability”. However, no methodological guidance is given for project management. In general, the term ”management” must be read carefully, because it could also mean the operational management of an existing Smart City and not the project management for the related development project. When project management is in the foreground, which rarely happens in the literature, it is considered at a very high altitude [1], [17].
Since neither researchers nor international standards do provide any references to project management in Smart City projects, no process model can be selected. Therefore, the only approach that remains is to select individual methods that fit the project context.

C. Selecting and combining methods with SIMOC

Methods are understood as the building blocks that make up a process model [3]. [18] shows that process models that seem to be the same at first glance can nevertheless consist of an individual selection of methods. In the end, this results in individual process models. Tab. II illustrates this for a number of process models that were listed in [18] as a Scrum-Kanban hybrid. Only a small number of methods are shown as examples. But one can already see that the process models consist of different and varying numbers of methods.

Suitable methods for a project can be selected based on an expert opinion or - if no expert is available - based on the given project context.
With a selection of methods - unlike the selection of a project philosophy - it is initially irrelevant whether agile or traditional methods are chosen. Methods are simply chosen which the present project can best be initialized, planned, controlled, managed and completed with. The method modules are then combined to form an individual process model. This is called a hybrid process model because the combined methods can originally be taken from several different process models. Two key questions are in the foreground: How can suitable methods be selected and how can it be checked whether they can be combined to an applicable process model at all?

The SIMOC method has been elaborated to answer these questions. SIMOC is a modification of the SIPOC model. SIPOC stands for supplier, input, process, output, customer. It is originally a Six Sigma tool used to describe a process and all its inputs (with related suppliers) as well as its outputs (with related customers) [3]. The “M” in SIMOC stands for

TABLE II
METHODS CHOSEN IN SEEMINGLY SIMILAR PROCESS MODELS (EXCERPT)

	Process models							
Methods (excerpt)	Kanban/Scrum 1	Kanban/Scrum 2	Kanban/Scrum 3	Kanban/Scrum 4	Kanban/Scrum 5	Kanban/Scrum 6	Kanban/Scrum 7	Kanban/Scrum 8
Limit work in progress						x	x	x
Manage flow	x			x		x	x	
Kanban board		x	x	x	x	x	x	x
Task prioritization	x	x	x		x	x	x	x
Visualize dev. process		x	x		x	x		x
Estimate story points		x				x	x	
Estimate hourly effort			x		x		x	
Retrospective		x	x	x	x	x	x	x
Scrum Board	x	x	x		x	x	x	x
Daily Scrum	x	x		x	x	x	x	x
Sprint Review	x	x	x	x		x	x	x
Self-organized team		x	x		x	x	x	x
Burndown /-up Chart	x	x				x	x	x
Backlog refinement	x	x			x		x	x
Velocity		x		x		x	x	x
Impediments	x	x					x	x
Number of methods	15	20	14	15	14	23	27	26

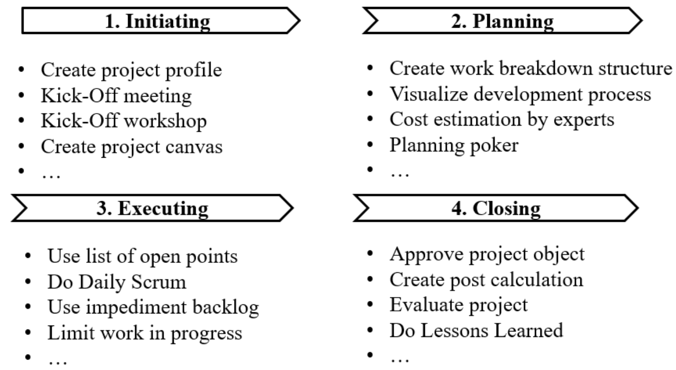

Fig. 1. Examples for methods in phases.

”method”, because the processes used in SIMOC represent a project management method each. It includes a compatibility check of methods based on their inputs and outputs that comprises the following steps [3]:

i. As preliminary work, potentially applicable methods must be collected for each project phase. If you often face the challenge of defining a suitable process model, it can be worthwhile to create and reuse a method catalogue.

ii. The first step is to rank the methods in each phase. A ranking criterion could be the effort for their application compared to the benefit in the individual context. If the team members already have experience from previous projects, they can also be involved in the ranking of the methods and contribute individual criteria.

iii. A process model (Fig. 2) is then created for each method, in which the inputs and outputs for each process step are shown. Inputs can be documents, data or other information. A supplier is defined as a method in which inputs are generated for the currently considered method. Similarly, customers are defined as methods that take the output from the currently considered method as an input and process it further. In this case, the processes are represented as BPMN 2.0 models.

iv. The next step is to create a network of effects (Fig. 3) with the highest ranked models based on single or multiple connections of inputs and ouputs. If the output of one method is used as input by another method, the two methods are connected with an arrow. A method can have none, one or more inputs or outputs. This can be done on a whiteboard by printing out the models, attaching them and connecting them with drawn lines. If you have higher expectations in terms of design, you can also visualize the network of effects with an appropriate software.

v. In the last step, the resulting network of effects is analyzed. The approach to the analysis depends on how many connections were created in the network of effects. For example: As there are no output connection from method E to any other method in Fig. 3, the question is if the outputs of this method are relevant for the project at all. The same

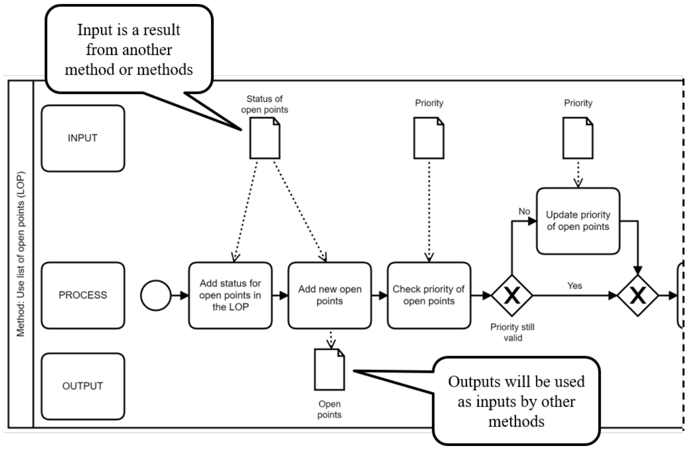

Fig. 2. BPMN 2.0 model of a method (extract).

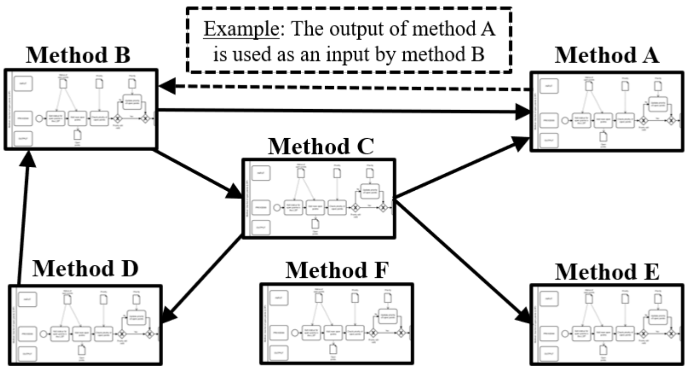

Fig. 3. Network of highest ranked methods.

question should be asked for method F, which does not have any input or output connection with the net at all.

If all methods have at least one connection to another method, they are assumed as useful, because at least one input or output per method is processed.
If two separate networks are created that have no connection to each other, some methods with less connections can be replaced by lower-ranked methods to create additional connections. Another measure is to add additional methods (ranked lower) which form a continuous network, as they close gaps with their connections.
Alternatively, a method that does not have a connection with the network but is useful for the project can also be declared as "always applicable". It must be added that it is best to declare these methods already during the preliminary work. Then there is no temptation to declare all methods that do not fit the network as always applicable. This is because there is a risk that methods are included in the process model that could be an obstacle to achieving the project goals.

The SIMOC method follows a structured process, which nevertheless leaves room for individual measures, which is a great advantage. In addition, the individual decisions leading to a process model are well documentable, because they can be related to individual methods and specific versions of the impact network.
The high effort involved in both preparation and designing is a major drawback. In addition, high competence in project management is required to be able to take the individual steps.

IV. Partial automation based on Simoc idea

A. *Concept of pre-selection and aggregation by dynamic terms*

High effort and equally high professional demands for the construction of an individual process model generally represent a challenge in the project world. For these reasons, in one work package of the project "Prague" (German acronym for "project management method and tool") it is being explored how the construction of a process model can be automated or partially automated. The developed construction technique is based on SIMOC and includes a pre-selection of methods as well as the so-called "element aggregation by dynamic terms".

B. *Parameters to describe the context*

In order to determine the project context, the emphasis was placed - in accordance with the project philosophy - on the specification of parameters. Depending on the project context, methods should be classified as suitable or unsuitable. However, the parameters described in Tab. I have not been used on the method level so far. In [18], therefore, method-oriented parameters were determined in a multistage procedure based on the Grounded Theory. The long list of 68 parameters cannot yet be reduced, since no correlations have been identified that would justify a combination or deletion of parameters so far.
The first 20 parameters interrogate the actual state in companies. They partly overlap with the parameters in Tab. I. Their characteristics can be determined both on a positive and a negative three-level scale (Fig. 4)). The remaining 48 parameters relate to goals or problems that might be relevant in the user´s organisation. Their values can be assessed on a three-level but one-sided scale (also Fig. 4). The evaluation of all parameters is based on a qualitative assessment. The value represents the relevance of the parameter for the respective project or company.

C. *Pre-selection of methods by ranking methods*

The methods that are supposed to be available for selection had to be defined first. Since the number of available methods is unmanageable, the prototype should initially be limited to methods that are most relevant in practice. Therefore according to [18] and [19], 186 methods of the process models Scrum, Kanban, the process-oriented approach of the Project Management Institute [20] and the competence-oriented approach of the German Association for Project Management [21] were considered.
In contrast to SIMOC, the methods were not assigned to project phases but to project management processes, which are defined by the HyProMM framework [19]. Thus methods of all essential project management processes are automatically

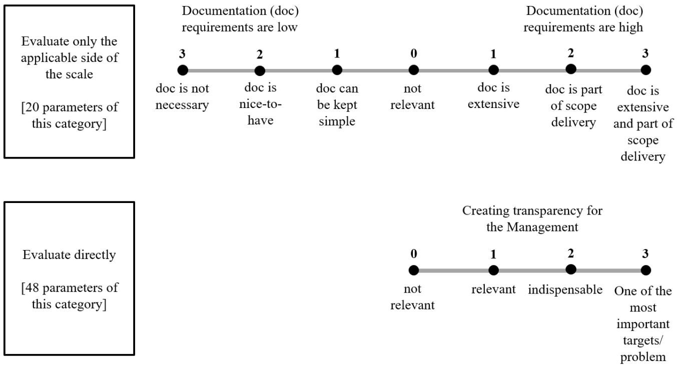

Fig. 4. Determination of the expression of parameters.

pre-selected and no process is forgotten. For preselection a point system is used, which is based on utility value analyses (Tab. III). For each relevance of a parameter (0-3), there is an estimation of how much the value implies the use of a method (0-10, with 10 as a very high implication). It is important to understand that Tab. III only shows relevance 1 and 3 and the weights for the parameters (highlighted with grey background in Tab. III) as an example. The original table includes weights for each relevance (0-3) of a parameter and only one relevance per parameter can be chosen (Fig. 4). The ranking of the methods within each HyProMM process is calculated as follows (Tab. III):

Ranking(Method1) =
[Rel(ParameterA) * weight(Method1)] +
[Rel(Parameter B) * weight(Method1)]

Example:
Ranking(Method ”Create project profile”) =
(1 * 10) + (3 * 3) = 19

D. Inputs and outputs as static part of the terms

One step missing in SIMOC is the ranking of HyProMM processes. This step is necessary to ensure that methods of highly ranked processes are considered first in the further course of the algorithm. This so-called process ranking is calculated by first summing up all weights belonging to the applicable relevance of a parameter and then dividing the sum by the number of methods in the respective HyProMM process which are just called ”process” in Tab. IV, in Tab. V and in the further course of this article. Analogous to SIMOC, in the next step the inputs and outputs of the highest ranked methods are compared. In order to automate this, all possible data and documents representing inputs and outputs are presented in tabular form. Tab. IV shows how these inputs (I), outputs (O) or both (B) are assigned to the methods they are a part of.

E. Element aggregation by dynamic terms

Subsequently, the method with the highest method and process ranking is ”qualified” (Both rankings = 1). That means the variable ”q” that is assigned to the method with rankings ”1” is set to q:true. This is visualized by setting an ”x” in Tab. IV in the line of Method 3 (M3). M3 forms the starting point for the first aggregation. The variable ”si” is also set to si:true. It stands for ”start initiated” and shows that the aggregation has already been started once with this method and should not start with it again.

During the first aggregation the qualified method is compared to all other methods ranked 1 regarding differences in inputs or outputs. This means that if another highly ranked method has an I or a B, where the already qualified initial method has an O or B, the method can be qualified, like M9 in Tab. IV. If this action were represented in an effect network as in SIMOC, any contrast in inputs and outputs between two methods would create a connector between these methods. This expresses that what is generated as output in one method is processed as input in the other method.

The comparison of Inputs and Outputs of methods ranked 1 is being processed for all data and documents available in the chosen method. For example in Tab. IV the comparison starts with D1 of method 3 (M3). D2 and D3 are checked for content by the algorithm, but as they are empty for M3 no comparison is being started. For D4 a comparison is started but no O or B are found in other methods ranked 1 as a connection for the I of method 3.

The next comparison loop that includes all documents and data (D1-4) starts with methods that have a process ranking 2 and again method ranking 1. In Tab. IV this second ”loop” starts with M9 and checks, if there are methods ranked 1 that match M9. In fact M8 can be qualified with the Input in column D2.

As soon as the second ”loop” is finished the algorithm checks for methods with process ranking 3 and again method ranking 1 to start the next comparison loop that includes D1 to D4 and all methods ranked 1 again. As there aren´t matching Inputs or Outputs in Tab. IV the algorithm checks for methods with process ranking 4 and again method ranking 1. To sum it up, the process ranking counter is incremented by 1 after each ”Loop” until the highest Process ranking available is reached.

If at the end of an aggregation there are still processes left without qualified methods (like I.2 processes in Tab. IV) the h variable is set true for all methods withing that process.

Tab. V shows the second step of the aggregation, which is used to check if methods with a method ranking 2 and an h:true can be qualified for the process model. The process ranking counter is incremented from 1 to 4 like in the first step of the aggregation, but only for methods with h:true. Another thing which is different in the second aggregation is that methods are compared with methods of ranking 1 and 2, but only with qualified methods. So M4 in Tab. V can be qualified during the second aggregation. Du to the qualification of M4 ”h” will be set h:false for M4 and M5 (so the ”x” in the h column of M4 and M5 will be deleted), which is not

TABLE III
RANKING METHODS

HyProMM Process No.	HyProMM Process Name	Method	Rang	Ranking = Rel*Weight	Parameter A Relevance (Rel) is 1	Parameter B Relevance (Rel) is 3
I.1	Start project	Create project profile	1	19	10	3
I.1	Start project	Projektstart-Workshop durchführen	3	10	4	2
I.1	Start project	Teambuilding fördern	2	9	6	1
I.1	Start project	Rollen genau definieren und abgrenzen	4	2	2	0
I.2	Define rough target	Zielarten definieren (Magisches Dreieck)	2	22	1	7
I.2	Define rough target	Machbarkeitsstudie durchführen	1	26	2	8
I.3	Identify customer requirements	Anforderungen sammeln	2	20	5	5
I.3	Kundenanf. ermitteln	Lastenheft erstellen	3	18	3	5
I.3	Kundenanf. ermitteln	Initiales Product Backlog erstellen	4	8	2	2
I.3	Kundenanf. ermitteln	Lastenheft aus Product Backlog erstellen	1	30	6	8
I.3	Kundenanf. ermitteln	Persona(s) definieren	3	18	3	5

TABLE IV
ELEMENT AGGREGATION BY DYNAMIC TERMS (PART 1)

Process	Method	process ranking	method ranking	D1	D2	D3	D4	q	si	h	zv
I.1	M1	1	2		I	O					
I.1	M2	1	3	I	I	O					
I.1	M3	1	1	O			I	x	x		
I.2	M4	3	2				O			x	M1
I.2	M5	3	1			I				x	
P.1	M6	4	2			O					
P.1	M7	4	3	O							
P.1	M8	4	1		I	I		x			
P.2	M9	2	1	I	O		I	x	x		
P.2	M10	2	2		I	O					

TABLE V
ELEMENT AGGREGATION BY DYNAMIC TERMS (PART 2)

Process	Method	process ranking	method ranking	D1	D2	D3	D4	q	si	h	zv
I.1	M1	1	2		I	O		x			
I.1	M2	1	3	I	I	O					
I.1	M3	1	1	O			I	x	x		
I.2	M4	3	2				O			x	M1
I.2	M5	3	1			I				x	
P.1	M6	4	2			O					
P.1	M7	4	3	O							
P.1	M8	4	1		I	I		x			
P.2	M9	2	1	I	O		I	x	x		
P.2	M10	2	2		I	O					

visualized in Tab. V.

In the algorithm there is also a third aggregation considered, but it isn´t necessary in the example in Tab. V, because at least one method per process could already be qualified.
If after the third aggregation there are still processes with h:true a suitable method must be searched manually. First the algorithm checks for methods with h:true, that could be qualified for the process model because of their Inputs and Outputs. Then users can answer questions on specific questions to decide whether they really want to qualify these methods for the process model or not.

In the very last step the algorithm recognizes that variable ”zv” contains ”M1”. This means that in the last step M1 should be qualified, because it creates Output that is an inevitable input for M4.

This mechanism (algorithm plus manual steps) is called ”aggregation by dynamic terms”, because the variables ”process ranking”, ”method ranking”, ”q”, ”si”, an ”h” are recalculated for each example and they can be connected as a coherent term, that could be annotated to methods in process model software. Terms have the same structure for each method and can easily be simulated in Excel by using columns.

Inputs and outputs as well as ”zv” form the static part of the term, because they are defined once and are not changed anymore. It must still be mentioned that some examples contain methods that are considered to be always qualifiable. They include - if present - another static variable ”iq”. Methods with iq:true are qualified by default at the beginning of each aggregation, provided they match the relevant ranking.

V. DISCUSSION

A. *Applicability of parameters*

The applicability of the parameters of all the above mentioned approaches to Smart City projects is assessed positively as long as the following factors are being considered.

- Smart City projects may include several projects. They all pursue the same overall goals. However, the parameters can still vary depending on the project object and project type. It may therefore be necessary to evaluate all projects belonging to the Smart City Initiative individually.

- Some parameters may not be relevant, e.g. the length of the product lifecycle as developing Smart Cities is more of an evolutionary process consisting of a sequence of projects. It is recommended to mark the non-relevant parameters and not to consider them in the evaluation.
- Furthermore, Smart City initiatives are new in many cities. So is the associated project work. Some parameters may therefore not be able to be evaluated before the project starts, e.g. the openness of the management to agile processes, the scope that comes with changes after project start and the sum of requirements over the project duration. For these parameters it should be discussed what effects both orientations would have on the process model and the project before a decision is made.

A comprehensive evaluation of the algorithm was carried out as part of a qualitative study. Project management experts have set the 68 parameters for one of their projects. Then they assessed the benefit of the automatically generated process model. Fig. 5 shows first results for evaluation projects A to O.

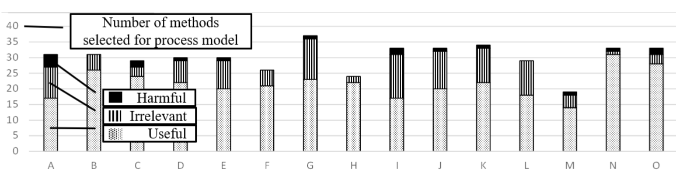

Fig. 5. First results of the evaluation.

Most methods are considered useful. It is pleasing that only very few are evaluated as harmful. For the methods evaluated as irrelevant, it is currently being evaluated whether improvement measures for the next version of the tool can be derived from them. The fact that some evaluation partners enjoyed reflecting on their current process model with the tool may reveal completely new starting points for its use in the future.

VI. Conclusion

In this article it is shown how unexperienced project managers can use the semi-automated "element aggregation via dynamic terms" to develop an individual process model for project management. As long as it is used individually for each project, it is applicable in smart city projects. Only in the parameters describing the project context, care must be taken not to evaluate parameters that may not apply. As the results of the first evaluation show, the algorithm selects mostly useful methods and measures to avoid the selection of the few harmful methods are currently in progress.

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Project Management Time-Cost Balancing Model for Smart Cities Transformation

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***Abstract*—The time-cost balancing management model for complex smart city transformation projects at the preliminary planning stages has been developed. The model is based on a graphical interpretation of the project implementation volume as the area of a right triangle in the space of its states, the dimensions of which are given by the coordinates of the basic indicators: cost and execution time. The essence of the study is to establish under what conditions the volume of project implementation (area) will be the largest, and the cost of resources (sides of the rectangle) will be the smallest. According to the results of the study it is established that of all the rectangles that determine the possible states of the project, only the square has the largest area with a minimum length of the perimeter (resource costs). To provide optimal solutions for correcting the deviation of the actual states from the planned ones, adaptive control is substantiated by calculating the smoothed value at the adjustment point as the arithmetic mean, planned, actual and predicted values.**

Keywords— smart city transformation, project management, adaptive process of managing complex projects. visual model structure, uncertainty in project, time-cost balancing model

I. Introduction

A smart city is an evolutionarily emerging strategy about where the city is going to end up in the future and how it may view its transformation. To implement the outcomes of smart city projects it is necessary to increase the level of development of this promising urban strategy [1, 2]. The city experiments and uses innovative technology to improve the livelihood of a community. These actions and relevant governance policies need to be completed for a city to become smart [2, 3]. These improvements ensure a higher quality level of urban living. A necessity in obtaining these outputs and outcomes leads to the complexity of such projects, issues with solving control and monitoring problems of resource efficiency, especially time.

Projects in general, seek to do something new, unique, once, rather than repeating a well-known process [4]. In order to improve our understanding of the nature of complexity and risk, a significant number of models of project management processes have been developed. Most traditional project models, management methods and tools assume that the path to the goal (i.e. a predetermined set of measures and dependencies) is known and will be quite effective and efficient. However, this is rarely the case in complex projects: the planned set of measures may be both insufficient and partially unnecessary, so many projects fail. The results of twenty years of research [5] show that, the share of successful IT projects averages only 30%, and - 70% were unsuccessful and problematic ", i.e. they were late, exceeded the budget or had fewer functions than originally indicated.

In this paper, we consider the adaptive process of managing complex projects. This adaptive process [4] aims to minimize the expected value of the project with time, cost and risk trade-off [6]. We propose rationale for a visual, intuitive structure of the decision-making model to balance time and cost in the smart city projects planning and operational management.

Usually the planning and the adaptation in a project are separated, in contrast to the existing approaches, we will view them as a whole. We assume that in circumstances at the initial stage of project planning of a lot of uncertainty about the amount of required resources and the time frame of a project, using the proposed visual model structure will implement the management process adaptation to the project objectives through a better understanding of the "project space" and potential paths to success. In order to improve this issue we have to make the management more agile and fast-responding.

II. Conceptual Underpinnings

Due to uncertainty at the beginning of the project, there are large differences in potential outcomes, and the most likely outcome falls well below the target value. To take into account the uncertainty in the technical capabilities of the project product, Browning and others [7] used the representation of expected results by random variables with probability density function or distribution.

However, for unique projects, such a presentation cannot be implemented due to the lack of statistics, which confirms a significant number of unsatisfactory project results. The main reasons for project management failures are poor management methods and technology (according to the International Project Management Association, IPMA), including lack of flexibility and activity and lack of sufficient control and monitoring of the project. An unclear way to achieve the project goal has been discussed in the literature in terms of process uncertainty and ambiguity. Both stem from a lack of knowledge about the problem at the time of decision-making, which affects its effectiveness. In essence, researchers [8, 9] explained uncertainty as "knowing what you don't know" and ambiguity as "not knowing what you don't know". The

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uncertainty meaning may to changing from variation to presumed uncertainty, to unforeseen uncertainty (ambiguity), to chaos [10-12].

Since most complex projects, like smart city transformations, are characterized by uncertainty, traditional models, methods and tools of project management do not ensure the timely achievement of the goal. Therefore, existing models, methods and tools need to be changed to take into account the risks and adapt them to the new conditions [13].

To provide innovative efforts to solve problems in the complex process of managing the whole project, it is decomposed into smaller, interacting actions [14]. Alternative process architectures that is alternative activity sets, results, and/or sequences, may differ in efficiency [15], often because of the assumptions number required for certain sequences, sequential iteration and processing when these assumptions are inadequate.

For this case, we proposed [16] to modelling the project as a sequence of interacting discrete events n1, n2 ... nk, which need to be performed to achieve the project goal. We give priority to the information flow of the adaptive management for intermediate results [17] by modeling the balance of time and cost to predict the risk situations of the projected results.

Process modeling can facilitate the description and study of the state space [18] (a set of possible process architectures) and contribute to the definition, size and planning of activities and results. It can provide a useful description of project behavior as a system that improves understanding, which is a prerequisite for effective planning and improvement of project management models and methods [19]. Thus, even when projects are less clear, modeling can structure the sorting of the known and the unknown [20].

Thus, the purpose of the modeling process is not to develop an error-free project plan, but rather to encourage a more complete study of project states and potential pathways between the current state and the desired state (s) - to better anticipate risks.

Several researchers use modeling to adapt management processes at both the strategic and tactical levels. Pich et al. [12] described the project processes in terms of its information structure and contingency plans, which managers can compare to dynamically redefine the relevant actions.

The information generated as a result of the project improves the distribution of results to achieve the goal, as well as demonstrates increased confidence in the final results by reducing the variance and range of deviations.

Sommer and Loch [21] mentioned the combined challenge of unpredictable uncertainty (inability to recognize influence variables and their relationships) and high complexity (large number of variables and interactions) and noted two approaches in this context: trial and error (continued, flexible adjustment actions and goals considered) and selectionism (pursuing several independent approaches and choosing the best of them ex post). Although these macromodels provide strategic advice, they provide less tactical advice to project controllers.

The concept of adaptive project management is given considerable attention in which scenarios for a purely theoretical understanding of the complexity of adaptive processes in product development projects are studied. Instead of assuming that a certain set of measures and interactions is necessary and sufficient to achieve the project goal, a model has been developed that better explains the set of potentially relevant modes of activity and interactions. [4] This approach transforms project planning from detailing individual plan processes to gaining an understanding of the process space by modeling smart city project execution.

III. Overview of the Developed Model

According to the literature review the management decisions in projects take place at circumstances of insufficient awareness of the conditions of its implementation in the future. The further we try to predict the future of the project, the greater the uncertainty [20]. This implies that the bounds around our forecasts must get larger as we go further into the future.

Under these conditions, we need to prove the new concept (which is achieved with a minimum of information resources) to build a model and method in the smart city project planning and control processes. The model should provide sensitivity to small changes, accumulating information about these changes, and on the other - the ability to level non-significant and detect or record and reflect the main, defining deviations [22].

Let's take a look at the structure of a simple model that is designed to solve the main task of planning which is finding the value of the target function. Target function is referring to the volume of project implementation at a given cost of basic resources: cost and time. The model is based on a graphical interpretation of the project execution volume as (through) the area of a right triangle in the space of its states, the dimensions of which are given by coordinates.

The planning process should determine the maximum value of the objective function - scope of the project at the lowest cost base of resources: cost and time. Thus, the essence of the study is to establish under what conditions the volume of project implementation (area) will be the largest, and resource costs (sides of the triangle) the smallest.

It is known from geometry that of all the rectangles that have the same area, only the square has the smallest length of the perimeter. The substantiated model allows presenting the planned volumes of all project works by an optimum ratio of expenses of resources to volume of works in the form of equilateral triangles.

From this approach, it is easy to present the dependence of project performed value (V) on resource costs (cost -C and time T for analytical evaluation. If the process starts at time $t = 0$ and has duration T and cost C, the project implementation volume will be $O= 0.5*C*T$). Therefore, the proposed model in the form of equilateral triangles makes it possible to reasonably represent the optimal ratio of resource costs to the volume of project work.

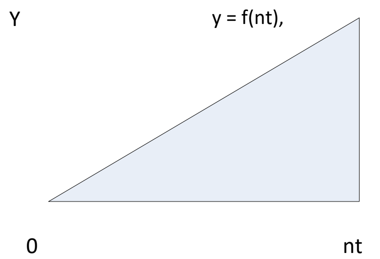
The model can be used to adapt different scenarios projects to get the most effective solution for planning, for example, for each milestone, since the project is selected following values time and cost characteristics balancing, displaying which form the sides of the triangle, as a result, maximize volume and minimize appropriate time and cost characteristics, or find critical values of resources at a given volume of project implementation. The application of the model is proposed as follows:

1. Drawing up of the optimum plan of performance of volumes of the project at the set restrictions on resources. On the basis of data on resources in the space of states with coordinates cost and time we construct a triangle. For an adequate assessment of the parties, time is expressed in the same monetary units as value. The unit cost of time is defined as the weighted average of similar projects. According to the values of the parties according to formula: V= 0.5*C*T we find the optimal plan for the implementation of the project.

2. Determine the necessary resources for a given project implementation. We assume that the set volume should be optimal. The sides of a right triangle should be equal (C = Ts) where Ts is the weighted average unit cost of time for similar projects. Then formula takes the form C= 0.5*V^2.

This approach increases the efficiency and effectiveness of planning, and the graphical representation provides visualization in the control process.

In the process of control the operational period of time, the target limit determined by the optimal ratio when planning will change and may include an area of risk. The actual state will be displayed by visually changing the image of the dimensions of the sides of the triangle next to the standard (planned state) Fig. 1. If the project execution process y = f (nt), begins at time t = 0 and has duration r, where r = 1,2, ……… ..n, the total value (earned) is computed by the integral (limit of the amount of work performed at each time Y1 + Y2 + …… Yn) i.e. equal to the area of the triangle In the general case, the function may be nonlinear, but we will proceed from a constant rate of project work then the function is considered linear.



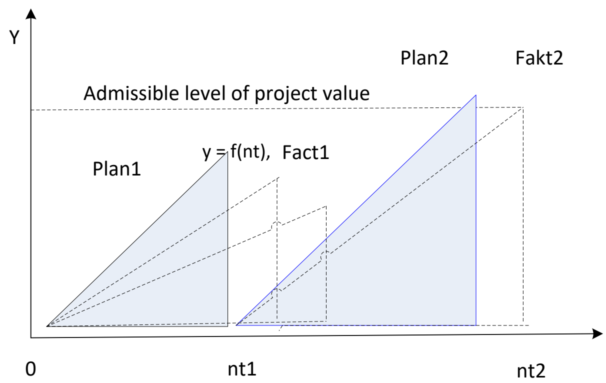


Fig. 1. Displays (by the size of the sides of the triangle) the actual state along with the planned state.

The use of the model for adaptive control is that for each milestone of the project choose the values of time and cost characteristics, the reflection of which is formed by the sides of equilateral triangles, as a result maximize the volume and minimize the corresponding time and cost characteristics.

Over the operational period of time, the target limit is determined by the optimal ratio will change and may include an area of the risk. This state will be reflected by a clear change in the image of the actual state rectangle next to the reference (planned state). This image allows you to quickly assess the increase or decrease in indicators of the state of project implementation in adverse environmental changes. In addition, such project state models are easily formalized to automate decision making.

The most rational, economically and organizationally justified principle of adaptive management in operational situations is the localization of disturbances, i.e. the desire to minimize interference in the planned implementation of project actions in temporal, spatial and "organizational" coordinates.

This requirement defines the conservative role of operational management and its regulatory functions in project management processes. However, when performing a maneuver is inevitable it is necessary to preserve the integrity of the target limit, preventing the transfer of disturbances along the chain of causation, which can lead to their avalanche.

At the same time there is a task to adequately present measurements in space of management of the project and accordingly to consider them in model for development and decision-making in the project.

Data on the future state can be predicted with an accuracy greater than 10 - 20%, so the accuracy of their final assessment should be limited.

Using approximate numbers instead of exact numbers is not an artificial technique; it is a reflection of reality. Project management processes are usually presented in the form of discrete models [23].

Dividing the continuous process into discrete stages, the area can be calculated using the properties of arithmetic progression. In a special case, if the difference of the arithmetic progression coincides with its first term, ie a = d, the given formulas are simplified.

In the process of operational project management, the adaptability of decision-making is to find the correcting arithmetic mean by finding the center of gravity of the triangle built on the points of the planned Yn -1, the actual Yn and the predicted values of Yn + 1 project volumes Fig. 2.

The purpose of adaptation - the choice of the most economical ways of operational maneuver, which can be used technical and economic characteristics of processes, such as calculating the reduction of organizational costs associated with redevelopment. To do this, the model criterion introduces indicators that minimize their deviation from the planned indicators.

This method of decision-making allows you to maintain the integrity of the target limit of tolerances. This ensures the stability of project management processes and prevents the transfer of perturbations along the chain of causal relationships and their avalanche-like growth, which can lead to bifurcation.

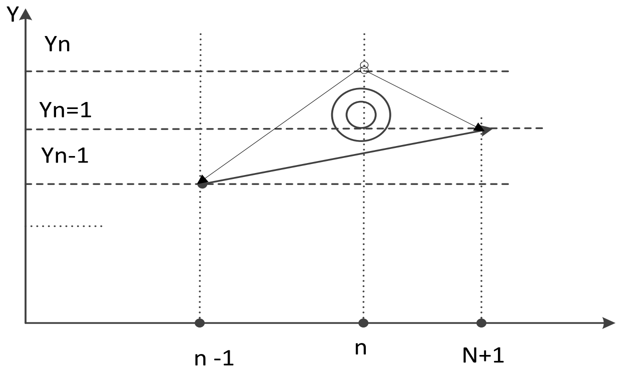


Fig. 2. Computation of the smoothed value of the adjustment at point n as the arithmetic mean, the planned Yn -1, the actual Yn and the predicted values of Yn + 1. GC-gravity center

A practical positive result in decision-making is achieved by reducing the room for maneuver between small values of changes to which the project result is insensitive and, accordingly, they can be neglected and the limits relative to the baseline, which require prompt adjustment.

Thus, the complex problem is reduced to a series of simple problems that allow the use of mathematical models. Decisions made by the governing body (choice of the area of maneuver, setting conditions on its borders) are quite meaningful, and cumbersome calculations are performed on a computer.

However, the decisions made on its basis can be optimistic and their straightforward imposition can cause opposition, in particular by distorting the initial information when building the model.

IV. CONCLUSONS AND OUTLOOK

Grounded for a new model of the objective function value - the amount of the project cost for a given basic resources, cost and time in planning projects. The model is based on a graphical interpretation of the scope of the project as the area of a right triangle in the space of its states, the dimensions of which are given by the coordinates of the cost and execution time. The model is based on knowledge of geometry, but of all the rectangles that have the same area, only the square has the smallest length of the perimeter, which allows determining the optimal value of the objective function - the volume of the project at the lowest cost and time.

The decision for the adaptability of project management processes is to find the correction values are also based on a geometric model by finding the gravity center (GC) of the triangle built on planned locations Yn -1, actual and predicted values Yn Yn + 1 volume projects.

This interpretation of the model allows quickly displaying the various disturbances in the functioning of the control object and accelerating decision-making in an automated mode.

The proposed model will speed up the planning of large-scale smart city transformation projects, as well as compare different options at the preliminary planning stage.

In the future, special research will be needed, for example, in the framework of a synthetic approach to the problem of harmonization of criteria [24] in decision-making at different stages of project management [25].

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Analysing the Impact of Agile Project Management on Organisations

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***Abstract*—This research examines the impact of agile project management on organisations. To investigate this issue, a case study and an additional external survey were conducted. The impact has been identified according to the aggregated enterprise agility dimensions, which are interconnected. Based on the survey, it can be stated that the impact depends on the number of interfaces into the organisation and the management commitment. The impact, however, can be a double-edged sword, as when the agile mindset is fostered, conflicts can arise when people are released, after agile projects, back into the old structures of the organisation. The survey also revealed that practitioners believe that after an agile project, there is the need for an agile support team in order to avoid a break in the agile supply chain. Furthermore, agile project management impacts the HR-processes, as the competence profiles of the employees are influenced. Consequently, agile project management can be seen as the gem cell for agility in (parts of) an organisation, whether this is wanted or not, due to its influence. Depending on the amount of agile project work, the organisation has to handle the VUCA-environment accordingly, where agile project management can help to learn and transfer agility into the organisation step by step until the desired and required need. Nonetheless, change management should be applied in any cases to ensure the right outcome.**

***Keywords*—agile project management, agile support teams, competence profiles**

I. Introduction

A. Motivation

The amount of project-related activities continues to increase [1]–[4]. This development forces organisations to restructure and adapt themselves [5], [6], as "[...] projects are no longer adjacent to operations but instead primary to how work gets done and problems get solved" [7].

As a response to detailed, far in advanced and little flexible management approaches, which were not appropriate for the high dynamics of the environment, agile project management has been developed as more lightweight processes [10]. Usually the agile manifesto is used as the common base, which impacts the way of project management, i.e. knowledge, skills, competencies, tools, methods, techniques and processes.

Although the understanding of traditional projects [11]–[16] is different from agile projects, as shown by their characteristics in table I, it does not mean that that the definition of a project or project management differ significantly between predictive and agile projects, but that they are built upon different assumptions [17]. Nevertheless, agile project management does not replace traditional project management, as they can complement each other, although some practices are in contrast with each other [18].

Different sources report varying distributions of the approaches used [19], [20]. However, agile approaches are present, either through their pure application, including selectively chosen or through hybrid approaches. In concrete terms, Scrum is the predominant agile framework for single teams [9], [20]–[22], while Scaled Agile Framework (SAFe) does take the front rank for scaled methodologies and frameworks [9], [20].

Although agile projects are (perceived) more successful than predictive projects [20], [24], neither predictive nor agile project management guarantees success[1] [23].

B. Problem Statement & Research Question

Considering the sphere of agility, which describes the range of agility, an impact from agile project management on the organisation can be expected, similarly to the influence of the agile mindset on project management.

As agile project management can cause challenges [33]–[35] in organisations which its introduction, this research investigates the impact in form of experienced or expected changes in the organisation.

Consequently, the research question was defined as 'what is the impact of agile project management on organisations?'.

The goal of the research was to identify the impact of agile project management on organisations themselves, from the perspectives of the aggregated enterprise agility dimensions. The first four influencing dimensions, based on the literature, are listed below [36]:

- People and (organisational) Culture
- Processes
- Strategy, Governance and Leadership
- Organisational Structure

Within the frame of this publication, the results are limited to the first two dimensions.

II. Research Design

This descriptive research used an inductive approach, as not a specific theory was tested, but an open question was defined

[1]There is no commonly agreed definition of (project) success and how to measure it [25]–[32].

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TABLE I. Comparison of predictive project management and agile project management. [36]

Characteristic	Agile Project Management	Predictive Project Management
Scope	-Fixed -Fully specifiable -Throughout analysed -Defined requirements	-Estimated -Evolving (flexible) -Driven by vision -Defined as deep as needed (just in time) -Feedback required
Cost	-Estimated	-Fixed
Time	-Estimated	-Fixed
Focus	-Tools and processes	-People
Planning	-Detailed and long term	-Detailed but minimal on the short term -High level on the long term
Documentation	-Comprehensive	-Reduced to the required minimum
Changes	-Defined process -Avoided (resisted) if possible	-Changes are predicted (expected) and welcomed
Team composition	-Functional teams -Usually distributed -Further tasks from the line organisation or other projects	-Cross-functional teams -Co-located -Dedicated to a single project
Project Leadership	-Project Manager connects and controls -Hierarchy	-Self-managed teams -Project Manager acts as facilitator -Networks
Client involvement	-At the beginning and the end (negotiations and acceptance)	-Throughout the project (collaboration)
Delivery Approach	-Sequential	-Iterative and incremental
Result delivery and Feedback	-At the end of the project	-At the end of each iteration
Communication	-Mainly for control -Formal	-Open, frequently and encouraged -Informal
Ownership	-Project Manager	-Team
Experiments	-Discouraged to meet plans	-Encouraged to identify the best way
Performance Targets	Iron Triangle -Scope -Schedule -Cost	Agile Triangle -Value (extrinsic quality) -Quality (intrinsic quality) -Constraints (scope, schedule, cost)
Organisation	-Very formal -Bureaucratic	-Flexible and cooperative
Task Management	-Push	-Pull
Resources	-Different experts at different times -Varying efforts	-Stable team -Stable efforts
Environment	-Static	-Dynamic
Role Competencies	-Expert	-Generalist rather than specialist
Contract	-Fixed price or fee	-Time and material (with a cap)

as the problem statement [38]–[40]. This research was divided into the following four phases.

The first phase was a literature review (secondary research [41]), which provided the foundation for further data collection.

The second phase was a set of expert interviews [40] to collect qualitative data (primary research) [41] as part of a single case study. The case study was utilised for theory-building [41] to understand how [39] agile project management affects an organisation. Due to the limited timeframe, no changes over time could be observed [42].

The third phase was a survey in order to validate or refute the derived statements in the form of a questionnaire. The questionnaire covered dedicated areas of the identified potential changes from the case study. Through this step, the gathered primary qualitative research data were validated through quantitative data [41].

The last phase contains the evaluation of the expected and or observed effects from qualitative results from the interviews based on the quantitative results of the questionnaire, and the literature.

A. Literature Review

For this research, the following search engines have been used, as they are free or offered for the students of the University of Applied Sciences and Arts Dortmund: Google Scholar, University of Applied Sciences and Arts Dortmund's Research in Orange, IEEE Digital Library, ScienceDirect and Google. Only sources in English and German were considered. Consequently, the search strings [39] have been applied in English and German. In order to include good and best practices, the search terms have been extended with well known organisation names. Furthermore, books, articles, white papers, case studies and research from well-known project management organisations have been included, e.g. from Deutsche Gesellschaft für Projektmanagement (GPM) and International Project Management Association (IPMA), Project Management Institute (PMI), Axelos, Association for Project Management (APM), Scrum.org, Scrum Alliance and Agile Alliance.

B. Case Study & Interviews

rku.it (rku), the organisation the author worked for at that time, offered to be the case study for this research. rku is an IT service provider in Herne, Germany, offering outsourcing and consulting services, primarily for the utility industry, local public transport and municipal economy. The company provides services to more than 130 organisations with more than 350 employees [37].

After a thorough analysis of the market and customers' needs, rku initiated a program to build the IT platform of the future. As rku has never worked in such a substantial agile way, not only were changes expected to the way of working within the projects, based on the agile approach, but also towards the organisation, wherefore this organisation was suited for the case study. During the time of the interviews, the organisation worked approximately half a year in a tailored, scaled agile approach.

The interviews carried out in this research were designed as semi-structured interviews to gather qualitative data and also allow new perspectives. The semi-structured interviews were based on the results of the literature review and performed in a one-to-one format. [38], [39]. Not only experienced project managers have been interviewed, but also people in other positions have been considered, as the impact of agile project management on the organisation as a whole was examined. The summary of the interviewed perspectives and the number of interviews is depicted in table II. As the impact of agile project management on organisations was examined from different perspectives, different questions were prepared for each perspective. However, the core questions stayed the same.

C. Survey

In order to weaken the limitation of the case study, a questionnaire was designed based on the results of the interviews.

TABLE II. Interviewees of the case study. [36]

Interview Group	Number of Interviews
Corporate Management	1
Corporate Development	3
Project Manager	3
Agile Project Team Member	3
Human Resource Department	2
Development Department	2
External Consultants	2

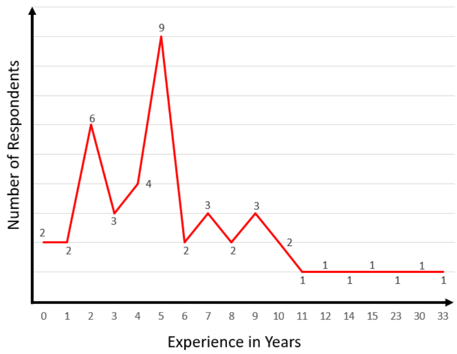

Fig. 1. Respondents experience in years. [36]

However, not all statements could be validated, as longer questionnaires will lead to less participation in web surveys [43]. The response-options were oriented on the Likert scale. Furthermore, while certain questions also allowed further feedback as free text, some questions were limited to given statements to verify these.

The survey was distributed solely in Germany in the following channels with the help of:

- GPM via the September Newsletter, Facebook and Twitter
- PMI Chapter Cologne via LinkedIn
- Bagilstein via LinkedIn

Within the time frame from the 14.09.2020 to the 04.10.2020, the survey was answered 45 times.

The majority of the respondents were *project manager* (38%), followed by a vast gap by *leaders and managers* (13%), *agile coaches* (13%), *product owners* (9%), *consultants* (7%), *development team members* (4%) and *others* (16%).

The range of experience with agile project management differs widely. For this survey, there were two peaks, with two years (answered six times) and five years (answered nine times) of experience. The distribution of experience is wholly depicted in Fig. 1. The experience of the respondents covers mainly one to three sectors[2]. Fig. 2 shows the areas of expertise in relative numbers.

In this survey, respondents from organisations with more than 500 employees were predominant, amounting to almost half of the group. The whole distribution is depicted in table III.

[2]Multiple selections were allowed

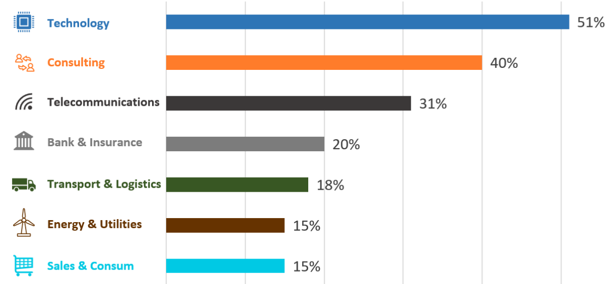

Fig. 2. Respondents experience in sectors. [36]

TABLE III. Organisations size (number of employees) of the respondents. [36]

Number of Employees	% of survey participants
>500	49
101-250	13
10-50	13
51-100	9
1-9	9
51-100	7

III. Results & Discussion

A. People and (organisational) Culture

Similarly as the interviewees described that agile project management is the germ cell for agility in organisations, 55.5% of the respondents of the survey agreed to this fully or to the greatest extend. Additional 28.9% agreed to this statement partly, while only 13.3% hardly agreed and 2.2% disagreed. The leading factor, which determines the strength of the impact of agile project management on organisations, is the number of interfaces of the agile project into the organisation (55.6%). Further, apparently less defining factors, are the management commitment (16%) and the time frame of the project (13.6%). [36]

Consequently, organisations should be aware that agile project management has an impact on organisations, whether wanted or not. This impact is also logically correlated to the amount of agile project-related work. Therefore, in rather traditional organisations, essential agile projects with potentially significant impact should be accompanied by the according change management.

1) Mindset: “Agility requires a true paradigm and culture shift of an organization[.]” [48, p. 9], at which core the agile mindset stands. Agile project management fosters not only the agile mindset within the project team but also within the organisation when agile project team members are released back after the project into the organisation (53.3%). In contrast to that, 66.7% of the respondents described that there are conflicts when agile project team members are released back into the old structures. One of them also highlighted that the people would leave the organisation if they cannot change the old structures after returning to these. Approximately 18% answered with both options. [36]

Both options show that once agile project management has been used, the organisation should adopt the achieved benefits

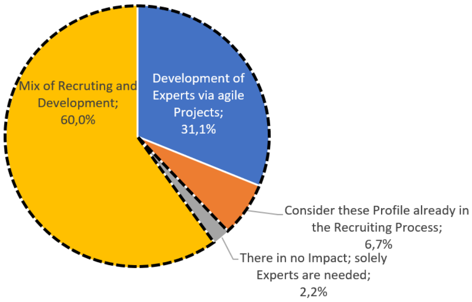

Fig. 3: How T- and π-competence profiles should be acquired. [36]

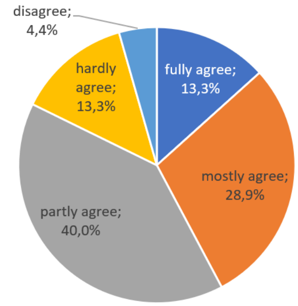

Fig. 4: Blend of projects and operation in product-oriented teams. [36]

permanently. Therefore, also the people outside of the agile projects have to understand for which reason an agile approach has been chosen and how to interact with such projects.

2) Competences: Through the fact that agile project management favours generalist over specialists, the requirements towards the people change. This does not mean that no in-depth knowledge is necessary anymore, but that broad knowledge is required in today's environments. Such combinations of the knowledge dimensions are usually described as competence profiles in T- or π-shapes.

This is not only seen by the interviewees of the case study but also confirmed by the survey participants. 97.8% of the respondents agreed that there is a need for these competence profiles. However, there are different opinions on how to acquire these competence profiles. [36]

These competence profiles are also reflected in the results of current working groups. The digital design professional even illustrates the Π-shape. The learning paths of the Next Level Working workgroup, whereof three of the four roles remind of the scrum roles, also show the importance of the breadth competences with the following exemplary extracts: [36]

- understands its role within the value stream
- understands the meaning of its product in the context of other developments

The advantages of these competence profiles are, that silo thinking is broken up, they foster mutual support and understanding, and help to avoid bottleneck resources.

B. Processes

1) HR-Processes: The new requirements for competence profiles of employees do not mean that experts are no longer needed but that a certain knowledge about adjacent areas is required. While it is unambiguous that these competence-profiles are needed, there are different opinions on how these are acquired (see Fig. 3). The majority stated that a mix of recruiting and development is favoured (60%). Further, 31.1% stated that experts should be developed towards these profiles through agile projects. [36]

Considering that the survey was distributed in German only, it is not surprisingly that only the minority chose to solely rely on recruiting, as in Germany, there is still a shortage of skilled labour, especially in the IT-sector [45]. As the digital sector is continually growing, the market is still an employee-market [46] and also as the COVID-19 pandemic triggered further thrust of digitisation [47]. Consequently, HR-departments should not only consider these profiles in the recruiting procedures, but also steer further training specifically on side topics, which can (partly) also be achieved through agile projects. [36]

Although it can be seen clearly that agile project management has an impact on recruiting, due to the employee-market in the IT-sector, the strong effect might weaken. However, in the end, as one interviewee stated, it might be that the mindset becomes more important, as it is easier to teach someone skills than a mindset. Consequently, behavioural interview questions might be applied to gather insights about the applicant's agile mindset. Nevertheless, it is difficult to find the right balance as organisations need people who can help them quickly. [36]

2) Value Delivery: Within the case study's interviews, the interviewees stated that there will be less differentiation between projects and daily businesses, as people will be gathered around products. While in total, slightly more survey respondents (42.2 %) stated this applies (fully (13.3%) or mostly (28.9%)), 40% stated that this only applies partly (see Fig. 4). The minority stated that there is hardly an impact (13.3%), while only 4.4% expressed no influence. [36]

Within the interviews, there was identified that agile project management fosters the transition of the agile project teams permanently, step by step, into the organisation in order to avoid that the benefits of the agile project teams are limited to that timeframe. Through that, the organisation would be restructured towards the products, product components, features or (customer) processes. As still further development might be necessary, next to the operation, project and operation activities blend. [36]

In any case, the respondents agreed (in total 91.1%) that there is the need for an agile support team after the agile project in order to prevent breakage in the way value was delivered in the project and afterwards (see Fig. 5). However, how this agile support team is staffed is seen differently. While 44.4% of the respondents stated that there should be a certain degree of the people who were part of the original development team, one-fifth pronounce for the same team. Slightly more than every fourth (26.7%) stated that is can be any agile support team. In contrast to this majority, only 8.9% of the

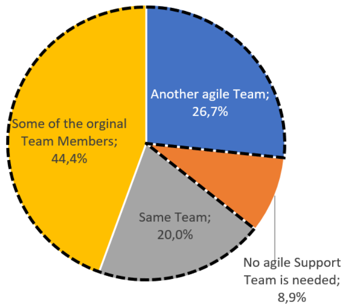

Fig. 5: Composition of an agile support team. [36]

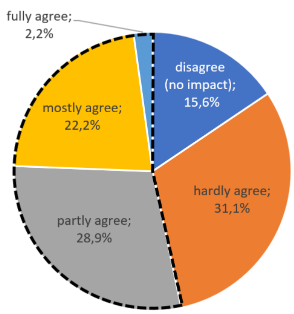

Fig. 6: Partial elimination of SLAs due to agile teams. [36]

respondents stated that support actions in classical ways are enough. [36]

Depending on how the team is assembled, these results underline that projects and operations blend when the deliverable is developed further. Agile support teams also could influence service level agreements (SLA), which are frame agreements, for future services within the scope of IT Service Management.

A typical example is a service request, which usually has certain response times in which they need to be taken into processing. This process could be simplified, as such tasks could be handled as "normal" items of a product backlog or Kanban board. With a product owner, these items can be prioritised for processing in iterations (sprints). Furthermore, similar tickets can be bundled and handled together to create synergies. Nonetheless, there was no impact expected regarding technical service level agreements, e.g. system availability. [36]

The set of answers provide a wide distribution. Roughly one third (31.1%) of the respondents hardly agreed to the statement, followed by partly agreement with 28.9% of the votes (see Fig. 6). Still, 22.2% of the respondents agreed mostly to the statement. Nonetheless, also 15.6% stated that there is no impact on the service level agreements. Noticeable is that only one respondent agreed to the statement fully. [36]

As the agreement is highly varying, further investigations are needed to define under which circumstances which impacts can be expected.

IV. Conclusion

This research showed that there is an impact of agile project management on organisations. However, as organisations differ, the impact also varies, which is underlined by the following metaphor: "Obviously, there will not be any universal 'Lean-Agile operating system' that runs on all 'enterprise hardware systems' " [48, p. 3]. Consequently, "[e]very path towards agility is unique in its route and needs" [49, p. 8].

V. Limitations

Generally, as there was a single case study used, the results are quite specific. However, this limitation could be weakened through the conducted survey in which certain aspects could be validated and are consequently true for other organisations. Nevertheless, due to the limited timeframe of this work, it can be assumed that not all implications might be entirely captured. Furthermore, other organisations might face other consequences due to agile project management. As the case study was conducted in a company located in Germany, and as the survey was published in German only, the results are generally limited to Germany, as organisations in other countries might operate differently, whereof different impacts might be observed. [36] In order to take this special situation into account, the interviewees were asked for the potential impact of this pandemic. Generally, the perception was that the agile mindset was fostered, while the social interactions were reduced due to the physical distribution of the team, which is, in general, contra productive for agile.

VI. Implications

A. Practical Implications

To cut a long story short, agile project management transfers many of its characteristics into the organisation. This is also reasonable, as when the environment requires agility in the projects, it is reasonable to assume that agility is also required to run the organisation in such an environment. Consequently, agile project management can be seen as an enabler to transform the organisation, which should be accompanied by change management initiatives to unfold the full potential.

B. Theoretical Implications

This research contributes to understand the impact of agile project management on organisations. Consequently, this research enables to further investigations into this topic. There might be different influences on different types of organisations. e.g. private and public organisations.

Besides that, the impact of agile project management might differ depending on how long the organisation practices it, so that the impacts can be differentiated according to the time axis.

Lastly, the scope of the research can be widened towards the environment, as there can be an impact assumed towards the external stakeholders of agile projects. Here mutual impact could be expected.

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The Concept of an Educational Ecosystem for the Digital Transformation of the Ukrainian Economy

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***Abstract*—The article notes that society is on the verge of radical changes in the educational paradigm, as a result of which universities play a key role in the implementation of innovations and commercialization of scientific and technical developments. The authors substantiate the role of transformation processes in Industry 4.0, which necessitate the formation of educational ecosystems in universities. The article is devoted to the description of the educational ecosystem, which offers a tool for creating conditions that increase the competitiveness of individual universities, organizations, territories and regions. The central element of the educational ecosystem is innovation as a process of transforming an idea into the final innovative product or service, the implementation of which requires many participants: universities, entrepreneurs, research centres, investment funds and more. The authors see the basis of the ecosystem as an innovative platform that allows you to regulate many horizontal communications, in the form of research centres, innovation laboratories, start-up schools.**

Keywords — Industry 4.0, university ecosystem, innovative platform, digital transformation.

I. Introduction

One of the key topics discussed at the 2020 World Economic Forum in Davos was the Reskilling Revolution. This initiative aims to prepare people for the professions needed to succeed in the Fourth Industrial Revolution until 2030. New skills should provide people with jobs and help them develop their professional careers. Industry 4.0 development trends already require people to be able to update knowledge in time and apply it in practice. Thus, the Reskilling Revolution platform provides for solving the problems of providing the economy with skilled human resources. According to the report [1], there will be 133 million new job openings in leading economies by 2022, and by 2030 1 billion people need to be trained and retrained due to a change in 42% of basic skills in the near future.

The current state of Ukrainian economy is characterized by degradation of industry, low regulator efficiency, weak domestic demand for innovation in Industry 4. 0 and at the same time by a strong IT industry, developed segments of integrator-developers of ICS and IT, as well as a still powerful system of higher education institutions (HEIs) [2].

Nowadays, higher education institutions (HEIs) have become the most important infrastructure for the innovative development of nations; they are strategically important in shaping the intellectual capital. The level of education is one of three components of the human development index along with GDP per capita and life expectancy. According to [3], opening of each new university increases country's GDP per capita by 0.05% on average and increases the economy of the region where the university is located by 0.4%. Information technology (IT) is the most promising sector in the development of Ukraine's economy.

Ukraine is placed 42nd among 63 countries in the global ranking of competitive talent according to the World Talent Ranking IMD 2020 [4]; ahead of some, more developed European countries, including Slovakia, Hungary and Croatia. The 42nd position in the world competitiveness ranking shows that the situation with human capital in Ukraine is far from being catastrophic. However, this potential has little impact on economic growth because of the low level of digital competitiveness. The digital economy in Ukraine is only 3% (2.6 billion USD) [5]. Ukraine was ranked 85th in the 2019 WEF Global Competitiveness Report among 141 countries of the world [6].

A digital revolution providing for the digital transformation of the economy is an urgent issue for Ukraine. The programme of such transformation is laid down in the Ukrainian Digital Economy Development Concept for 2018-2020 [7]. The "Digital Agenda of Ukraine –2020" project [8] considers digitalization as the main direction of technological changes in Ukraine. Ukraine's digital agenda priorities are digital economy and telecommunications legislation, digital infrastructure including a broadband communications strategy, a cashless economy program in e-commerce, e-trust and cybersecurity, and a "Smart Cities-Smart Regions" initiative focused on decentralization and implementation of electronic skills, e-health and e-commerce in the regions of Ukraine.

The development of digital skills and competencies in Ukraine is chaotic and haphazard: Outdated teaching methods, lack of educational platforms and trained teachers, and unavailability of modern digital technologies for the teaching process have led to extremely low levels of digital literacy in all current segments of the state education system. As a result, there is a growing discrepancy between the outdated model of vocational education, based on the established list of professional skills, and the accelerated pace of scientific and technological progress. A new paradigm for the education system is needed to address these constraints, including the digital divide, the problem of information overload and the increasing economic, social and intellectual inequality.

The aim of this article is to provide a concept of educational paradigm built on the laws of digital education ecosystem that implements the competence models required for the labour market in the context of current trends of the world economy development. In order to achieve this goal, it is necessary to address the following tasks:

- to analyse the digital trends in the world' s leading economies and their impact on the development of digital competencies of people;

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- to analyse models of industrial ecosystems and their impact on transformation in the field of education;
- to define the essence of innovative educational ecosystem mode;
- to review examples of successful implementation of innovative educational ecosystems in Ukraine.

II. Digital challenges for Ukraine

Digital transformation of the economy and society will be based on digital trends [9] that can be implemented by the IT industry: Internet of Things, Artificial Intelligence Technology and Machine Learning, Big Data Analytics, Digital Transformation Implementation, Data Sharing Technology, Virtualization of IT systems, Distributed Blockchain Technology, Visual and voice search services, Cloud Computing. Grid Computing and Quantum Computing, Autonomous Robotic Systems Technology and Robotic Process Automation Technology, Human-Machine Interface Technology.

The rapid spread of digital technologies makes digital competencies the key ones for people among other competencies. Today, digitalization and cross-platforming are the main trends in the Ukrainian labour market. The ability to use digital technologies in work is becoming necessary for most specializations and professions in Ukraine. The immediate goals of the newly created Ministry of Digital Transformation of Ukraine are to digitize all public services, teach at least 6 million Ukrainians digital literacy and attract up to 10% of IT to Ukraine's GDP. The concept of the development of the digital economy and society of Ukraine determines the creation of an innovative ecosystem of industrial high-tech segments, including full integration with the research space, a strategic direction of Ukraine's economy.

III. Review of the theories of the innovative systems

The concept of innovation ecosystems is based on a number of theories, in particular, the theory of innovative development J. Schumpeter [10], the concept of open innovation H. Chesbrough [11], the cluster concept of M. Porter [12], the concept of national innovation systems K. Freeman [13], the concept of the "triple helix" H. Etzkowitz [14].

J. Moore considered the concept of ecosystem as an economic category. He defines ecosystems as dynamically evolving communities made up of players from different sectors who jointly develop competencies around the innovations with which they work in cooperative and competitive logics [15]. The concept of ecosystems allows us to consider it in the context of interconnections and interactions between its components. R. Adner describes ecosystem as the alignment structure of the multilateral set of partners that need to interact in order for a focal value proposition to materialize [16]. A business ecosystem is "a network of different organizations involved in providing a particular product or service through both competition and cooperation" [17]. The concept assumes that each member of an ecosystem influences and is influenced by others, which creates a continually evolving dynamic [18]. According to the concept of K. Freeman [13], the innovation system is a complex system of economic agents and social institutions (norms, law) involved in the creation, storage, dissemination and transformation of new knowledge into new technologies, products and services consumed by society. The concept of innovation ecosystem by K. Wessner [19] offers a tool with which it is possible to increase the competitiveness of national and regional enterprises. Innovation is seen as the process of converting an idea into an improved product or service introduced into the market and as a result of the intellectual activity of universities, research centers, companies, venture funds, and other stakeholders. J. Howells' research [20] in the field of innovation intermediation determines the systemic role of innovation intermediaries in the innovation system. Innovation intermediaries help to transform innovative inventions into economical products, thereby contributing to the development and acceleration of the innovation process.

The territorial principle makes innovation systems related to territorial or industrial clusters. M. Porter [21] considers a cluster as a local industrial specialization of enterprises, a spatial economic agglomeration in the form of their geographic concentration, based on their network interaction and innovation. The formation of clusters in many European countries and the definition of cluster localization areas is based on the strategy of "smart specialization" considered by D. Forey, P. David and B. Hall [22 - 23].

The main feature of the smart specialization strategy is the "process of entrepreneurial discoveries", which involves the business community to identify the most promising areas of development in the region. H. Etzkowitz' triple helix model: "industry - science - government" [14], according to the concept of "smart specialization", should be expanded into a Quadruple Helix model through the participation of civil society and investors [24]. The weakness of the triple helix model is that it does not sufficiently consider the role of society, which is often the end user of innovation and therefore has a significant impact on the creation of knowledge and technology. The Quadruple Helix model of innovation connects social ecology, knowledge generation of Mode 3 and innovation. It's most important system-forming element is the resource of knowledge, which is transformed into innovation and know-how, and implemented in society and the economy. Thus, the Quadruple Helix model visualizes the collective interaction and exchange of knowledge within the education system, economic system, political system and civil society [25].

IV. The Ecosystem Approach for the Digital Transformation of the Ukrainian Economy

The socio-economic ecosystem is seen as an aggregation of local enterprises, research organizations, educational institutions, innovative products and projects, infrastructure facilities capable of long-term independent activity through the circulation of resources [26-27]. Education as a social system is an organic, complex and unified system in which all the factors (educational institution, teachers and students) are organically linked, which in turn demonstrates consistency and contradiction, dynamic equilibrium and imbalance.

The National Industry 4.0 Strategy of Ukraine defines the industrial ecosystem as the basis for the development of innovators and innovations in the markets of high-tech industrial segments. The ecosystem model consists of innovation, incubation and expertise zones, which usually correspond to different zones of the innovation diffusion curve known as adoption curve [28].

The value chain zone includes actors who play the role of enablers and policy makers at various levels, from national to sectoral. As a rule, these are various clusters and associations, development, innovation and investment agencies. The innovation zone includes elements that often generate innovation: universities, laboratories, design bureaus of large companies, research institutes or start-ups. The incubation zone includes elements that create opportunities for incubation and acceleration of innovators. These are incubators and accelerators, private informal investors (business angels), various foundations, donor organizations, etc. The experience and testing zone contain elements for verifying the viability of innovations. This zone is the end zone for rapid approbation and market launch of innovations and includes organizations that facilitate rapid testing, approbation and certification of new innovative products and solutions.

The model of innovative ecosystem of industrial high-tech in Ukraine is shown in Fig. 1. As of 2019, only the IT sector of Ukraine meets the requirements of the Industry 4.0 strategy. Ukraine has 20 regional IT clusters, 8 IT associations, 10 IT incubators and IT accelerators, 50 hubs, 19 venture capital funds, 4 technology parks, and over 100 research and development centres [28]. In addition, a large number of co-working spaces serve as development centres for fledgling start-ups. However, these ecosystems, which employ some of Ukraine's best young talents, are mostly aimed not at Ukrainian consumers but at the world markets.

The development of digital economy and society and implementation of a sustainable development strategy for Ukraine up to 2030 requires a skilled workforce that meets market demands and is able to constantly evolve and adapt to global technologies that are changing rapidly.

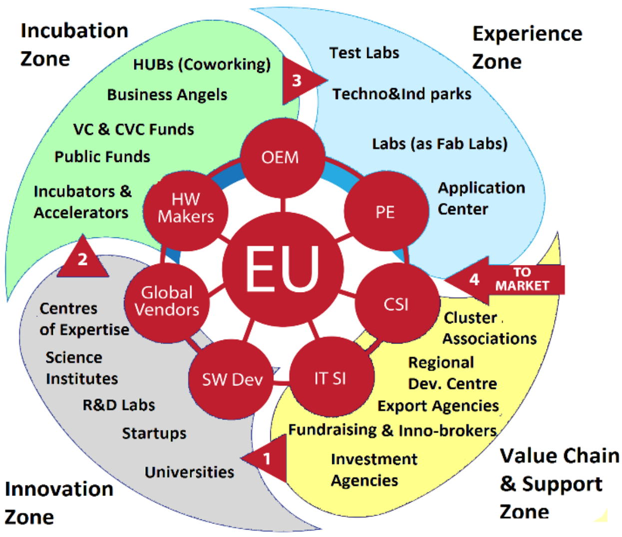

Fig. 1. The draft model of an innovative ecosystem of Ukrainian industrial high-tech [8]

V. INNOVATIVE EDUCATIONAL ECOSYSTEMS

The orthodoxy of the classical education system does not allow for a flexible response to scientific and technological progress challenges; it cannot identify talents and provide an opportunity to develop individual educational trajectories. The gap between educational system training and the real market demands makes school and university graduates detached from applied tasks. The absence of a creative component in the classical educational system reduces people's desire to learn. The educational ecosystems provide [29 – 30] diversity to ensure ecosystem stability; maximal productivity and circulation of resources in the ecosystem, including knowledge, which are optimized and distributed; adaptation to the needs of learners and changes in the institutional environment; scalability in the process of functioning from groups of learners or schools to the world community.

An ecosystem approach to education can demonstrate greater efficiency and productivity compared to traditional hierarchical models, in particular allowing for the diversification of learning resources and educational pathways for learners, to ensure the necessary dynamics of updating the content of educational programs in accordance with the needs of the labour market and economic development. To develop competencies relevant for the digital transformation of society, the digital education ecosystem must implement new formats of education based on individual educational trajectories defined on the basis of students' motivations, skills, professional aptitudes and desires. The digital education ecosystem is a student-centred system that motivates students to self-study and self-manage their learning. Active teaching methods (business games and role playing, business cases, gamification) encourage students to be active in their intellectual and practical activities while mastering the educational materials. Project-oriented and practice-oriented approaches with the development of real-world projects for real customers synthesize the elements of game-play, cognitive, value-oriented, transformative, occupational, communicative, educational, theoretical and practical activities. Mixed learning (combining online and classroom courses) expands the learning process boundaries and ensures that it is personalised according to the student's needs. Mobile learning allows studying anytime and anywhere. The personalized learning model with an individual mentor and tutor considers weaknesses and strengths, talents and abilities, the learning environment and the culture context of the student.

Let us focus specifically on the cluster model of education with the establishment of network interaction between universities and employing companies. In [31] the an industrial-educational cluster is considered as a network of industrial enterprises, scientific and educational institutions focused on joint business activities, the result of which is innovation as a product of synergy between education, science and production.

New educational formats will use digital technologies based on the methods of artificial intelligence, e.g. informational technologies for adapting educational material to the abilities and capabilities of students; interactive intelligent textbooks with built-in artificial intelligence; information technologies for real-time assessment of students' competences and making recommendations on their development strategies; intelligent technologies to increase students' motivation to learn.

The central link in the education ecosystem is the concept of innovation in the form of investing an intelligent solution in the development of a new product or service and generation of new knowledge, the implementation of which requires a multitude of participants: Universities, businesses, R&D centres, investment funds, etc. Uniting all participants, the university ecosystem allows realizing the full cycle of development and implementation of innovations. The authors see an innovative platform that allows for the management of multiple horizontal ties, in the form of science centres, innovation laboratories and start-up schools as the basis of the educational ecosystem.

At the stage of developing the concept of digital educational ecosystem of the university, the authors propose the composition of the conceptual model in the form of a set of platforms (Fig. 2).

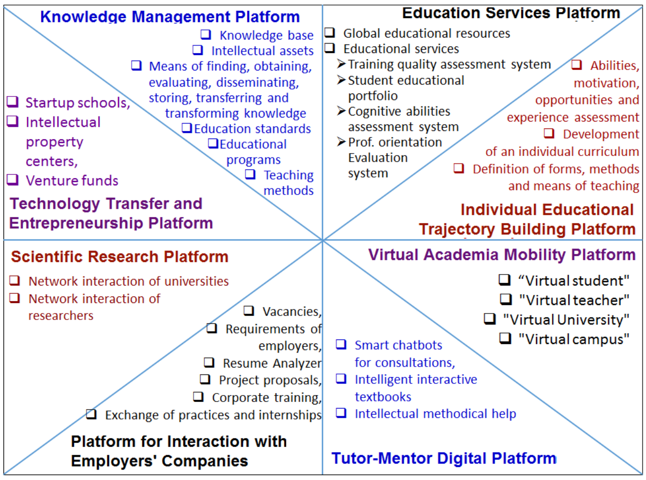

Fig. 2. Conceptual model of the university ecosystem

The platform for the construction of an individual educational trajectory should accompany the process of developing an individual curriculum, the choice of forms, methods and technologies of teaching. The education services platform will implement the education quality assessment, student's individual education portfolio, evaluation of student's cognitive abilities and determine their professional orientation. The global learning platform will deliver educational content. The virtual academic mobility platform will enable students to realize their preferences for studying at partner universities. The platform for interaction with employers' companies will generate information on job vacancies and requirements, will offer a resume designer, test projects for a trial period for employment, corporate training and internships. The knowledge management platform can be based on knowledge management models, for example, E. Carayannis' knowledge management model [32] with the expansion of the knowledge production system architecture towards innovative network and knowledge clusters [25]. The tutor-mentor digital platform will provide an interface for communications in the process of consultations, methodological assistance, individual cooperation, etc. Interaction of researchers will be carried out on the scientific research platform. Technology transfer is proposed to be carried out through the companies' interaction platform. Innovative technological environment platform is intended to support start-ups and entrepreneurship.

VI. Implementation of Innovative Ecosystems in Ukraine

The Sikorsky Challenge startup school established at the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" with the support of the Science Park "Kyiv Polytechnic" can be considered the first integrated innovation ecosystem created on the basis of a university in Ukraine. The structure of the Innovation Ecosystem Sikorsky Challenge is shown in Fig. 3.

Innovation Ecosystem Sikorsky Challenge includes [33]: Startup School, Business Incubator, Festival of innovation projects, Innovative technological environment "Sikorsky Lab", Center for Intellectual Property, Venture Fund.

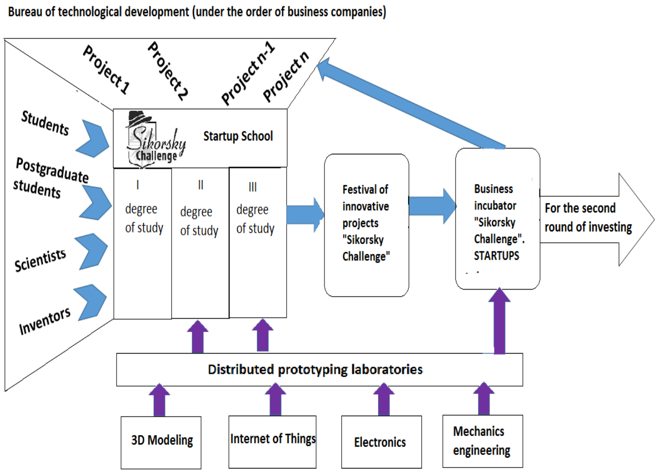

Fig. 3. Sikorsky Challenge scheme of training and incubation

Innovation Ecosystem Sikorsky Challenge implements the full technological cycle of innovative entrepreneurship: from searching for new ideas to attracting investments to create an innovative product. For this, the ecosystem Sikorsky Challenge attracts creative youth, inventors, scientists and students of the Igor Sikorsky Kyiv Polytechnic Institute and other universities. Selected participants are trained in innovative business enterprises. The training is designed to result in technological and business ideas of the students. Sikorsky Challenge School assists participants in project development and prototyping business products and seeks investors / business angels to invest in promising ventures. To find and engage investors Sikorsky Challenge festival is held annually, where a competition for innovative business projects with participation of coaches, experts from foundations, investors and business angels is conducted. Innovative Ecosystem Sikorsky Challenge assists investors, in the initiation and launch of start-up companies. It also helps with registration of copyrights, patents, licenses, making start-up companies international and provides legal, organizational, and accounting support to start-up companies in the second round of investments.

Prominent Ukrainian and international companies, such as Boeing, benefit from the Sikorsky Challenge ecosystem services. As an advantage of the Sikorsky Challenge innovation ecosystem, the founders and leaders acknowledge the high flow of students, graduates, postgraduates and researchers; scientific & technological and infrastructural support for innovators by the university's departments; availability of opportunities for creating start-ups in various fields of science & technology and industry, not just IT; high level of project management, which is exemplified by one of the most renowned innovators of Ukraine rector M. Zgurovsky; unique methodology of nurturing start-ups and innovations.

Since 2012, more than 80 projects presented at the Sikorsky Challenge have received investment support. In 2018, the start-up school model was expanded to 10 regional technical universities of Ukraine. Analysis of 175 projects submitted in 2019 demonstrates balanced distribution across different sectors and fields. More than 50% of applications are aimed at the industrial sectors of the economy. The overall experience and growth of the Sikorsky Challenge innovation ecosystem allows us to classify it as the first comprehensive and successful industrial high-tech innovation ecosystem based at a technical university. The proposed Sikorsky Challenge ecosystem model appears to be considerably more balanced in comparison with other sectors of the high-tech industry.

Elements of the educational ecosystem can also be found in the corporate university created by IT Company SoftServe [34] for cooperation with the Lviv Polytechnic University. Within the framework of the SoftServe corporate university, a number of projects are in progress. There are Talent Development Center (training solutions for talented people who are beginning their career in IT); Business School (training solutions for advancement of leadership and management competencies); Technology school (teaching solutions for development of technical skills and competencies); Intercultural communication centre (improving the level of proficiency in national and foreign languages); Certification centre (international certifications from Microsoft, Oracle, PMI, Amazon, Salesforce, iSQI); training excellence centre (implementation of the best methods and efficient tools for teaching management based on international trends and innovations); the e-learning team (development of distance learning solutions for specific business cases, creating media content for educational programs). Here are the activity indicators as of 2020: 1150 unique educational solutions, 15000 participants of educational programmes, 5100 graduates, 5300 certificates issued.

The Innovation Technology Centre launched at the V. Hetman National Economic University by IT-Enterprise Company [35] provides students with the opportunity to acquire the necessary practical skills in business management. The training programs at the Center are developed by IT-Enterprise specialists and draw on the vast experience of the company both in Ukraine and in Europe. The training programs include the complex ERP solution for the management of an enterprise, namely: modern IT solutions for systematic work organization; accounting of public and private enterprises; online procurement and tendering procedures; Industry 4.0 solutions for Ukrainian enterprises.

As an example of a technology ecosystem, let's review the fast-growing Ukrainian IT sector, whose ecosystem encompasses around 1,300 start-ups, investors, accelerators and investments. The Ukrainian IT sector is valued at 4.5bn USD in exports with approximately 160,000 IT specialists employed by over 4,000 companies. According to the report by StartupBlink in 2020 [36] Ukraine was in the 29th position among the top 30 best eco-systems all over the world. The Ukrainian ecosystem consists of 7 cities. Kyiv as a start-up city has risen rapidly to the 32nd position (from 63rd in 2018) among 100 cities, ahead of the start-up ecosystems of Helsinki, Munich and Dublin. Kyiv is now ranked 10th among European cities.

VII. Discussion

In this article, authors have presented the hypothesis of ecosystem approach to education aimed at the development of digital economy and society. The educational ecosystem is analyzed using a systemic approach and considering the interaction between the subjects of the educational process (students, teachers) and the educational infrastructure objects. The cluster model, which is the basis of the educational ecosystem, is designed to implement the interaction of educational and scientific institutions, industrial companies and business structures, government and public organizations to solve problems in education efficiently and optimally.

Today, digital innovations in Ukrainian education are limited to the use of information and communication technologies (ICT) in the teaching process of educational institutions and the use of ICT in the management and development of the infrastructure of higher education institutions. The main disadvantages of the Ukrainian educational system, despite numerous reforms in the context of digital ecosystems, are as follows:

- the lack of implementation of intelligent systems in education in line with the trends of digital industry development (IoT, artificial intelligence, machine learning etc.) Theoretically, such technologies are being studied, but they are not used by educational institutions in practice;
- the non-constructive role of regulators (the Ministry of Education and Science and the National Agency for Higher Education Quality Assurance), the interaction with which is difficult due to bureaucracy;
- lack of genuine steps towards the development of creative skills of students and their motivation to study. Consequently, the results of the Programme for International Student Assessment (PISA) assessment of the Ukrainian pupils' educational achievements show that the quality of education in Ukraine is below the average for OECD countries in all areas of education: reading, mathematics, science and natural sciences.
- limitation of the student-centered education paradigm to the creation of an individual educational trajectory through the selection of courses from the provided list of disciplines. No changes in the direction of development and creation of new forms and methods of education, competency development technologies, in accordance with the current trends of Industry 4.0, have been made.

Therefore, a number of issues remain relevant. How to encourage the educational system to follow the dynamics of sustainable development with a focus on the formation of digital skills according to Industry 4.0 trends? How can students be motivated to engage in creative and self-directed intellectual work when rigid education laws and standards are in force, and failure to meet these standards can result in higher education institutions losing their licenses for educational activities? How to determine the value of the educational program under conditions of severe centralization and the necessity to follow the current trends of economic and social development? How can the processes of adaptability and self-organization of educational process be implemented?

To solve the above-mentioned problems in Ukrainian education, the authors find it advisable to create digital educational ecosystems that can adapt to the rapid changes of educational content, forms and methods of teaching, modern trends in digital economy, and effectively cooperate with business and government.

VIII. CONCLUSIONS

The feasibility of changing the educational paradigm to meet the requirements of Industry 4.0 has been established. The model of industrial innovation ecosystem is examined and it is shown that only the IT sector in Ukraine meets the requirements of Industry 4.0 strategy. It is imperative to develop and implement an innovative educational ecosystem model in Ukraine. It has been proved that ecosystem approach to education can manifest great effectiveness and efficiency compared to traditional hierarchical models. The components of the innovative educational ecosystem and mechanisms of interaction between the subjects of the educational ecosystem are revealed. The conceptual model of digital education ecosystem based on education and production clusters as a universal model of collaboration of complex nonlinear systems was created. Implementation of the innovative educational ecosystem model is illustrated by examples of innovative ecosystems Sikorsky Challenge, SoftServe Corporate University and IT-Enterprise Innovation Center. Directions for further research: Monitoring of innovation infrastructure facilities of Kyiv region, development of platform for interaction with graduates as agents of influence and sources of examples of success, development and maintenance of alumni, investors, experts, students database to manage the alumni association and networking activities.

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Networking in Smart Cities: Qualitative Analysis for the Demand-Oriented Development of a Care Platform

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***Abstract*—Smart Cities are considered to have the potential to improve the quality of life of the population. Besides, they offer numerous opportunities to shape social coexistence in a meaningful way and to network people and organizations within a Smart City, thus also counteracting loneliness to a certain extent. In this context, a care platform could promote exchange in a Smart City, reduce administrative processes in the care sector and contribute to more efficient provision of the limited resources in the health sector. There are already several care platforms in Germany, but none of them have yet been fully implemented. An important factor for the successful implementation of a care platform is the involvement of the people and organizations within a Smart City. The needs of the future users, i.e. people in need of assistance and their relatives, can provide important impulses in the development of the platform so that it provides real added value for the people and is used accordingly. On the other hand, the involvement of the providers, for example, service providers who offer their services on the platform, is also crucial, as this is the only way to create a network. This paper presents the results of qualitative analysis to determine the needs of potential users and providers of a care platform. The results serve as a basis for the further development of the platform.**

Keywords—smart city, care platform, user-oriented development, qualitative analysis, demand-oriented development, networking

I. Introduction

The technical term Smart City refers to digital measures and strategies that contribute to an increase in the quality of life of the population [1]. Also, the exchange between the various actors within the Smart City is to be made easier and more efficient [2]. With the development of a Smart City, the cities hope to achieve high potentials and chances for social coexistence [3]. For this reason, Smart City projects are increasingly being promoted worldwide. In 2019, for example, around 104 billion US dollars (USD) were invested in Smart City initiatives worldwide. Investment sums of 124 billion USD are expected for 2020, 158 billion USD for 2022, and 189.5 billion USD for 2023 [4]. In addition to other thematic priorities, Smart Cities have increasingly focused on the health and care sector in recent years [5]. After all, demographic change in particular poses major challenges for municipalities [6]. The growing demand for care and support services is confronted with both financial restrictions on municipal budgets and supply-side obstacles due to the shortage of skilled workers [7]. Nursing care in Germany is a very complex system, which poses challenges for both private individuals and organizations. The first step is to determine the severity of care needed by a person on-site and to apply for a degree of care. The degree of care can be between 1 and 5. As the degree of care increases, a person also has higher claims for care allowance and benefits in kind [8]. Besides, the level of benefits varies according to whether a person is receiving outpatient or inpatient care. Care at home is becoming less and less frequent, as people more often live in 1-person households and their children rarely live in their neighborhood [9]. Neighborly cohesion has also declined, especially in urban areas [10]. For this reason, cooperation with professional care services is more often required [11]. However, these do not always have to take over the care completely but can also be called in to support private care in everyday life. This can relieve caring relatives, such as working women, who statistically often take on these tasks [12]. Situations that caregivers take on in everyday life range from support in the household to shopping, the completion of bureaucratic tasks to physical care [13]. If a private nurse cannot perform these tasks due to time constraints, the person to be cared for can fall back on the support of the nursing service. Even if the living environment of the person in need of care no longer matches his or her restrictions, subsidies can be applied to adapt the living space [8]. The possibilities of requesting support are manifold and characterized by a high bureaucratic effort and require a high level of information knowledge so that many services are not taken up [14]. On the other hand, a high level of administrative effort is also incurred by the nursing care service providers in addition to their actual work [15]. As a rule, they do not bill their services to the person in need of care, but directly to the nursing care insurance funds by documenting and billing all services in detail [8]. If the services provided by the nursing care insurance fund are not sufficient for the services required, the nursing care service provider must also settle accounts with the person in need of care himself or herself or his or her relatives [16]. If care services are needed immediately due to a sudden event, the

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care provider must first pay in advance. The person can then invoice the services in part only weeks or months later [8]. It is, therefore, only logical that a solution to the increased need for care should be created in the area of smart cities, with the help of which, for example, the available resources in the health sector can be provided more efficiently [17]. One approach to this is the development of an innovative care platform that creates a network both in the digital and social areas within a Smart City in order to improve the quality of life of people in need of care and to enable them to stay in their own homes for longer [18]. The paper serves to present the results of qualitative analysis for the demand-oriented development of a care platform, which was carried out within the framework of the Smart Care Service project funded by the EU and the State of NRW. The research provides initial insights into the demands of people in need of care or assistance and their relatives. Furthermore, they reflect the views of care and service providers, but also volunteers. They show how networking within a Smart City could be designed and how a needs-based care platform could be created. Also, possible reasons are given why a platform has not yet been established. Related works to this paper are published by Wang et al. [19], Li and Huand [20], and Wutzkowski and Böckmann [21]. These papers examine care platforms, but the focus is not on the demands of users and providers as it is the case in this paper.

II. Research Design

This chapter explains the research design for the qualitative analysis. For this purpose, the kind of the conducted interviews, the preparation of the interview guide, the selection of the sample, and the conduct of the interviews are explained. Besides, a description of the sample is given to gain an insight into the interview partners.

A. Expert Interviews

In order to find out what specific wishes people in need of assistance and their relatives have on the one hand and providers of products and services on the other, and how their lives could be improved with the help of a care platform, qualitative guideline-based expert interviews were conducted. This method is characterized – in contrast to standardized interviews – by a higher degree of openness, which is intended to enable a more impartial understanding of the respective views of the interview partners [22], [23].In qualitative social research, the term guideline interview is understood as an umbrella term for different types of interviews, which have one thing in common: the survey instrument used, the guideline [24]. The expert interview is regarded as an "application-field-related variant of guideline interviews" [24] and is characterized by the fact that the interviewees themselves are less of interest for the survey, but rather act as representatives of their profession or field of action [11]. This approach was considered particularly promising in terms of pursuing research interest.

B. Preparation of the Interview Guide

The questions for the interview guide were compiled and structured using the SPSS principle of guide creation according to Helfferich [22]. This method was used to ensure a certain openness in the interview without losing the necessary structure. The interview guide consists of 32 questions divided into 8 categories. Depending on the survey group, it has been slightly adapted. However, the guidelines for interviewing experts in one topic area are identical to ensure that the interviews can be compared afterward [22], [25].

C. Selecting the Sample

Once the survey method had been determined, the interview partners had to be selected. Following Kruse's [24] remarks on qualitative representation, an attempt was made to consider the heterogeneity of the research field in the case selection and to depict it qualitatively, even though it was not statistically representative. Since a theoretical sampling was not suitable for the research project here due to the limited time frame [24], a selective sampling was carried out instead. This approach is characterized by the fact that the structure and criteria for selecting interview partners are determined in advance. In total, between July and November 2020, 15 persons with many years of experience in the areas of voluntary work, counseling services, nursing care insurance, nursing care services, etc. were interviewed.

D. Conducting the Interview

Most of the interviews were conducted face to face in a protected atmosphere on the experts' premises and recorded with a dictating machine for later transcription and supplemented by handwritten postscripts [25]. Due to the special request of an expert, an interview was conducted by telephone and documented as an audio file. None of the interviewees had any objections to the recording of the interview after the purpose and handling of the data had been clarified [24]. Following the requirements of the European basic data protection regulation (DSGVO), this could be recorded in a data protection declaration drawn up specifically for this purpose. The duration of the interviews varied between 45 and 90 minutes depending on the interviewee.

E. Sample Description

Between July and November 2020, a total of 15 persons with many years of experience in various fields were interviewed. Fig. 1 shows the areas from which the experts were selected.

Fig. 1 Composition of the Sample.

The composition of the sample is quite complex. The experts in the field of care services are experienced in the care of senior citizens as well as especially in the care of younger people in need of care such as children and young people and people with disabilities. The experts in the field of care and social counseling are in daily contact with people in need of help and their relatives. They are advised in person or by telephone about care and service offerings, financial support options. It turned out that the counseling services are offered on a very small scale, so that, for example, a city with about 588,000 inhabitants and an area of about 280 km² offers twelve counseling centers for senior citizens financed by the city. Besides, an expert from the health and nursing care insurance sector was interviewed. This expert has many years of experience in this field and knowledge of billing processes and the possibility of the insurance companies' participation in a care platform. Experts were also interviewed from the field of housing counseling; whose target group is primarily people with illnesses or disabilities as well as senior citizens and their relatives. The experts from the field of volunteer organizations deal with people who want to become volunteers. They bring the persons together with the appropriate organizations. The organizations that are looking for volunteers are non-profit associations or foundations as well as non-profit companies. An expert from the financial services sector was interviewed who works in a company that specializes in billing processes. Accounting and administrative processes that will arise between doctors, patients, health, and nursing insurance companies and care services are handled by the company when commissioned. In an additional survey, a senior citizen representative was interviewed who represents the interests of the older generation in political committees and all institutions that are important for senior citizens and who is also the contact point for people aged about 60 and older. The experts from the field of mail-order pharmacies have expert knowledge in setting up and designing a platform as well as in the areas of target-group-specific addressing and customer conditions. They also represent potential providers who may also be represented by a care platform. The sample presented is thus diverse and can be considered highly qualified concerning the objective of the survey.

III. Results

The following chapter serves to describe the results of the qualitative analysis.

A. Needs and Challenges of Potential Users

The interviewed persons described the current offers for persons with assistance need as very perplexing. Especially when people need immediate help, for example, due to an accident or a sudden event, the market is difficult to understand for both the person in need of help and their relatives. There is, therefore, a need to support these people quickly and to put them in touch with suitable service providers on-site who still have capacities. This requires easy access to precisely tailored, bundled, and understandable information, to products and services that can be taken advantage of, and to subsidies from the nursing care funds and social welfare offices that can be applied for. At present, there is also the problem that legal texts, for example on applying for financial subsidies and a degree of care, are seldom understood by those affected and their relatives, who would therefore like to have an overview of the required information in an easily understandable language. The application for services and subsidies as well as the processing of contracts would also often still take place in an analog form so that a digital processing of the processes and thus faster feedback on prices, capacities, subsidies, etc. is desired. The communication of price structures when applying for services is often very intransparent so that more transparency is required here. An illustration of the information that is important for a person with additional pictures or videos was considered helpful. In addition to senior citizens in need of care, there is a need for advice and information from younger people in need of care, people with disabilities, and people who do not yet have a degree of care but still need assistance or need support in applying for a degree of care. For these target groups, there are currently only insufficient contact points. These groups of people are interested in a holistic care platform, as their Internet skills may be more pronounced. Besides at present a holistic care platform, which goes beyond the care topics and makes for example the reservation possible of low-threshold or household near services, like purchase services, medicines, driving services, etc., is missing. There is also a lack of social contacts and opportunities for communication and exchange between people in need of assistance and their relatives. Regarding a holistic care platform, the respondents emphasized that it should have a user-friendly layout, use a comprehensible target group-specific language and be easy to use. Furthermore, a personal contact person should be available for any additional questions.

B. Needs and Challenges of Potential Providers

The different needs of the providers resulted from the various interviews. This also included that all necessary information should be available in an easily understandable form This includes, for example, explanations of the healthcare insurance system, clinical pictures, or care facilities. A further advantage would be for offerers, if one could refer potential customers to this platform, to find a fast overview of suitable offers and information. The reduction of the temporal expenditure by customer contacts over e.g. telephone calls or consulting times would be, therefore, a desirable effect. Besides, the platform can be used to record customer master data, which would be an additional time saving for the providers, since this information is already available in advance. The request for a simplification of organizational, bureaucratic, billing matters was mentioned several times. This should result in faster and more transparent processing of formalities, applications, and approvals. This is accompanied by a demand from the providers that there should be compatibility with the different systems on the platform to implement the interfaces. An advantage of such an integrated platform would be that it would be easier to compensate for employee absences (due to illness, vacation, etc.) via the platform. The refinancing of the consultation by the platform would be a further point since at present the consultation is made free of charge in most cases. The care system should be described in a way that is understandable not only for the users but also for the nursing staff on the platform. The effect would, therefore, not only provide an advantage for the users and providers, but also for the employees who want to inform themselves about certain topics.

IV. Conclusion and Discussion

The results of the qualitative interviews give a good insight into the needs of persons in need of care or assistance and their relatives who are not yet covered by other existing solutions and platforms. In addition, they reflect the views of care providers and service providers, but also volunteers. They show how networking within a Smart City could be designed. Also, the results provide valuable information on how a needs-based care platform should be designed. Here, the networking of people with each other and with the corresponding service providers plays a decisive role. Potential users also want to have the opportunity to network with other people who may be in a similar situation to themselves and to exchange and communicate with them. In addition to information that should be easily prepared and tailored to the needs of people in need of assistance, there is a need for both sides to reduce and make more efficient the administrative workload. As a result of the surplus demand in the care sector, providers do not currently feel compelled to actively look for customers; on the contrary, they have a long waiting list of customers that they are currently unable to serve. It has, therefore, turned out that the involvement of potential service providers is very useful, as they only become active on a platform if it brings them a direct benefit and, for example, reduces their workload. Despite the extensive results of the qualitative study, there is still a need for research on the part of potential users, i.e. persons in need of assistance and their relatives. Because of the statutory corona requirements that will apply in Germany in 2020, no potential users were interviewed personally to avoid endangering them. Instead, experts were interviewed, who deal with this group of people daily in their work. As there were many people among the interviewees who were asked for advice and help by people in need of assistance, they were able to reflect the needs of this group of people well in the interview due to their many years of experience. In the further course of the project, however, the potential users were also to have their say in person to compare the results once again and, if necessary, contribute new impulses. The results from the interviews will continue to be reflected in the exchange with the project partners and used selectively to improve the platform. There will also continue to be ongoing feedback from respondents.

V. Short Outlook

Based on the results of the qualitative analysis a care platform is to be developed, which orients itself at the determined needs, to create so an increase in value opposite existing care platforms. Besides in the course of the development process, again and again, different participants both on the user and on the offerer side are to be included, to receive new impulses and ideas, besides, important references to problems, to the use, etc. This is also decisive later for the acceptance and readiness to use the platform. Accordingly, a platform is to be created that enables networking between people in need of assistance, their relatives, service providers in the vicinity, and volunteers. Also, the platform should provide suitable information already filtered and in an easily understandable language. The services that are relevant to the platform from the needs of users and providers are therefore bundled well-prepared, and easily understandable information. Pictures or videos, for example, in which the information can be presented, are also suitable for this purpose. The aim of the services should be to simplify and reduce the administrative, billing, and bureaucratic workload. The platform should also offer communication, exchange, and networking opportunities, be target-group specific and offer interfaces to other already known platforms.

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Smart Competences for Smart Citizens

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***Abstract*—Applying technology for solving urban issues and improving the quality of citizen's life are significant features of smart cities [1]. In the current literature on smart cities, it is already recognized, that digital citizens are one of the critical success factors for digitalization of smart cities [2] [3]. However, the literature focuses on technical aspects of smart cities' digitalization, although human factor or people are the key factor for a project success. Especially, in such projects as smart cities, where the quality of people's life belongs to the definition of smart city itself. Smart cities imply high technological complexity. Does it have an impact on the competence level of their citizens? When one uses a calculator for a long time, one's capability to count in mind reduces with the time. Will smart cities have the same impact on their inhabitants, or, to ensure cities' functioning, "smarter" citizens would be important? In this paper, the author represents an analysis of literature on related factors of "smart" citizens and suggests the smart citizens' competence profile.**

Keywords—smart citizens, smart cities, smart city projects, smart citizens' competences

I. Introduction

Smart cities research area is bound to integrate diverse disciplines, including engineering and computer sciences as well as social sciences [4] [5], in order to manage urban issues in efficient and sustainable ways [6] [7].

Among different existing definitions of the smart city, the Caragliu et al. definition is used in this research. A city can be defined as smart if "investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance" [8].

Molnar's extended literature review showed that there is a lack of educational initiatives to address the needs of smart cities [9]. Education of citizens is one of the key components of a smart city and essential for its future innovations processes [10].

Axelsson and Granath developed a framework to analyse and to evaluate smart cities' planning project outcomes and stakeholder's contribution [11]. Moreover, people as social capital have been mentioned as a part of some smart city definitions [12] [13] [14].

The need to reinforce citizen's skills and competence, so that they are better engaged and support locally developed technologies is highlighted in the research by Kummitha. The researcher studies human-technology connect in smart cities and offers such aspects further research as organisational, social and multi-level interactions. The role of local authorities and communities as users is studied along with the need to promote their engagement in the development and appropriation of technology. [15]

In order to measure technology anxiety, work–life interface, engagement orientation, support orientation, and quality of life, corresponding competences in socio-psychological field might be required. However, the literature analysis reveals that most publications on smart cities appear from computer (57,8%) and engineering (35,5%) sciences. Only each fifth article highlights smart city development from the social science's point of view. [5]

The analysed project management related literature (i.e. the International Journal of Project Management and the Project Management Journal) seem to miss any relevant researches or considerations on how citizen competence development can be planned for smart city development projects.

In this paper, a notion of a competence profile is used from the competence management science. Competence management exercises the term of a competence besides other purposes for people development needs [16]. A competence profile is a set of individual competences. Competence profiles became a common tool not only for job descriptions, but for competence development plans, too. In general, there are two distinctive approaches used for the term of 'competence'. The first one refers to the outputs, or results of the training (also called 'job-task competencies') and is called 'competency'; the second definition refers to the inputs, required of a person to achieve competent performance, namely 'behavioural competencies' and is used as 'competence' [17]. The output approach implies more detailed definitions of a competency, whereas, the input approach offers shorter definitions rather on a meta level. As the subject of smart citizens' competences appears to be a rather underexplored area, the author chose to operate with competences in their input form. In other words, competences of smart citizens are defined at this stage of the research at their meta level.

In this article, the author introduces the competence profile of smart citizens, outlining competences that have to be studied across all sciences to prepare future citizens for a qualitative and sustainable life in smart cities. The research methodology is based on the literature review and the system analysis, where smart cities are approached as a system of complex technical, social and human factors within a smart city's life cycle.

II. Literature Analysis

A. Engagement and Participation

In the context of smart cities, technology is meant to support the process of citizen participation [7][18][19] [20].

Lytras et al. proposed five distinct dimensions: technology anxiety; work–life interface; engagement orientation; support orientation; and quality of life, in order to measure citizen's perceptions on smart city services and applications, aiming at enhancing the decision- and policy-making processes [4].

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These dimensions point out, in turn, at the psychological aspect of the citizens' competences.

Guimaraes et al. studied the influence of smart governance factors on quality of life in the context of smart cities. This research highlighted the significance of transparency, collaboration, participation and partnership, communication and accountability in relation to smart cities. [21]

Special attention has to be devoted to designing of citizen participation based on each city's specific context. Here, participation strategy plays a big role, having to be adapted to five contextual factors, such as the smart city consideration, the drivers for participation, the degree of centralization, the legal requirements, and the citizens' characteristics. [20]

Citizen's participation level might be compromised in case there is a gap between citizens' and authorities' perceptions on smart city's challenges. Such gap has to be detected and respective smart city development programme has to be justified. [22]

Staletic et al. addressed citizen participation in the developing countries, highlighting that in those smart city development is not yet fully aligned with smart city standards. Their research provided results on acceptance of e-participation services, which requires citizen engagement, varies from city to city and have to be supported. [23]

Giffinger et al. clustered characteristics and factors of a smart city in six areas, among them are "smart people (social and human capital)". This area was described through the following characteristics and factors: level of qualification, affinity to life-long learning, social and ethnic plurality, flexibility, creativity, cosmopolitanism/open-mindedness, and participation in public life. [24]

B. *Cyber Security Issues*

Privacy and security issues were defined as one of negative results of smart city development [7] [2].

Colding et al. considered security issues as of high priority for smart city development. The researchers stated the need of a security policy on different levels (logical, organizational, and physical) which would be conducted through preventive, detective and responsive actions. [5]

Respect for information rights of a person is considered to be another common challenge in ensuring smart city citizens' cybersecurity. It is recommended to protect information rights through such measures as "ensuring of cybersecurity for smart cities at the level of national cybersecurity strategies", "approval by the authorized central executive body of the national standard of smart cities' cybersecurity", etc. [25]

C. *Smart mobility competence*

Smart mobility represents another inevitable part of smart cities, including e-ticketing, e-parking, live-tracking, etc. as well as autonomous vehicles one day [2] [13].

Surdonja et al. research showed that smart citizens' transportation habits have to be consciously developed towards sustainability [13].

D. *Civillizational competences*

Zait explored intangible components of smart city development and highlighted their importance. The intangible components have an impact on all classical dimensions of smart cities such smart economy, people, governance, mobility, environment, living. The author elaborated on civilizational competences, soft skills or human-related characteristics of cities that are affected by culture to a major extent. Here, culture has to be considered at many levels such as national, regional, organizational and individual. Zait grouped civilizational competences in four categories: enterprise culture, discursive culture, civic culture and daily culture. Their detailed definitions, related factors and measurement methods are to be researched further. [14]

Thus, civilizational competences for a particular smart city project will reflect the uniqueness of the existing citizens' culture. In other words, smart city solutions applicable for a culture of a megapolis in China will differ from those applicable for a smart city in Holland.

III. Smart Citizens' Competence Profile

The literature overview provided above showed that competences necessary for smart citizens are as following:

- engagement and participation,
- cybersecurity,
- smart mobility,
- civilizational competences.

These competences are defined as a smart citizens' competence profile.

Due to the lack of research and empirical evidences, the competences are fist elaborated on the meta-level. A further elaborated research is necessary to analyse and define respective sub-competences that would make smart cities' citizens "smart" indeed. However, certain assumptions based on the literature review are discussed below.

Engagement and participation requires transparency, collaboration, communication, flexibility, and accountability from smart citizens. A greater need of conscious and willingly participation in a testing phase of smart city development is stated in the literature, too, which means co-design and co-creation from the side of people. All these facets conform to the agile mindset competences and values [26] [27]. Accordingly, agile soft skills might be another required set of competences for residents of a smart city.

Cyber security issues and information rights mean that smart citizens have to become educated in cyber security legal aspects, as well. In other words, it means legal awareness of rights and duties in respect to smart city cyber security.

Smart mobility aspect addresses a need to enhance the understanding of sustainable development with its participative and proactive attitude. Digital solutions in a smart city should easily understood and accepted by the end-users. Moreover, usability peculiarities for elderly and handicapped people, as well as, for tourists from other (rural) areas have to be taken into account.

Cultural aspects and cosmopolitanism are mentioned as necessary for citizens' engagement and participation, pointing out to civilizational competences that would add to smart residents' competence profile.

IV. ICB Competences In Relation to Smart Competences

The mainstream competence-based project management standards, such the IPMA Individual Competence Baseline (ICB) [28], PMI Project Management Competence Development (PMCD) framework [29], and the Australian Institute of Project Management's (AIPM) Professional Competence Standards for Project Management [30], were reviewed in order to define any correlations to the competences detected in the previous chapters. As those standards are not tailored to a specific type of projects, for example, digital transformation or, especially, smart city projects, no direct overlaps were found. However, the ICB competences and their elaboration showed some correlation to the defined smart citizens' competence profile and, therefore, were analysed.

ICB offers the Eye of Competence, splitting competences into three areas: Perspective, People and Practice [28] . Based on the defined competence profile the author analysed ICB competences and their application for a smart city project. The following ICB competences [28] were defined as relevant and elaborated further in this chapter:

- Perspective 1: Strategy
- Perspective 3: Compliance, standards and regulations
- Perspective 5: Culture and values
- People 4: Relationships and engagement
- Practice 12: Stakeholders
- Practice 13: Change and transformation

ICB competence 'Perspective 1: Strategy' requires an "alignment with the strategy and the vision" and "the mission and the sustainability" [28]. Each of the defined meta-competences - engagement and participation, cybersecurity, smart mobility, and civilizational competences – is important to ensure the sustainability of smart city projects.

ICB competence 'Perspective 3: Compliance, standards and regulations' "interprets and balances the external and internal restrictions in a given area such as country, company or industry", "including legislation and regulations, […] safety, security and environmental protection and professional standards" [28]. As stated, a smart city project has to take into consideration not only cybersecurity issues but also a need to develop the cybersecurity competence for smart citizens. Thus, respective compliances and regulations have to be developed and implemented.

ICB competence 'Perspective 5: Culture and values' is about integration of "the influence of internal and external cultural aspects on the project approach, objectives, processes, sustainability of the outcomes and agreed outcomes" [28]. Civilizational competences correspond to this ICB competence.

ICB competence 'People 4: Relationships and engagement' highlights the need to build "the foundation for the productive collaboration, personal engagement and commitment of others" as well as "sharing visions and goals with individuals" [28]. This competence directly corresponds to the engagement and participation competence.

ICB competence 'Practice 12: Stakeholders' "includes identifying, analysing, engaging and managing the attitudes and expectations of all relevant stakeholders" [28]. This ICB competence plays an essential role and explains the system approach used for developing of the smart citizens' competence profile. Smart citizens are one of the key stakeholders in smart cities projects. Their role cannot be underestimated and explained in Chapters I and II. This ICB competence coincides with the engagement and participation competence and, thus, ICB competence indicators can be applied for smart city projects.

ICB competence 'Practice 13: Change and transformation' states that "newly developed capabilities only deliver benefits when they are put to use and when they are supported by the organisations and the people receiving them" and it is important to "help individuals and organisations to make successful personal and organisational transitions resulting in the adoption and realisation of change" [28]. This ICB competence, again, represents the part of the applied system approached. In every smart citizen project is important to plan and control, how exactly smart citizens will be affected through changes and transformation caused by the 'smartization' and how their competences will be developed. Therefore, three competences - engagement and participation competence, smart mobility and civilizational competences - are related to the ICB Competence 'Practice 13: Change and transformation'.

The correlation between smart citizens' competences and ICB competences is presented at Fig. 1.

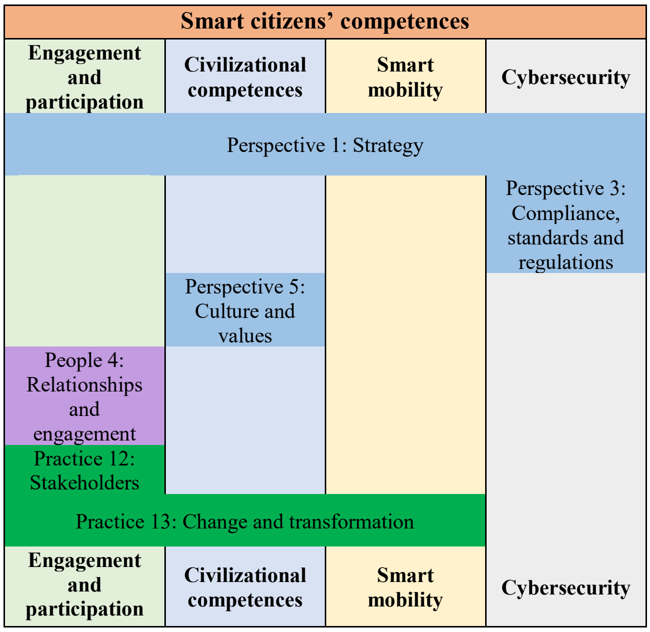

Fig. 1. Correlation between smart citizens' and ICB competences.

Thus, ICB offers a few competences that can be relevant for smart city projects and engagement of smart citizens. The smart citizens' competence profile defined in Chapter III and ICB competences can be combined. For example, the smart citizens' competence profile can be used as a smart city projects' specific extension of the ICB standard.

V. Conclusions and Further Discussion

In this paper, the author provided evidences from the literature analysis, that smart cities' high technological complexity implies the development of additional competences from the side of smart cities' residents. Project management related literature shows a lack of research on which smart citizen competences should be planned for smart city development projects to ensure their success. The overview of related to smart city researches across different disciplines shows that mainly computer and engineering aspects have been studied. Nevertheless, the social aspect is discussed, too, and the need for smart citizens' participation and engagement was recognized.

The conducted literature overview provides for the evidences and factors on the following smart citizen competences that seem to be important: socio-psychological, agile, sustainable development, legal awareness, and civilizational ones. However, there are no clearly defined competence profile for smart citizens. The author developed a meta-competence profile for smart citizens based on the interdisciplinary literature review of computer, social and project management sciences. This competence profile was defined at a meta-level, as there is no evidences and research materials to define concrete and elaborated 'sub' competences, yet.

The smart citizens' competence profile is based on a hypothesis that technological complexity of smart cities can be successfully supported and maintained by its biggest end-user group – smart citizens – through the development of their respective competences. This hypothesis is a theoretical assumption based on the literature review and the system analysis, where smart cities are approached as a system of complex technical, social and human factors within a smart city's life cycle.

Furthermore, the ICB standard were analysed as it provides a range of the competences that are relevant for the smart citizens' competence profile.

The developed smart citizens' competence profile is to be proved by the means of empirical studies. The author suggests that such this profile in combination with the ICB competences can be proved in the form of a case study within existing smart city project(s). Moreover, further interdisciplinary research is required to elaborate the defined smart citizens' competence profile.

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Active History: Creating Sustainable Cities Through Heritage Trails

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***Abstract*—Sustainable city planning plays an important role in fighting climate change, and heritage trails are critical to this effort. Heritage trails are walking, hiking, and biking paths that link features of historical interest. Examples include paths in parks, trails connecting villages, and walking routes in the historic centers of cities. On its face, historic conservation is not a sustainable practice. Heritage sites can be constructed with non-sustainable materials, and they occupy valuable space that city planners could otherwise use. Heritage trails offer a solution. In addition to providing access to cultural sites, these trails are beneficial to the environment for two reasons. First, they promote emissions-free activities. Second, they are green spaces that offset carbon emissions. In order to create buy-in, constructing heritage trails should include a wide range of stakeholders from across the community.**

Keywords—heritage trail, smart city, city planning, green space

I. Introduction: Heritage Trails and Sustainability

Historical sites are an ongoing link between our past and present, telling the stories of our societies. According to the UNESCO Convention Concerning the Protection of the World Cultural and Natural Heritage (1972) monuments, groups of buildings, and sites that are of outstanding universal value are part of cultural heritage [1]. Access to culture and cultural heritage is a human right protected by international law [2]. Additionally, around the world, historical sites are protected by local and international statutes that urban developers cannot ignore. Therefore, heritage protection is a critical part of the city planning process.

Fortunately, the protection of important cultural sites can be integrated into city planning through the inclusion of heritage trails. Heritage trails are walking, hiking, and biking trails that link features of historical interest and offer multifaceted benefits. The green spaces on heritage trails protect local flora and fauna, offset carbon emissions, promote sustainable leisure activities, connect communities, and conserve important historical landmarks by encouraging "active history."

Active history is the combination of sustainable leisure activities, such as hiking and biking, with the viewing of historical sites. Being active while learning improves memory [3]. Because heritage trail users are actively engaging with their environment, visitors are more likely to retain what they learned [3].

Further, incorporating heritage trails into smart cities provides two key benefits. First, it encourages emissions-free travel, and second, it increases awareness of local history. Heritage trails provide expanding cultural heritage education through a more accessible platform for viewers. As urban tourism rises, heritage trails allow visitors to holistically engage with both local culture and important sites [4].

However, creating heritage trails requires cooperation between multiple stakeholders, including city planners, preservationists, archeologists, lawmakers, government agencies, and community members [5]. They must work together in order to build a community centered around sustainable living and providing modern uses for historical spaces.

"Smart cities" must incorporate heritage trails because sustainable living is holistic. When developing smart technology for sustainable city design, planners must integrate access to culture and physical activity that promote a high quality of life while increasing access to cultural heritage.

II. Methodology

This paper will present case studies from the United States, Ireland, and Croatia in order to highlight both the successes and challenges of incorporating heritage trails into areas attempting to achieve various sustainability targets. These examples are not exhaustive, rather they provide an overview of the different methods used in incorporating heritage trails into smart cities. Each case study provides a brief overview of legislative protection for heritage sites, a description of the sites, and lessons learned from the current manifestation of the heritage trail.

III. Planned Green Spaces: New York City

New York City is a major metropolis that stands out as the home of the most visited urban park in the United States, Central Park. The result of city planning, Central Park is a place where local and global history intersect. It contains numerous heritage sites, thereby connecting its historical past to the present and demonstrating how green spaces can connect heritage sites.

A. Legislative Control for Cultural Heritage in New York

In New York, federal, state, and local statutes control conservation. For federal projects, the National Historic Preservation Act regulates historic preservation law [6]. At the state level, The New York State Historic Preservation Act of 1980 declares historic preservation to be public policy, emphasizing accessible, public heritage [6]. Additionally, the State Environmental Quality Review Act ensures review of historic buildings [6]. Created in response to cultural heritage destruction, the NYC Landmark Commission predates both federal and state legislation [7]. With over 36,000 landmark properties, it is the oldest municipal preservation agency in the United States [7]. Theses acts control conservation of Central Park.

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B. Central Park: Planned Urban Spaces

In 1853, The New York State Legislative set aside 750 acres for America's first major, landscaped park. Designed by Frederick Law Olmsted and Calvert Vaux, Central Park now stretches over 843 acres [8]. Central Park is the third most visited tourist attraction in the world [9]. It receives 37-38 million visits from 8-9 million different people annually [10]. Thirty percent of its visitors are from outside the city [10]. The Park houses many famous locations, including the Metropolitan Museum of Art and the American Museum of Natural History. Archeological remains include the ruins of Seneca Village, once home to the largest community of African American property owners in the United States [11]. Visitors use walking trails, equestrian paths, and cycling lanes in the Park, providing a chance for people to view its sites while participating in active recreation.

As the "city's backyard," the Park requires significant upkeep. While expensive to support, the biodiversity of Central Park offsets the carbon dioxide of New York City. The Park is the "lungs" of the City, providing the City with a "gigantic natural air conditioner" [12]. As a result, it increases the City's oxygen levels from 20% to 40.6% and also moisturizes aquatic areas [12].

To ensure the Park's environmental, cultural, and recreational benefits, it is managed through a private-public partnership. While New York City owns the Park, the Central Park Conservancy, a non-profit organization that includes thousands of volunteers, manages day-to-day upkeep [11]. Interaction between stakeholders guarantees the continued success of Central Park.

However, in New York City, it is important to stay connected, even in the middle of a park. Therefore, Central Park contains numerous free Wi-Fi zones [13]. Further, on the surrounding streets, there are numerous LinkNYC kiosks which provide free Wi-Fi, the ability to make phone calls, phone charging, and public service announcements [14]. Free Wi-Fi zones provide visitors the ability to explore online resources for the Park in an accessible manner.

C. Lessons from Central Park

Although urban constraints prevent most cities from creating such a large, contained space, Central Park provides valuable lessons to city planners. First, pedestrian and bike paths can connect museums and heritage sites to green spaces, thus linking education to recreation. This connection encourages museum visitation in a more sustainable fashion. Using areas around museums and heritage sites as mini green spaces to plant trees and encourage biodiversity helps promote sustainability even where there might not be a large open space. Additionally, museums can expand their digital technology to share resources and develop interpretative exhibits for heritage trail visitors [15].

Second, multi-stakeholder investment helps protect heritage trails. Although protected by legislation, heritage sites and parks are usually publicly owned, so funding can be scarce. Creating public-private partnerships allows additional funding for day-to-day conservation. Further, multi-layered involvement helps ensure community support for the protection of heritage sites and allows for continued maintenance and guardianship.

Integrating technological access on heritage trails connects people. Adding Wi-Fi into green spaces complements a visitor's experience because mobile technology provides immediately viewable and accurate information. For example, mobile applications can provide access to information on local conservation efforts, local heritage sites, and local businesses.

Moreover, technology encourages active history engagement on a heritage trail. Location-based mobile content introduces a narrative for the trail by providing historical information [16]. Mobile platforms offer an inexpensive way for cities to provide heritage education to visitors. Extensive spaces such as Central Park could especially benefit from a centralized, historical narrative easily accessible on a mobile app.

IV. The Suck Valley Way: Translating the Landscape

While Western Ireland is not home to any major metropolises, there is a plethora of heritage sites nestled in and around small towns. In particular, the Suck Valley Way demonstrates the connective power of heritage trails. As such, smart cities can learn lessons from this rural heritage trail.

A. Legislative Protection for Irish Heritage Sites

Conservation in Ireland is dictated by a multitude of laws. There is "no single piece of legislation in Ireland, dealing exclusively with the protection of the built heritage" [17]. However, the National Monuments Act and the Local Government (Planning and Development) Acts protect historic sites. Moreover, developers must seek approval by the City Archeologist's Office for their plans [18]. In Ireland, there are around 750 national monuments in state care [19]. Moreover, there are over 138,000 records relating to archeological monuments with most of the monuments predating the 1700s [19]. Along its 105-kilometer route, the Suck Valley Way includes numerous protected sites.

B. The Suck Valley Way: Connecting Heritage to the Land

The Suck Valley Way winds through Roscommon and Galway counties in Western Ireland. While the Way is primarily a walking path, it includes areas for cycling, canoeing, and fishing. On the trail, walkers engage with different heritage sites, such as monuments from the Iron Age, religious and royal sites, and nineteenth century peat bogs.

A prime example of active history on the Way is Ballintober Castle in Roscommon, Ireland. Built in the early fourteenth century, the Castle serves as a symbol for the complicated relationship of a colonial landscape [20]. The Castle lies on the ancestral home of the modern-day O'Connor family. However, the Castle was built by the de Burghs, a powerful Anglo-Norman family that controlled most of western Ireland in the twelfth century. In the seventeenth century, the O'Connor family victoriously reclaimed the land around Ballintober as their seat of power. Today, visitors journey through the Castle's past. Directly interacting with this historical structure evokes the spirit of the ancestorial land. Walking the Way, visitors travel from Ballintober Castle to Clonalis House, the O'Connor family's current home. This piece of Irish history is brought to life; visitors physically connect to the heritage site in a way that books and pictures cannot.

Additionally, the Way is part of an initiative to increase tourism and economic regrowth to the inland areas of Western

Ireland. Supporting the Way is an ongoing project continued by the Roscommon County Town Council. Local government and civil support are critical to its continued sustainment. First, the Way crosses through private land, whose owners have opened their farms to visitors. Second, villages along the Way work collectively to showcase their historical sites and provide visitors access to local businesses. Third, in order to increase tourism, the Suck Valley Way website provides accessible information to visitors for the whole trail.

C. *Lessons from the Suck Valley Way*

While the Suck Valley Way is a rural trail system, it provides many lessons for urban planners. Foremost, it demonstrates the importance of community support for heritage trails and how to successfully encourage community partnership. Community members are key stakeholders in the planning of heritage trails. If they are not included, heritage trails could be seen as a negative addition. To avoid this issue, the Way showcases personal and local histories. By emphasizing local history, the Way creates community buy-in. Because the trail shares local history, communities want to use and preserve the trail.

Second, the Way is a model for sustainable tourism. Visitors access adjacent towns on foot or by bicycle. To further increase sustainability, cities can add low-carbon technology, such as water-recycling toilets or solar panels, to visitor centers and heritage sites [21].

Tourists want to be engaged by the sites they visit, so city planners should take advantage of heritage trails as educational spaces [22]. By viewing different cultural sites instead of seeing them in isolation, heritage trails connect visitors to engaging educational spaces. The active history on heritage trails can provide a deeper connection to cultural heritage. Tourists can not only see history but connect to it, while travelling in a sustainable way.

Next, although the Suck Valley Way stretches along rural countryside, cities often have distinct urban zones. Different areas of a city have their own history and character. Connecting different urban zones on a heritage trail allows communities to retain their individual identities while contributing to a larger sustainable project. Cities can showcase community history on heritage trails just as the Way allows visitors to access centuries of community history.

On the Suck Valley Way, once unused areas are now conserved for community gathering and tourism. Even heritage sites outside of the urban center become accessible when included in a heritage trail. Heritage trails that connect to the countryside provide access to large open spaces for a constrained city. Expanding a trail to heritage sites out of the city allows people to vividly envision the historical landscape.

V. Dubrovnik, Croatia: Traditional Sites on Sustainable Heritage Trails

The traditional Old Town of Dubrovnik, Croatia is a UNESCO World Heritage Site protected under international law. Designated a World Heritage Site in 1979, the Old Town reveals how a heritage site can be incorporated into heritage trails [23]. As of 2017, Old Town has been a point on the Ćiro cycling trail, a transnational heritage trail that connects Mostar, Bosnia to Dubrovnik, Croatia [24].

A. *International Protection for Old Town*

Croatia manages heritage conservation through The Cultural Property Protection and Conservation Act [25]. Because Old Town is a World Heritage Site, the World Heritage Committee mandates adequate conservation management of the site, additional regulations, and reporting of any changes made to the site [23].

In the 1990s, Dubrovnik and Old Town faced destruction from the Yugoslav Wars. The Yugoslav People's Army (YPA) shelled Old Town, damaging hundreds of its historic buildings and resulting in numerous civilian casualties [26]. This attack on a World Heritage Site shocked both Croatians and people around the world. Old Town's destruction led the International Criminal Tribunal for the Former Yugoslavia to declare cultural heritage destruction a war crime [27].

B. *Old Town: Cultural Heritage Protection as Economic Regrowth*

Throughout history, Dubrovnik has been an important port on the Adriatic Sea. Old Town showcases hundreds of years of history in the form of a preserved, medieval city. The newly created Ćiro heritage trail connects Old Town to the surrounding region. Specifically designed to both preserve historical sites and increase tourism, the Ćiro trail increases economic activity by providing access to less visited destinations [24]. Ćiro connects the urban area to the land, telling the region's stories.

While Old Town was a UNESCO site and tourist destination before the Yugoslav War, tourism has recently expanded. Every year, approximately two million tourists visit Old Town for its medieval history and recognizable sites from popular television shows and films [28]. This activity generates over nine million euros annually, greatly impacting the local economy [28].

The increase in tourism and film production revenue has allowed for the restoration of Old Town. However, this economic growth is not without its downsides. First, the high costs associated with tourism have forced some locals to leave the city [28]. Second, as tourism grows, tragedies experienced during the Yugoslav Wars are forgotten. Finally, the large volume of tourists and cruise ships cause environmental damage.

C. *Lessons from Old Town*

Dubrovnik is a prime example of how heritage sites and trails can encourage economic recovery. Old Town's lucrative model of increased tourism and exposure in film have restored the city. However, city planners must balance economic growth with locals' needs. Initiatives such as the Ćiro heritage trail can help by increasing accessibility to the regions surrounding congested tourist destinations. Heritage trails expand economic growth to smaller cities and towns, thereby improving locals' access to their own city.

Second, it is important to contextualize the role of tragedies, such as war, in the history of certain regions. In sites that have seen great tragedy, city planners must include space for local memories. If not, the community is no longer connected to the site. Heritage trails can include memorials at specific sites. These locations provide an important space for reflection and memory sharing.

Third, in order to be sustainable, smart cities must weigh the environmental impacts of tourists. The increase in tourism in Dubrovnik created negative environmental effects. Cruise ships are especially damaging, as they pollute the sea and overwhelm old infrastructure [29]. City planners must calculate the environmental risks of tourism with the economic benefits.

Smart cities should encourage tourism that leaves a smaller environmental footprint. The negative effects of tourism can be diminished by offsetting carbon emissions through creating “green beltways” [30]. Green beltways are densely planted trees and greenery that reduce carbon dioxide levels. Planting green beltways on heritage trails will offset carbon emissions in cities [30]. City planners can alleviate the environmental impacts of tourism to heritage sites by creating sustainable, green heritage trails.

VI. Discussion: Heritage Trails Around the World

A. *The Benefit of Heritage Trails*

The inclusion of heritage trails in sustainable city planning is beneficial to the wellbeing of the community. They encourage sustainable tourism, economic growth, and help create a sense of belonging. Additionally, they help protect cultural sites that are vulnerable to the effects of climate change and destruction from increasing urbanization. Therefore, city planners must manage limited urban green spaces carefully, in order to maximize their benefit.

B. *Further Research*

There are two key areas for further research. The first is exploring more heritage trail case studies in order to offer city planners more information. As previously stated, the three examples discussed in this paper are not exhaustive. One example of further research is in Budapest, Hungary, where running has been on the rise [31]. This sustainable and healthy habit has been encouraged by a 5,350-meter running track, which circles the ruins of a Dominican convent on Saint Margaret Island. The convent was constructed for Saint Margaret of Hungary and stands where she died in 1270 A.D. [32].

This combination of sport and historical conservation is innovative because the convent’s ruins were preserved. Budapest is a disconnected, sprawling city [33]. Trails like the running track on St. Margaret’s Island can provide space for connection. Further research of St. Margaret’s Island will be useful in the development of other sprawling, smart cities.

Second, further research on active history is needed. Examples of further research include surveying heritage trail visitors on their experience. The survey should ask about their habits to determine whether they are environmentally friendly. In addition, surveys should ask whether visitors benefitted from any of the cultural education opportunities available. Both of these questions can help further research into active history. Additionally, aggregating this data would provide insight on heritage trail usage, impact, and sustainability optimization.

VII. Conclusion

The examples provided by Central Park, the Suck Valley Way, and Old Town help lay the foundation for future city planners to create or expand their own heritage trails. Heritage trails provide space for sustainable activities while protecting historical sites. They are community spaces and economy builders.

Moving forward, city planners must include heritage trails in the development of smart cities. Such trails need to be designed according to the historical sites and space available. A sustainable heritage trail is the result of engagement between public and private stakeholders, the promotion of active history, and the use of technology to provide information to visitors. Benefits of heritage trails include access to historical sites and open space. Further, heritage trails offer emissions-free activities that offset a city’s carbon emissions. From long, extensive trails, to small, open spaces, heritage trails provide support for sustainable habits in smart cities and connect people to their past.

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A Crypto-Token Based Charging Incentivization Scheme for Sustainable Light Electric Vehicle Sharing

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***Abstract*— The ecological impact of shared light electric vehicles (LEV) such as kick scooters is still widely discussed. Especially the fact that the vehicles and batteries are collected using diesel vans in order to charge empty batteries with electricity of unclear origin is perceived as unsustainable. A better option could be to let the users charge the vehicles themselves whenever it is necessary. For this, a decentralized, flexible and easy to install network of off-grid solar charging stations could bring renewable electricity where it is needed without sacrificing the convenience of a free float sharing system. Since the charging stations are powered by solar energy the most efficient way to utilize them would be to charge the vehicles when the sun is shining. In order to make users charge the vehicle it is necessary to provide some form of benefit for them doing so. This could be either a discount or free rides. A particularly robust and well-established mechanism is controlling incentives via means of blockchain-based crypto-tokens. This paper demonstrates a crypto-token based scheme for incentivizing users to charge sharing vehicles during times of considerable solar irradiation in order to contribute to more sustainable mobility services.**

Keywords*— sharing economy, micromobility, scooter, light electric vehicles, solar charging stations, blockchain, distributed ledger technology, cryptotokens, ethereum

1. Introduction

Free float *light electric vehicle sharing* (LEVS) has great potential to reduce greenhouse gas emissions and air pollutants, congestion, space demand, and noise in an urban environment [1]. However, the ecological impact of LEVS can still be improved, especially with regard to their energy supply. In many cases, vehicles or batteries are collected using diesel vans in order to charge empty batteries with electricity from unknown origin. This battery charging practice is one of the main contributors to life-cycle greenhouse gas emissions accounting for up to 50% of the total life cycle greenhouse gas emissions of LEVS [1]. At the same time, it constitutes a significant cost component [2]. A solution could be to let users charge the vehicle themselves whenever it is necessary. However, there is a lack of understanding of user behavior when it comes to charging the vehicles. If a user is tasked with charging the vehicle, it compromises the convenience of a free float LEVS since it costs time to identify a free charging station, approaching it and plugging the cable in. In case a charging station is not at the user's destination, the willingness to charge might be lower. Hence, an incentive in the form of free rides or discounts is an option to compensate for these inconveniences. A possible solution for charging points needed in such an incentive scheme could be a decentralized network of small off-grid solar charging stations, like suggested by Martinez-Navarro et al. [3], providing renewable electricity where it is needed, without requiring a grid connection, therefore increasing flexibility and reducing costs. In order to utilize solar off-grid charging stations effectively, the generated electricity must be used instantly instead of storing it in a battery for later use. Matching production and demand, so-called demand side management, in order to decrease costs and emissions, constitutes a well-known procedure in the solar energy sector [4]. However, for LEVS demand side management is a novel approach.

In this paper we propose an incentivization function and an exemplary software architecture for implementing a crypto-token based charging incentivization scheme for sustainable LEVS, with crypto-token being defined as a purpose bound cryptocurrency [5]. We therefore attempt to answer the research question: How can a token-based incentive concept for loading LEVs be conceptualized to enable ecological and economic improvements in a mobility service?

In addition, non-functional properties for the system design, such as cyber-security, data-security and privacy need to be considered. We therefore preliminary limit our solution space to *distributed ledger technology* (DLT) based solutions, since they are well suited for implementing systems that cater for those requirements, while at the same time providing additional technical and operational properties, such as decentralization, integrity, and overall resilience [6]. In order to assess potential patterns of light electric vehicle user behavior, currently available literature was taken into account [7, 8]. Accordingly, prior academic and community work about DLT and crypto-token based incentivization schemes was analyzed, with the goal of extracting potential blueprints and best practices [9-11]. A special attention was given to the

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work by Gogerty and Johnson, who conceptualized linking electricity to a cryptocurrency in the form of *SolarCoin* [12, 13]. Furthermore, the proposed system architecture is developed regarding technological feasibility in order to allow for future implementations, thereby limiting the solution space on already existing technologies. In this regard, this research intents to explore the possibilities and applicability of a DLT based system for the outlined use case.

In the following chapters we describe the assessment of the underlying incentive function that is implemented using a crypto-token based mechanism as well as a proposed system architecture.

II. Assessing the Incentive Function

Since the goal of the incentivization is to use solar energy as efficiently as possible, the charging should be incentivized during times of sufficient electricity availability. Hence, the produced electricity must not be stored in a buffer battery, thus reducing costs and greenhouse gas emissions. For the following calculations, a solar charging station of one kWp installed capacity and 2.4 kWh of lithium-ion battery storage is assumed. The charging station is facing south without shading and is located in Bochum. For assessing the sunshine and the electricity production respectively, we are using a typical week in mid-May as this season of the year is representing the most average sunshine conditions in Germany [14]. On the consumption side we assumed that the station itself continuously consumes 50W to provide for the microcontroller and other small loads. Furthermore, other scooters are already charged in order to simulate load variations. In this example one scooter charges with 80W load. For instance, at 13:00 two scooters are charging with 80W each, plus the base consumption of 50W, resulting in 210W of total load. For the solar off-grid system an efficiency of 86% is assumed [14].

In times of excess electricity production, the battery is charged accordingly. Fig. 1 depicts the resulting production and consumption curves in Watt on the primary x-axis as well as the State of Charge (SOC) of the battery on the secondary x-axis over the course of a day.

The most relevant parameter is the SOC of the scooter battery itself. With a fully charged battery there is no need for charging. On the contrary, if the battery is low the incentive to charge the scooter must be higher. Hence, Table 1 summarizes all relevant parameters for the scale of the incentivization considered in this paper.

It is worth noting that these parameters need to be computed in advance using weather data for each specific charging station near the destination because the charging process can take up to three hours depending on the SOCS.

Hence, the following incentivization function can be derived:

$$f(IC) = \frac{f\left(\frac{W}{W_{dmax}}\right) * f(SOCC)}{f(SOCS)} \qquad (1)$$

Due to a lack of data about the user behavior each function is an equally weighted linear function in this paper. For a practical implementation, the parameter weights of the incentive function and the impact on the user behavior need to be assessed in the field using e.g., an iterative approach. The resulting function is then normalized to show the fraction of

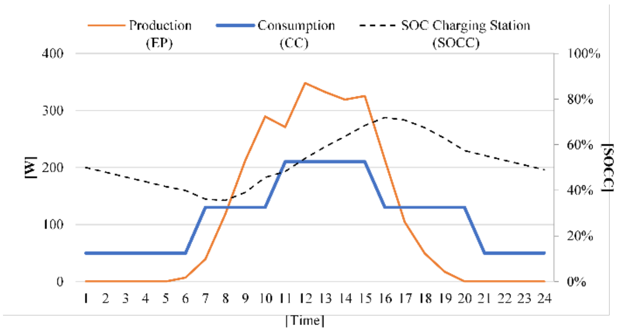

Fig. 1. Production, consumption and SOC of an off-grid solar charging station.

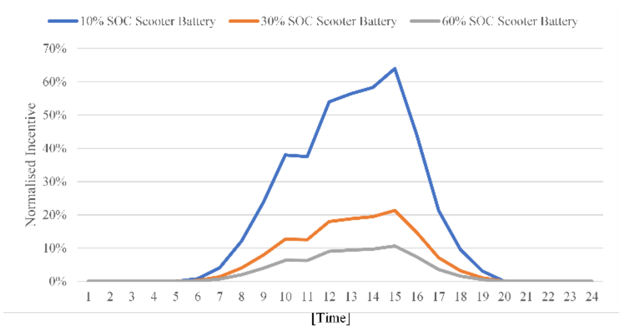

Fig. 2. Normalized incentive curves for a SOCS of 10%, 30% and 60% respectively.

the maximum possible incentivization for each period of time. E.g., if the incentive is a maximum of ten free ride minutes worth of token, a normalized incentive of 70% would mean an effective seven free ride minutes for charging the vehicle at the destination.

Fig. 2 shows the normalized incentive curves for a SOCS of 10%, 30% and 60% respectively. For a better user experience (UX) the scale should be less granular in order make sure the user understands the incentive provided. One option could be to split up the incentive scheme in four levels and indicate the size of the incentive by a more intense color as depicted in Fig. 3.

According to this incentivization function, we designed a blockchain-based crypto-token system, that uses a smart contract as an escrow for the scooter renting business transaction, similar to existing research designs for using blockchain-systems as an escrow component in business transactions [15 – 17], informed by an external weather station acting as an oracle [18].

III. Software Architecture and Incentive Design

The software architecture for the system design is depicted according to the C4 model [19, 20]. The system context diagram (see Fig. 4) provides a high-level overview with regard to interaction with other systems and the container diagram (see Fig. 5) acts as a more detailed breakdown of the logical deployment units involved in the design and operation of the system. Our system, hereby defined as *Solar Token System* (STS), interacts with several external systems (*Charging Station*, *Weather Station*, *Scooter*), all of which can

Normalised Incentive	Tier Level	Effective Incentive
<20%	0	0%
20% - 40%	1	25%
40% - 60%	2	50%
60% - 80%	3	75%
80% - 100%	4	100%

Fig. 3. Schematic representation of the proposed UX for incentivizing users to charge the vehicles.

be considered cyber physical systems [21]. In addition, the user, in the role of a mobile citizen, is the main driver of system interactions. The STS acts as a core business component, integrating the aforementioned cyber physical systems to allow for completely automatable business transactions for the use case of scooter renting and return, while at the same time adding a dynamically and automatically adapting incentivization layer based on weather data and remaining scooter and station charge.

As a technological basis for implementation, a combination of classical software components and blockchain technology is used. At the core of the system, an Ethereum smart contract implementing an ERC-20 token [22], *Solar Token Contract*, is responsible for handling all business transactions based on the configured incentivization scheme formular. The current solar radiation is continuously and transparently updated by an independent process (*Solar Oracle Proxy*), acting as an oracle for ingesting the current weather readings, as well as reasonable forecast, from the Weather Station into the Solar Token Contract, where the data can be used as input parameters for the incentivization scheme formula. On scooter return, the charging station reports the charging event, containing the remaining scooter and station charge, in the form of a Smart Contract transaction to the Solar

TABLE I. INCENTIVATION FACTORS

Parameter	Impact on Incentivization (II)	Indicator/ Unit	Time Reference
Electricity Production at the Charging Station (EP)	Higher EP, Higher II	W/W_{dmax} (W)	Prediction from weather station
Current Consumption at the Charging Station (CC)	Indirect, through EP and SOCC	N.a.	Current Status
SOC of the Charging Station (SOCC)	Higher SOCC, Higher II	(%)	Prediction from EP and CC
SOC of the Scooter in Use (SOCS)	Higher SOCS, Lower II	(%)	Current Status

Token Contract, which then finalizes the renting process. In this way, the Solar Token Contract acts as a Smart Contract in the most classical sense (as a machine controlling property by digital means, providing observation and verification) [23]. It thereby fulfills a role as the independent machine-controlled intermediary in the scooter renting transactions, where it acts as an escrow holder for the initial deposit of the user, which is dynamically redistributed to user and scooter on return, based on the current solar radiation and remaining scooter and station charge.

IV. DISCUSSION AND FUTURE WORK

The scheme developed in this paper is the basis for a future technical implementation of a crypto token-based user incentivization-scheme within a research project case study, which would allow for the implementation of a decentralized system, that is decoupled from traditional drawbacks of payment provider integration, such as high transaction fees (especially high minimum fees, rendering micropayment practical infeasible) and vendor-lock-in effects. In addition,

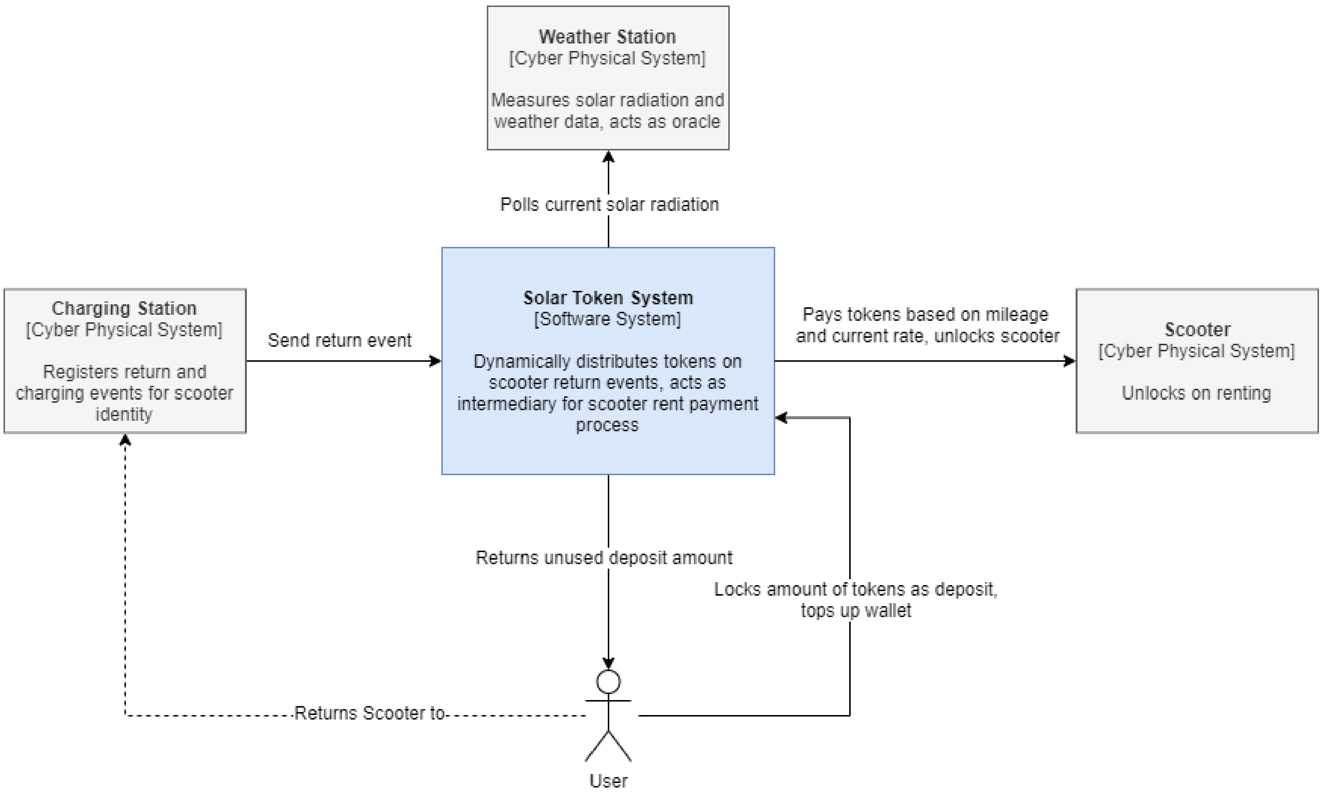

Fig. 4. STS system context diagram.

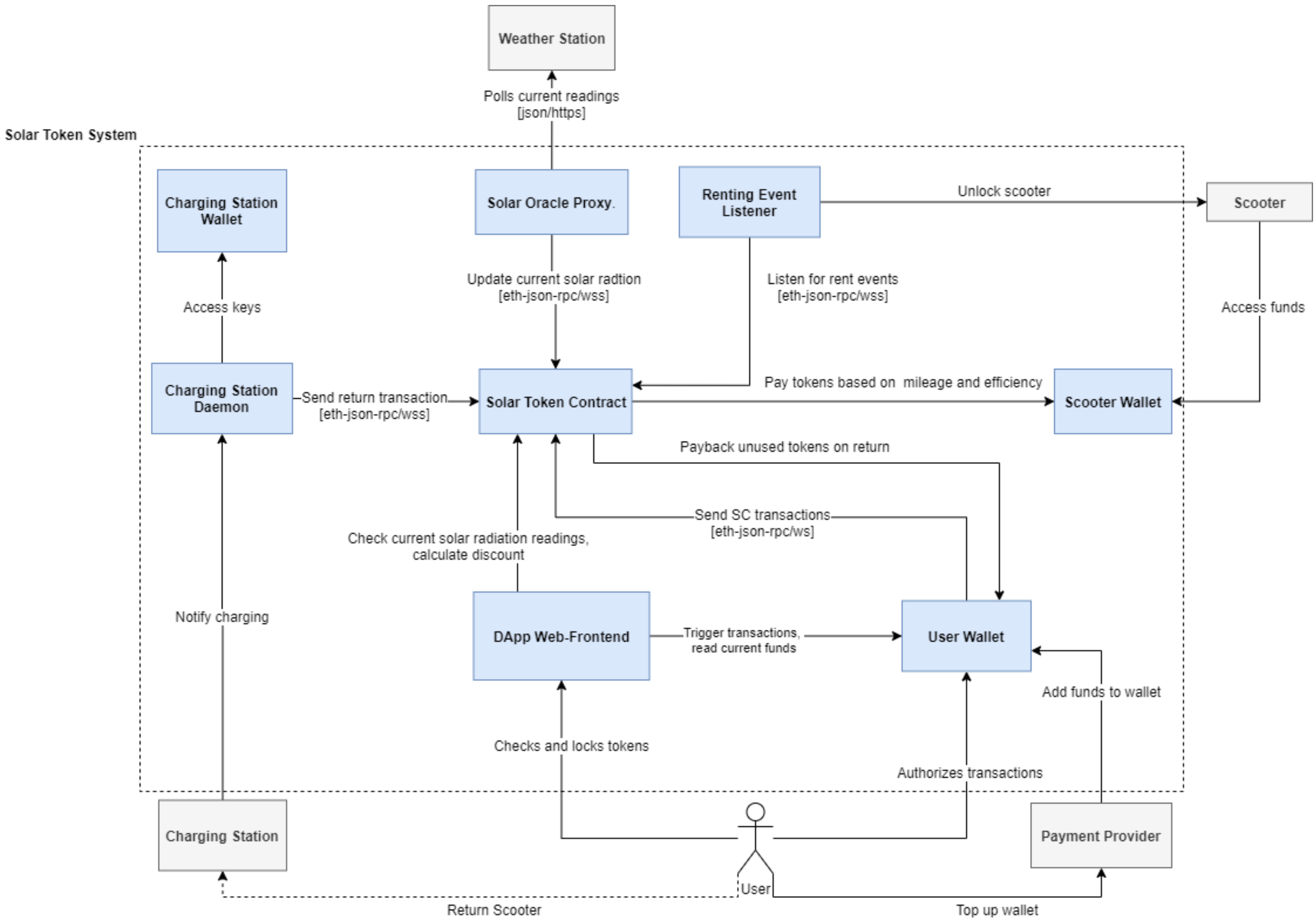

Fig. 5. STS container diagram (detailed descriptions and concrete technology selections omitted to improve readability in print).

such a system would be operated not by a central authority, but by a network (or decentralized organization), lending itself well for the context of urban networks spanning multiple cities, providing services to their citizens across their respective city limits.

During this project, the weighing factors and the function of each factor influencing the incentivization need to be assessed. This can be done using controlled experiments such as A/B testing [24]. Furthermore, the user acceptance for such an incentivization scheme as well as the parameters influencing the acceptance should be evaluated. The user needs to understand the benefit and the charging must be as convenient as possible. This could include measures like inductive charging, a clear and easy to understand UX as well as a dense network of charging stations in order to keep the benefits of a free-floating system. In addition to incentivizing users to charge scooters it is also possible to offer discounts incentivizing users to rent the scooters e.g., during traffic congestion periods using a dynamic price model for scooter usage. This can also be implemented via means of DLT based crypto-tokens. These tokens can be used to establish a closed-loop token economy, by allowing the payment of the scooter rent with aforementioned tokens. By freezing a certain amount of a user's tokens for future transfer to the scooter's account as a deposit, further securities against a shortfall in payments can be established within the system, allowing for a high degree of automated business transactions. Since the distribution of tokens back to the user and to the scooter on return is determined by formular (1), the encoded formular itself acts as a distinct control instrument for influencing user behavior.

In practice, the technical layout of the crypto-token based incentive scheme as well as the incentive function and the UI and UX of the proposed system need to be tested as part of the implementation. This requires a critical mass of users in order to allow for statistically significant results. Also, it must be evaluated in what scale there are ecological and economic benefits associated with the implementation of such a scheme.

Besides an empirical evaluation of an actual implementation and the analysis of resulting human interaction using behavior-science paradigms, the proposed design artifact of the underlying information system should be assessed using a scientific methodology such as design science [25]. The proposed system can, therefore, act as an initial starting point for an iterative generate/test cycle, which would ideally generate machine-readable artifact models. As part of this research methodology, special care should be giving to comparing and contrasting a DLT based design with more classical architectures for information technology systems. Note that this research process itself could benefit from an increase in transparency, integrity, observability, and reproducibility, by incorporating and integrating against DLT [26, 27].

Furthermore, this system might be extended by additional use cases and services, that can benefit from such a "green" token-economy blueprint, thereby creating new digital markets and ecosystems. While those token economies can be easily envisioned, the usage patterns and potential ways of exploitation by users are sometimes counter intuitive [28, 29].

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Agile Principles in Automotive Software Development: Analysis of Potential Levers

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***Abstract*—Cars are becoming software-defined products and mobility is in a transition to become a digital network business. This leads to a high pressure on automotive software developers to deliver more and more complex software in ever faster innovation cycles. The classical development process of a car is a holistic and complex systems engineering approach which delivers a fully developed car (mechanics, electrics, electronics and software) after several years of development. This car will be produced (without major changes) for many years. The automotive industry mainly applies the V-model, a complex and much elaborated development process which systematically leads from a comprehensive set of requirements to a car which exactly fits the requirements. Very much different from this, agile development methodology starts with very fuzzy and uncertain requirements and drives the development via incremental improvements with close customer integration towards a product which might deviate a lot from the initial idea. For a number of reasons, this purely agile approach is not possible for automotive development. Therefore, ongoing research is conducted on integrating agile methods into the V-model – an approach which isn't foreseen by the Agile Manifesto. Nevertheless, substantial progress is made and the automotive industry put big hopes into this approach. This contribution identifies four promising approaches for the integration of agile methods and principles into V-model. The approaches are analysed based on a literature review. A first set of hypotheses about the possible improvement and leverage for the automotive software development is developed. The hypotheses are tested in an early validation step with industry experts in order to support the design of experiments and surveys for further research.**

Keywords—agile methods, automotive software development, customer collaboration, requirements, iterative development

I. Introduction

The introduction of Agile manifesto [1] transformed the software industry with respect to customer focus, flexibility, speed and reduction of overhead. Agile enables early and continuous delivery of working software, quick response to varying needs of market and changing requests from customers, focus on team management and communications within team and close interaction with users. Success stories about agile are not only limited to development processes in software industry, however from last few years this agile transformation can also be seen in automotive software development [2]. The development of automotive software differs a lot from other software engineering domains, e.g. business applications or mobile applications on smart phones. This applies both to the product and the process:

- Automotive software is embedded into a technical product of high complexity (the car) which cannot be modified by just compiling a new version of a piece of software. Many implications on the holistic system (containing mechanics, electrics, hardware) make the software "embedded" into the system.
- Automotive software development has to comply with regulations, especially concerning safety, like Automotive SPICE, ISO26262, or VDI 2206. Therefore, a heavy-weight development process like V-model is used [3].
- In most cases, automotive software can only be fully tested and assessed in combination with the hardware (in worst case: the full car). User feedback on pure software artefacts is difficult.
- The development of a car usually takes several years. The release of the car to the markets assumes that it is a "final" product which will be used largely unchanged for several years. This contradicts with the release of minimum viable products (MVP) which are continuously updated and improved while already deployed in the application field (on the road). Software updates over-the-air (OTA) are still not very common due to safety and security concerns.

The introduction of agile methods into the V-model has to take into account the differences and constraints of automotive software development (and automotive systems engineering) in comparison with other – already more agile – software engineering domains. With growing complexity, it becomes more challenging to combine the safety demands, constraints and quality requirements of traditional car development with the need to keep pace with advanced market innovations.

To encounter the key challenges of automotive domain and to accelerate the development process, there is a need to adopt agile methods in automotive software development.

A. Motivation for the Combined Use of Agile and V-model

Currently, the automotive domain is facing both rapidly changing market demands and new, disruptive technology innovations. Advanced trends [3] in automotive sector i.e. autonomous driving, connected cars and electric mobility require a leap in innovation. The typical timelines of automotive systems development cannot cope with the speed of change and the project design and project management approach do not cannot handle the complexity and uncertainty. Successful implementation of agile methods in large scale software development and in many other domains has proved the importance of agile principles [4].

Considering these trends and upcoming market demands, for example the demand for recurrent delivery of advanced product functionalities or safety related updates, results in a need for more flexible processes and shorter software release

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cycles. However traditional processes for automotive software development are inefficient to fulfil such demands and constrain the software release in shorter iterations [3].

Project Management and Technology & Engineering Management to delivers solutions for this dilemma. Integration of agile methods in automotive software development is a potential solution to confront the challenges and to fulfil the needs of a dynamic market environment [4].

Within the automotive industry V-model is most common and conventional approach [3]. However, when it comes to requirements engineering for software intensive systems, development methods in the automotive domain are not efficiently acclimatized to the needs [5]. For example, when system complexity is relatively high, traditional V-model often results in very high cost during the late verification phase and is inflexible towards late market and customer requests. Agile principles promise an early customer feedback (which serves as a verification) and a higher flexibility towards changes. Therefore, it is proposed to incorporate the combined use of agile methods and V-model in the context of automotive software development.

This paper aims to provide insights to the identified key problem areas in automotive software development processes. Moreover, it highlights a transition of automotive software development towards agile by analysing the applicability of agile values and principles to automotive software development challenges.

B. *Research Outline*

This paper is formulated into six sections. The first section (above) contains the introduction and motivation of the research. The second section contains the theoretical framework providing a short description of the V-model and the agile processes. The third section includes details about related work and the literature review. Within the fourth section, four key areas for agile methods in V-model are analysed and discussed. For these four key areas, first hypotheses are formed about how to implement the agile principles and about what lever and improvement to achieve with this. The main goal of the research is to formulate the outline of the hypotheses and to plan their further elaboration and validation. The fifth section of paper contains an early validation of the hypotheses based on a short survey and semi-structured interview amongst industry experts. This serves as a first indication on whether the deductive formulation of the hypotheses meets the reality. The last section six concludes results and gives an outlook on the further research.

II. Theoretical Framework

To understand the concept and scope of selected methodologies related to the formulations of the hypotheses, a short description of the theoretical background will be provided based on a literature review. The section starts with the introduction of the traditional software development process based on V-model in automotive domain and will be continued with providing a short state-of-the-art of agile methods in automotive software development.

A. *Traditional V-model*

Within automotive domain V-model is one of the most common, state of the art and conventional approaches. The use of this traditional process in the context of the automotive domain is referenced within the Automotive SPICE standard [6]. Furthermore, it is the basis of the safety standard formulated in ISO26262 and for the more general standard VDI 2206 for the development of mechatronic systems. V-model is deeply integrated into the Systems Engineering methodology [3] [6]. The V-model (Fig.1) is a comprehensive and detailed development process, starting from the very first

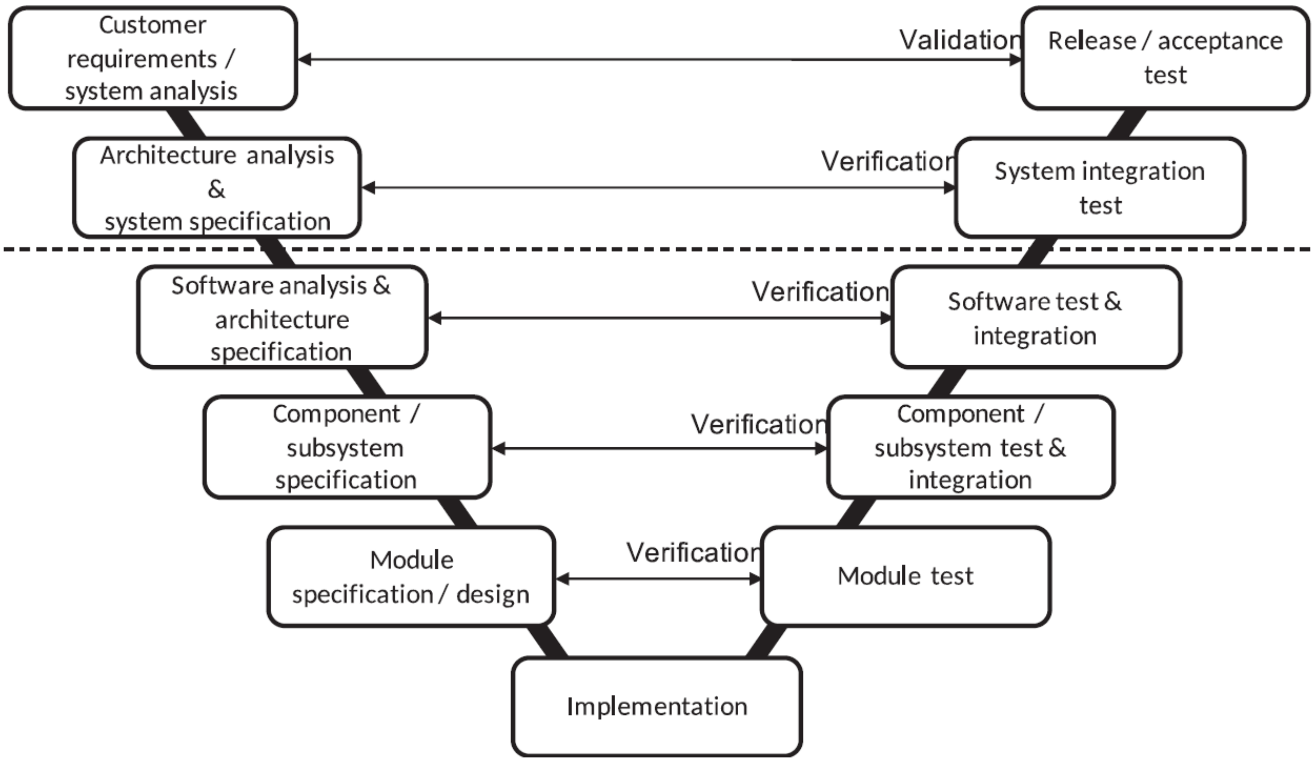

Fig. 1. V-model as used in Automotive Software Development [6].

phase of requirement definition and analysis for the intended project to be developed and continued with next phases of architecture specification & analysis, design specification & analysis, implementation, testing and integration. It ends with the final phases of release and acceptance test of a system. It is designed as a sequential process running from start to end. However, "going through the V" can be repeated if requirements change.

The characteristic elements of V-model are in two branches of the V. The left branch is going "down" from the holistic user requirements to the detailed implementation while the right branch is going "up" from the implemented result to the integration into a tested final and complete product. In automotive software projects for example, development starts with the specification of requirements for the desired vehicle, in the top-down approach (along the left branch of the V) followed by the specification and analysis – from whole set of system requirements via system architecture down to system design and implementation. From here the bottom-up approach (along the right branch of V) conducts the testing and integration phases from module level – component – subsystems and system level. The process of verification and validation is done in the left branch of the V, bottom-up with test and validation of the specifications and features relevant on the respective level of detail [7]. The V-model is a "folded" sequential process which goes from "system level" down to "detail level" in the left branch and back to "system level" in the right branch. The hierarchal decomposition of the system into smaller, more manageable sub-systems and modules is a key feature. The integration of the resulting modules back into the sub-systems and afterwards into the complete system is complimented with tests (verification and later validation). This approach allows testing already on module and sub-system level instead of using the much more complex full system which is only available late in the project. By adopting the V-model in development process, it is utterly presumed at the beginning of desired development project that the set of requirements from users and customers is clear, complete and sufficient. A change in requirements leads to a full repetition of the complete V which usually takes a long time. Therefore, a major effort in V-model development is put into the design automation of the whole process, meaning, the project team builds an automated tool chain (connected IT tools) which can push a change request (changed or new requirement) through the V. This design automation is done while progressing with the project through the V. At the end of the project, changes can be "run through the V" much faster than in the beginning. Nevertheless, V-model is quite inflexible in case of changed requirements during the project. Iterations can be done in the V in case a bug is detected in testing. In that case, only the steps on the respective level of detail need to be repeated. E.g., if a bug is detected in sub-system verification, it is reported on the same level of detail and incorporated into the sub-system specification. It can be fixed by running it only through module design, implementation and test, not through the whole V. Customer involvement is only foreseen in the requirements phase at the start of the V and in the release/ acceptance test at the end of the V. In between, sometimes for

more than a year, the customer is not involved into the project and does not get any information. This is very critical since market expectations and technology trends change in between, leading to changing customer expectations.

B. Agile Methods

Agile is not a single certain method; it covers both a holistic philosophy and a collection of methods that share common goals and attributes. For example, Scrum, Kanban, Extreme programming, Lean software development and crystal methodologies are existing under the umbrella term "Agile" [3]. With the introduction of the Agile Manifesto [8], the associated values and principles of agility became more significant in the software domain. Agile enables:

- "Individuals and interactions over Processes and tools
- Working software over Comprehensive documentation
- Customer collaboration over Contract negotiations
- Respond to change over following a plan" [1]

Agile is a flexible approach which allows the incremental development based on customer feedback and desired results. It is based on the development of software in short iterations. Agile principles recommend to start a software development project without a full set of requirements but based on a rough idea. A prototype is generated quite fast and shown to the customer in order to get feedback, new ideas and new or changed requirements. In an iteration loop a new increment of the software product is developed and again shown to the customer. This is possible if prototypes can be generated very fast and with low effort and if these prototypes are good enough to get a meaningful customer feedback. Furthermore, the customer needs to be willing to participate in the project during the whole runtime.

Lack of information and insufficient requirements in early stages result in changing requirements in later stages of development process. Agile methods welcome changing requirements even late in development process. The aptitude of fast response to changing or new user requirements are making agile methods such as Scrum or Kanban more promising for innovative software development [9].

Therefore, the implementation of agile methods for achieving quality and efficiency is declared as first priority for automotive software development [10].

With the growing demand for innovation and improved functions, automotive industry faces key challenges - for example improved quality, software reuse, collaboration issues and flexibility. To deal with such issues, research studies encourage the adoption of agile methods in automotive software development [11] [12].

III. RELATED WORK

This section presents existing theories and work related to the research topic. It also provides instances from the literature about the adoption of agile methods and implementation of the combined use of traditional processes and agile methods in automotive domain. Based on this literature review, the hypotheses of section IV are derived.

A study [12] highlights the challenges related to the practicing of the combined use of agile methods and traditional approaches in release planning of automotive domain. For validating results, semi-structured interviews and online surveys were conducted. Results of this study indicate that adoption of agile practices such as continuous integration and daily stand up meetings can address the identified challenges.

However, in order to overcome such factors which hinders the implementation of agile, it is preferred to adopt agile methods like scrum [14]. This certainly results in mixed approaches for development processes extending from traditional approaches towards agile transition [12]. The use of hybrid approaches for software development in automotive domain becomes more common [15].

The complexity of automotive software is growing exponentially [16]. The automotive domain deals with large projects which include multiple sub projects and suppliers. Such large projects also covers geographical distances. In order to integrate all involved areas and distances, benefits of agile processes like coordination and knowledge sharing can overcome such issues [17].

In order to keep pace with competitive market environment many OEMs focuses on need to speed up the development process, early time to market, quick response to change and enhanced quality of product [18]. Studies show many ways to speed up the software development process by including agile methods. It is also evident from literature that traditional approaches for software development are not sufficient to encounter increasing challenges i.e. complexity, safety and innovative market demands [18].

A hybrid methodology [18] integrating Scrum with traditional V-model in safety critical software development with the goal of process improvement. This study also focused on the implementation of scrum elements inside V-model. By keeping the V-model framework it assures the required quality and safety measures in automotive domain.

Nevertheless, existing literature related to automotive software development specifies that traditional software development processes are insufficient to support the increased innovation, complexity, flexibility and dynamic market demands. This pushes the automotive manufacturers to restructure and implement flexible development processes for automotive software development [7] [18] [20]. Traditional processes in automotive software are not sufficiently efficient since V-model is a strictly linear development approach. This assumes that the requirements are complete and detailed from start of the project. After the development is done, the software product is tested, and validated against the explicit requirements in this sequential approach [7]. The current state of the art regarding V-model assumes that user and customer requirements are clear and completed from start of the project [6] [19]. The hierarchical requirements decomposition via many levels of abstractions forces early design decisions, which results in big delays in development process if they are taken wrong. Agile avoids doing too many decisions early. Moreover, once development process has started, it is difficult to integrate changing user requests and requirements since both the developed software artefacts and the created test cases are related to these initial requirements[3].

Another issue of late feedback - due to long time duration between initial requirement specification and integration and acceptance testing of a software – is the need for requirement changes at late stages of development. A study [18] finds that such issues lower the speed of development process drastically. Even more severe, the delays are noticed at a very late stage since the missing acceptance of the customer is the planned end of the project. Instead of going back to the start from this late point, early customer involvement can detect a missing acceptance earlier during project runtime. The characteristics such as shorter time to market, flexibility and frequent user involvement enable agile methods as a promising approach for software development [14].

Agile methods address the issue of insufficient requirements in a better and flexible way by implementing short iterations and enabling product delivery in increments [9]. Before each iteration, requirements are updated and by the end of iteration developed software is tested against updated requirements. During the development process agile methods focus on continuous refinement of final product which shortens the time to market [17] [21].

IV. Key Problem Areas

The main reason for the adoption of agile methods is the analysis of key problem areas in the current state of the art of the application of V-model and the potential opportunities and advantages associated with Agile. The four identified key problem areas are the result of detailed literature analysis on automotive software development, mainly described in section III of this article. The identified problem areas are classified in four categories: lengthy development cycles, late changes of requirements, customer collaboration and insufficient requirements or uncertainties. For each problem area, it is explained how agile transformation offers solutions and recommendations to deal with the problem areas.

A. Lengthy Development Cycles

In automotive software development, lengthy development cycles are found to be challenging in terms of long project runtime and causing delays [6]. Currently, in the automotive domain it takes several months for completing a development cycle, especially in case in-house development is not possible and supplier cooperation is needed. For example, if a supplier is needed to develop software, the Original Equipment Manufacturer (OEM) is only able to test and validate the result once the product is delivered (end of the V) which can be after eight or ten months. Consequently, only after this duration the OEM is able to clarify whether the result fulfils the functional requirements and the software can be integrated. This raises uncertainty in the OEMs planning.

Agile methods support flexible ways [3] to deal with such problems. Solution approaches have been developed in order to address mentioned issue. It is recommended to implement incremental development on the module level in order to break complexity up, to allow user involvement and to support late changes. The proposed agile method is to break the module development up into several incremental steps. These steps serve as agile sprints which implement the functionality based on the features requested by customer in an incremental way. For each sprint the customer gets involved into reviewing the results in the sprint review. This assumes the ability of the customer to take part in the sprint review and the feasibility of a proper result assessment at that point of time, of course. It can require a design automation of the right branch of the V to get testable prototypes faster. In Fig. 2, the left box indicates key problem area, middle box represents transition towards agile and right side shows the proposed solutions/levers in context of automotive software development.

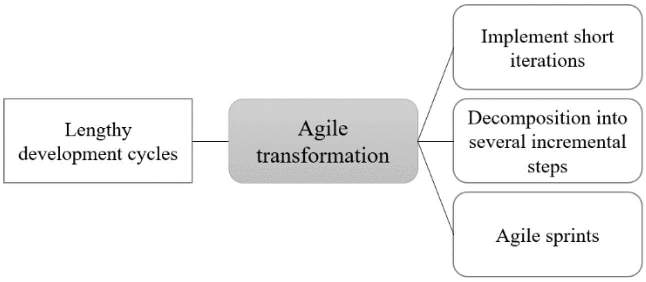

Fig. 2. Lengthy development cycles.

B. Late Change of Requirements

In V-model a strictly linear development is assumed. Early design decisions are taken based on the assumption that requirements are final and stable. Design decisions are usually taken under uncertainty since customers cannot know the final requirements at this early stage – given the pace of market and technology changes. Once the development process has started it is difficult to integrate changing user requirements. In most cases, time duration between initial requirement specifications, integration of software and acceptance from customer is very long. The combination of the uncertain user requirements and the possibly wrong design decision in the early phase of the project with the late user involvement with late feedback at the end of the project results in requirement changes at very late stages of development. Formulating requirements early without proper knowledge and checking results late causes a maximum of delay and effort.

The proposed solution for the mentioned problem (Fig. 3) is the transition to a whole set of agile practices. It suggests the decomposition of module development (lowest layer of V) into several incremental steps. These steps are conducted as agile sprints which implement the functionality based on the features requested by the customer in an incremental way. For each sprint (or a set of sprints) the customer gets involved into reviewing the results in the sprint review. Another principle is to foster user involvement by agreeing on the goals for incremental sprints instead of negotiating contracts for the complete delivery of the software product. This changes the planning horizon from complete project runtime to the runtime of some agile sprints. This allows the strong user interaction throughout the process and avoid too many late changes while adding flexibility if there is a change. Additionally, getting away from paper-based specifications and using instead working software allows users to assess the results in an early stage, e.g. by delivering prototypes, mock-ups and executable specification, which is validated according to scenarios and user stories. Since automotive software usually requires the hardware (or car) for demonstration and validation, model-based methods like Software-in-the-Loop (SiL) or Hardware-in-the-Loop (HiL) can be applied. In Fig. 3 the left box indicates the key problem area, middle box represents transition towards agile and right side shows the proposed solutions in context of automotive software development.

C. Customer Collaboration

The challenges of customer collaboration are addressed in traditional V-model projects with detailed and comprehensive customer contracts. These contracts are becoming an issue at

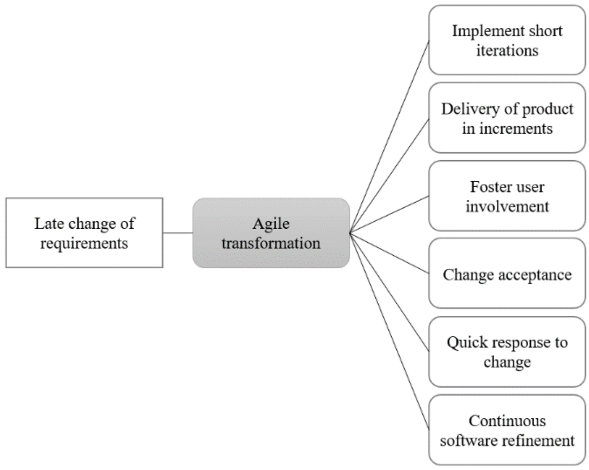

Fig. 3. Late change of requirements.

the end of project since these contracts did not sufficiently reflect reality due to the uncertainty in automotive software development projects and the continuous need for change and adaptation. Moreover, in software development based on V-model, long development cycles result in the very late involvement of customer and user feedback. This leads to starting the development cycle again from the beginning in case of a disagreement on the results and a rejection of result acceptance by the customer.

Additionally collaboration across different domains within automotive context leads to additional problems [4]. For the development of an automotive vehicle different domains need to cooperate, i.e. hardware, software, business, mechanics, electrics, and many different suppliers involved. This leads to complex supplier and project networks which require a "common language" and good collaboration in order to avoid misunderstanding. The cooperation environment within a domain (e.g. mechanics or software) is quite established in most cases. However, when it involves different multiple domains, there is a need to adopt flexible, conventional and transparent collaboration approaches.

To address this issue, agile methods facilitate individuals and interactions. Agile methods propose to have constant customer interaction throughout the project execution, appreciate feedback and welcome change requests of individuals. The goal is to come to a consensus about the expected results while jointly developing and reviewing the software during the process. Additionally, the forming of multidisciplinary agile project management teams with experts from each domain can be a good solution to address collaboration issues across domain boundaries. In Fig. 4 the left box indicates key problem area, middle box represents transition towards agile and right side shows the recommended solutions in context of automotive software development.

D. Insufficient Requirements/Information or Uncertainties

Insufficient requirements or uncertainties during the early stages of software development process can lead to changing user requirements in late stages of the development process. Moreover, once the development process has started, it is difficult to integrate changing user requests and requirements. Software test cases are also related to initial requirements [3].

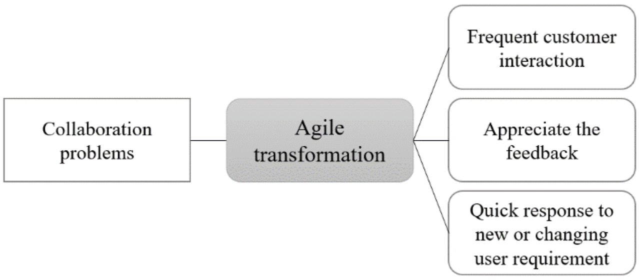

Fig. 4. Collaboration problems.

The automotive industry has to answer to a market which expect new and attractive features constantly, even for cars already driving in the streets. Meaning, new requirements have to be implemented not only in the ongoing development projects but continuously for the complete fleet of cars in the application field. This paradigm of continuous integration/ continuous deployment (CI/CD) assumes that requirements are never final and never fixed.

The characteristics of agile methods support quick reaction to changing or new requirements [3]. This flexibility to facilitate new requirements is enabled by the feature of incremental development and adaptability of short iterations for product development. With a high degree of design automation, new features can be implemented and released continuously and the time from a new requirement popping up to the release of a new feature into the car can be shortened.

Agile methods address the issue by implementing short iterations and enables product delivery in increments [9]. Before each iteration, requirements are updated and by the end of each iteration, developed software is tested against updated requirements. In the development process agile methods focus on continuous refinement of products rather than on delivering a final product [17]. New requirements are not seen as an issue but as a source for new features for the car. Delivering new features constantly is perceived as a competitive advantage. In Fig. 5 the left box indicates key problem area, middle box represents transition towards agile and right side shows the recommended solutions in context of automotive software development.

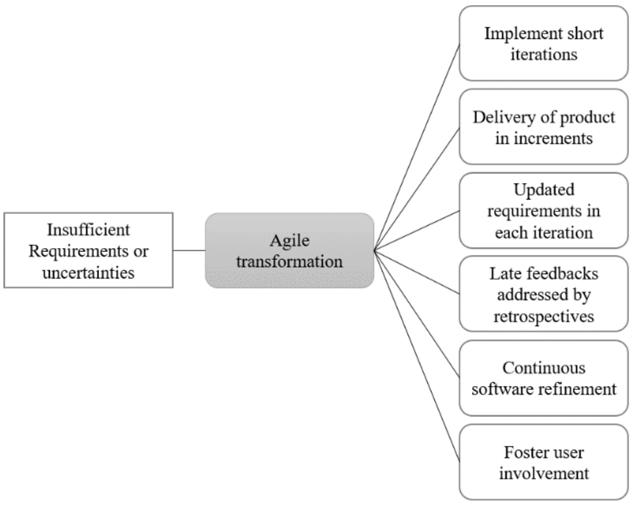

Fig. 5. Insufficient requirements.

V. Validation Results from Expert Feedback

For the future, it is planned to conduct more detailed research on the four key problem and solution areas. The idea is to create experiments in real automotive software development projects in order to try out some of the proposed solutions and to investigate and to compare case studies of projects where the solutions were either used or not used. Since such experiments and case studies require a very high effort and since such real projects are not repeatable, it is necessary to put the hypotheses on a strong footing. It is planned to refine the hypotheses about the four key problem and solution areas step by step in an iterative process by developing solutions based on literature and expert recommendations and by validating them in reviews and discussions mainly with industry experts. Only if the hypotheses are mature enough, they will be tested and validated in the experiments and case studies.

The four hypotheses about the key problem areas and possible solutions described in section IV were presented to industry experts to receive a feedback which can complement the literature findings which initially led to the hypotheses. An online survey with elements of a semi-structured interview was conducted to confirm the validity of the identified key problem areas in order to confirm that the hypotheses are compliant with reality. 9 experts from 4 companies and 1 research institute were interviewed, mainly with 4-20 years relevant job experience in automotive software development.

The majority of the respondents is familiar with V-model, they apply it in their work (66%) and they agree that it is commonly used in automotive software development (89%). This is supporting the state-of-the-art from literature. Furthermore, they disagree or formulate a neutral answer to the question if agile principles are already common in the automotive industry (100%). All of the respondents see agile methods as useful especially for Infotainment/HMI/ Connected Car applications. This again is compliant with the literature findings.

Much more interesting is what the experts stated about the relevance and the difficulty of implementation of agile principles for the four key problem areas regarding automotive software development (Fig. 6).

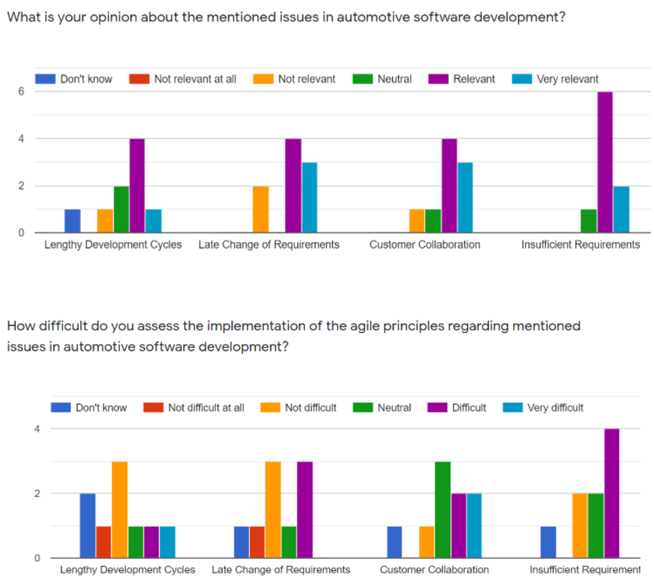

Fig. 6. Results from the surveys on the 4 key problem areas.

The experts perceive all four areas as relevant while they describe the issues with late and insufficient requirements and the customer collaboration as more relevant than the lengthy development cycles. The lengthy development cycles and the late changes of requirements are perceived as easier to address than customer collaboration and insufficient requirements. It is interesting that 77, 7% of the respondents already use agile solutions to address some of the four key problem areas. With these results, it makes sense to continue to elaborate the four areas and the solutions. It is planned to involve the respondents as reviewers and experts in the development. The experts were not randomly chosen but are long time research partners and therefore known as persons. They are supportive for the further research.

VI. Discussion and Conclusion

The analysis of the literature and the relevant state-of-the-art shows that the implementation of agile principles into V-model is a relevant topic for automotive software development. The industry expects relevant improvements for their projects. The trend towards agility is perceived as a major requirement for better and faster innovations in the automotive industry. Nevertheless, literature clearly shows that the implementation of agile principles into the V-model has only started and that it is facing major difficulties. Our small survey amongst industry experts clearly supports this.

Based on the literature, four hypothetical key areas for issues in V-model development and possible solutions by transition to agile principles have been developed. In these areas, we expect a high potential to lever the effectivity and efficiency of automotive software development to new levels. Again, the small feedback from industry experts supports this idea. As a summary, the areas with a big leverage are seen in addressing the issues with lengthy development cycles, late changes of requirements, customer collaboration and insufficient requirements or uncertainties.

The plan for future research is to elaborate further on the issues both within literature and by conducting interviews with practitioners. Based on that, concrete solutions based on agile principles are developed which are again reflected versus literature and reviewed by the experts. Currently, it is just a small and initial survey to check the validity of our hypothesis and in future we will go into deeper analysis by conducting case studies and surveys with more people .We plan to test the solutions in experiments in real software development projects. Furthermore – since some of the solutions are already applied in industry – we will investigate and compare them based on projects conducted with agile methods versus projects without them.

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Holistic Concept for the Implementation of Smart Parking in Small and Medium-Sized Cities

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***Abstract*—Smart parking is often looked at from a technological-driven perspective in smart city projects as a use case where the usage of Internet of Things (IoT) solutions can easily be demonstrated. However, what exactly smart parking can mean for a city and how the process can be implemented is often neglected. Solutions can only be beneficial for cities when they are integrated in a smart parking management concept and develop it also in line with the cities' overall strategic goals. For smart parking solutions it is important to take a holistic view of the approaches. Our approaches converge in a sustainable concept, which gives a city sufficient space for continuous development within a fast changing environment. Moreover, the concept in its holistic view also includes all stakeholders of a city who are involved in the parking context. This is essential because smart parking solutions can solve various problems, which should be addressed in a smart parking management system. The holistic concept for smart parking implementation, developed in "Lemgo Digital" covers the requirements and identifies the added values for different stakeholder groups. It consists of an actual state analysis, the park management with sensors, data and visualization and the realization of business models. The developed concept is currently being transferred to another city to show the transferability and validate it at the same time.**

Keywords—*smart parking, medium-sized city, holistic and future-oriented concept, living lab, smart city*

I. Introduction

Finding a free parking lot in cities is a time-consuming process for citizens, residents and visitors. Waste of time and frustration are not the only consequences. This also leads to air pollution and traffic congestion [1]. One powerful tool to address the city's individual challenges is the implementation of a smart parking system. In this context the role of the local authorities is changing and their employees have to take on new tasks that require new skills. The fragmentation of the parking space management and a high number of stakeholders involved impede the implementation of smart parking systems. For a city, it is crucial to not only evaluate the functionality of technology but also the long-term consequences of the implementation. This is a major challenge especially in view of rapid technological development [2].

As a result of the living lab "Lemgo Digital" [3], implemented by Fraunhofer IOSB-INA, an approach for the implementation of smart parking has been developed. One aspect of the project focusses on the consideration of sensors and networking (IoT) in the smart city context for medium-sized cities (20.000 - 99.000 inhabitants [4]). In this context, the holistic concept was developed from an IoT-driven perspective. As a funded research project "Lemgo Digital" has been established as a living lab to address smart city topics in medium-sized cities and to combine it with the involvement of the community and citizens at a very early stage. The participative approach enables the development of accepted and tested products and services. The results of the projects are not limited to the living lab of Lemgo, but can be transferred to other small and medium-sized cities and municipalities from the start. The approach for smart parking developed in Lemgo can therefore to be regarded as a template for other small and medium-sized cities. Medium-sized cities often have different needs and requirements compared to large cities. For example, medium-sized cities in Germany tend to have a historic center with narrow streets or even a one-way street ring around it, with parking spaces in the streets, small parking lots or streets with mixed permissions for parking (parking ticket or resident's card) around the city center. Due to the catchment area, which is often characterized by surrounding villages, the amount of individual traffic is usually high.

The concept described here takes into account the requirements and added values for different stakeholder groups and builds on a state analysis, the park management with sensors, data and visualization and the realization of business models. In cooperation with the Fraunhofer IEM the developed concept is currently being transferred to another city to demonstrate the transferability of the individual steps and validate it at the same time.

This paper is structured as follows. Section 2 presents related work and strengthens the relevance of our holistic concept. The Smart Parking concept as developed within the project "Lemgo Digital" is presented in detail in section 3 and the transfer of it to another city is described in section 4. Finally, the conclusion and outlook are presented.

II. Related Work

Due to the rapid developments and the relevance of the topic of Smart Parking, there are already a number of approaches and procedures in this context [1], [2], [5] – [8]. Initial approaches for implementing Smart Parking largely address mostly the technological issues of a Smart Parking system rather than having a holistic view at it ([1], [5] – [7]). Therefore, previous work has concentrated on pilot implementations and neglected the comprehensive requirements of a holistic implementation.

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Within the framework of the research project "Smart Urban Services", the Fraunhofer Institute for Industrial Engineering (IAO), among others, developed a strategy approach to identify initial proposals for smart urban services in the ideation phase. In four steps, ideas for challenges, required data, sensor technology and services are identified in workshops [8]. This method enables a general, well-founded and topic-independent collection of ideas in an ideation phase for smart cities.

In a further analysis, Fraunhofer IAO examines the changes in municipal parking against the background of the change in the use of traffic modes from a holistic perspective. The investigations concentrate on creating transparency in the broad range of different solutions in the context of parking management [2]. As a result of this in-depth analysis, this paper concludes with 21 action modules that have to be considered for the introduction of parking management systems. Thus, parking management is understood here as a design instrument that demands new competencies from municipalities and involves a wide range of stakeholders [2]. The analysis makes it clear that the subject area is very complex and that there is no general recommendation for implementation [2]. However, as municipalities are faced with the challenge of how to conduct an implementation process, this challenge reinforces the need for a concept and structuring framework for the introduction of Smart Parking. In particular, there is a need for a procedure that integrates Smart Parking sustainably into the urban space and does not just address pilot applications.

III. Concept Description

The holistic concept is structured in 4 phases as shown in Fig. 1. The first step of the holistic concept is to define the goals and added values that are relevant for all stakeholders. It is important to cover this at the beginning because the design of a solution depends on the requirements that lead to the choice of elements for the parking management system. Simultaneously, the actual parking situation must be mapped. Not only the location of parking spaces or payment options have to be documented, but also the surrounding conditions. Based on these findings, hardware and software components can be chosen. One component of smart parking, can be the selection of parking sensors. The technical implementation can be divided into the field of sensors, data management and data visualization. Before selecting a data platform, a detailed evaluation is necessary. In any case the future viability and integrability must be ensured. Data processing implies the generation of added values by data fusion and analysis. There are different ways to visualize the added values and information. Visibility, reach, acceptance and the usability are of great importance. Finally, the project has to be based on a sustainable financial concept covering costs and responsibilities for data ownership and maintenance. It therefore needs to be based on the realization of suitable business models. Throughout the entire process, the focus should be on achieving the pre-defined strategic goals and added values.

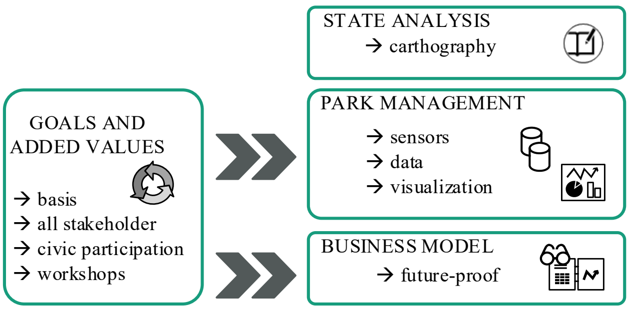

Fig. 1. Structure of the holistic concept for the implementation of smart parking.

A. Goals and Added Values

The definition of goals and added values that should be achieved by smart city solutions in the area of parking is the basis for a structured and holistic procedure. All stakeholders (e.g. city employees, retailers or citizens) should be involved in this process, to bring in their individual perspective on the added values and challenges. Structured workshop formats in combination with e.g. surveys and interviews can help to create and develop ideas and evaluate existing processes and their optimization potential.

The identified goals and added values can focus on three major elements. For example, they can be separated in acquisition and analysis of the situation, parking management and -guidance system or process and economic efficiency optimization of the city. The three elements are not mutually exclusive.

The situation acquisition describes the recording of the parking data e.g. as a decision-making basis for further urban planning, in connection with traffic recording or road planning or for statistical evaluations and analyzes. The city could also generate an information cockpit on the current situation, e.g. the occupancy status and the utilization of the parking space.

If a city sets the goal to derive at a holistic of parking management and parking guidance system, one of the main goals could be the reduction of the traffic jams caused by drivers looking for parking spaces through targeted guidance. A parking guidance system should not only display the free parking spaces, but also integrate traffic conditions, city events or flexible parking spaces that are only available at certain times. In a parking management system, the availability of special parking spaces, such as e-parking spaces or disabled parking spaces, should be displayed transparently. The profitability of charging stations can thus be increased, because in particular it can be checked whether a car is only parked there or whether it is also using the charging station. Thanks to the greater transparency, optimal utilization of the parking space can be targeted.

As part of process and economic efficiency optimization for of the local authority, prohibited parking zones as well as exceeding parking times could be controlled more effectively through the support of the parking sensors. Parking could also be combined to the retail sector. So that the parking process is linked to a City Card (a city bonus system). The longer customers are in town and the more they buy, the cheaper it is to park in a particular parking zone. In this regard, a time-based tariff is also conceivable in order to equalize the flow of visitors to the city via low parking prices at certain times. Using suitable sensors, an automated parking process could even be possible: The vehicle is recognized and assigned (e.g. via the license plate) and the payment for the parking space runs automatically in the background, because the sensor detects the end of the parking process when the car leaves the parking space. The prerequisite for this added value, however, is that the parking spaces are equipped with the appropriate parking sensors and that the data is processed in a platform in the background.

All in all, the inclusion of several stakeholders of a city and the users enables a comprehensive goals and added value analysis. The results form the basis of the holistic concept and must be considered at every point in the further process.

B. State Analysis

During the step of recording and analyzing the current situation, a map of the city's parking spaces should be created, taking into account all relevant information in the context of smart parking. Fig. 2 shows an overview of the relevant aspects that should be considered at the state analysis. It is important to record the condition, e.g. the underground, of the parking spaces, because this way it can be checked whether e.g. gluing or screwing of floor sensors would be possible. The number of parking bays, the type and function of the parking space (electric parking spaces, family parking spaces, ...), an overview of whether there are markings for the individual parking bays and the type and number of access roads must be recorded. With regard to the entrances to the parking lot, the access roads, possibly information on the traffic situation at this point and possible city locations for a potential parking guidance system should be documented. In any case, the actual recording should always take into account which sensors may already be available, how they can be converted if necessary and which sensors could also be newly installed. Positions of signs, parking ticket machines and street lights, but also trees or a power supply in general need to be listed. The street light network, which is predestined as a sensor carrier, is often switched with ripple control technology, especially in small and medium-sized towns. Therefore, permanent power is only given when the lighting is turned on. That is among other things the reason why the power supply for sensors, base stations or gateways is one of the major challenges in smart city environment. This was also revealed in the projects in Lemgo and Paderborn. To record the current situation, all lamppost locations should be noted as well as the wiring between them. Another important detail is the height of the street light, as e.g. for optical sensors cost-benefit assessment is often depending on installation height. In simple terms: the higher the sensor is installed, the more parking bays can be recorded. The different parking sensors also place different demands on their energy supply. For example, camera-based parking sensors cannot be operated permanently by a battery alone. However, battery packs that charge at night when the street lights have electricity can supply the sensor with energy from the battery during the day.

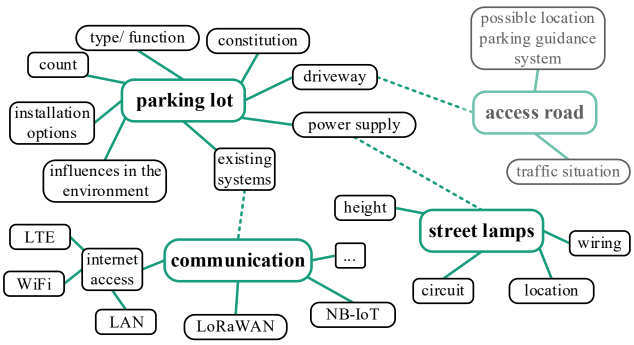

Fig. 2. Overview of the main aspects of the state analysis.

Certain sensors can be operated via solar panels and/ or in combination with batteries. Parking sensors, installed at the ground often operate with low power technologies and are e.g. linked via Long Range Wide Area Network (LoRaWAN). The sensors can then be operated with batteries for 3-8 years or longer according to the manufacturer. Just like the power supply, the supply of the locations with wireless technologies such as mobile radio, Wireless Local Area Network (WLAN), Narrow Band IoT (NB-IoT) or LoRaWAN must also be checked in order to finally select the appropriate sensor technology. It must be checked which radio technologies are already available in the city and whether the radio coverage is also given at potential sensor locations. If the radio coverage of e.g. LoRaWAN is not given, possible locations for gateways must be found and assessed.

The result of the state analysis should be a detailed cartography of the city and the relevant parking spaces. The elaborated basic factors should be the location and function of parking lots the position, height and power supply of street lights and the radio coverage of the common wireless communications. This should also be graphically documented in addition to the written documentation for a better overview.

C. Park Management

The elements of park management can be divided into three parts: sensors, data management and data visualization. The sensors part could be more generally described as hardware and software in the context of smart parking. In "Lemgo Digital", hardware was specifically considered for the use case of parking space detection. Therefore, in this paper the focus is on sensors for detecting parking space, the processing of newly generated as well as the inclusion of existing data and the visualization of the information for the end user. Other requirements and scenarios (e.g. access authorization or payment solutions) can be verified in a similar way. The general split in hardware or software, data and the transmission of information to the end user remains. Because of different installation conditions and application dependent technical requirements, there are various parking sensors. The choice of the sensor for a parking space should always be made according to the local conditions and the defined goals. When choosing the sensors, the data transmission of the sensors must also be considered. In particular, the data approach, data quality and data content must be inspected in order to evaluate whether they are suitable for the goals defined at the beginning. The visualization of the data must be prepared for a specific purpose. The requirements can vary depending on the target group.

a) Sensor

Parking sensors must be able to detect different parking spaces. Parking space can be divided into two categories, off-street and on-street parking [2]. Closed off outdoor parking areas are called off-street parking. Cars leave the street and drive to the parking area, which is divided into parking bays. Car parks also belong to the off-street parking category. On-Street parking is located directly on the street and the parking bays are located parallel or perpendicular to the street. If parking bays are parallel to the street, the length of the parked vehicles is decisive for the number of vehicles find place in it. Especially according to this type of parking bays, cars looking for parking spaces can slow down the following traffic by passing slowly through the parking bays or by long parking procedures. Therefore, a detection of these parking bays can be crucial to reduce the search traffic for parking space.

In a car park parking space is often stacked floor by floor and can be stored in an underground car park. Entrance and exit are usually lane-guided and controlled, as the right to enter is granted e.g. by a parking ticket. Hence the lane-guided entrance and exit in multi-storey car parks and underground car parks is quite common. In car parks the method of balancing of parking vehicles is possible. When balancing parking space, tolerances must be taken into account e.g. in the case that a vehicle occupies several parking spaces. The occupancy of special parking spaces (e.g. handicapped or e-loading parking spaces) would have to be recorded by individual sensors. It has to be checked what kind of technologies are already in use in existing car parks and which data quality is provided by the sensor technology. Parking lots and underground car parks with barrier systems also offer the possibility of digital access authorization e.g. via license plate recognition or Radio Frequency Identification (RFID) at the barrier system.

In comparison to car parks, parking spaces off-street are mostly not regulated by barrier systems, furthermore there is often no lane entry and exit with structural separation. Off-street parking areas can have paved or unpaved surfaces, therefore parking bays are not always clearly highlighted by markings on the ground. Influencing factors for the sensor selection are for example the condition of the underground, markings of the parking bays, a possible power supply for sensors or communication availability (e.g. WLAN, Long Term Evolution (LTE) and LoRaWAN). Furthermore, overhead sensor technology need to be installed in height and obscuring objects such as trees, buildings or high vehicles must be considered.

It should also be checked whether a detection of the parking cars with balancing methods is feasible. The function of the parking bays plays an important role in this inspection. For example, an accounting for mixed parking of residents and guests of the city, where parking spaces are assigned to the respective user group is not necessarily suitable for balancing methods. Parking bays with special assignment would then have to be recorded additionally with sensor technology, as well as special parking bays (e.g. handicapped parking places).

In order to detect off-street parking lots completely, a combination of several sensor technologies is often necessary. For example, the installation could include camera-based optical sensors, which detect the majority of the parking area, and single-space sensors, which detect the parking bays, which might not be efficiently detected by camera-based optical sensors. But also a combination of balancing and detection and camera-based optical sensors for residents parking bays can be useful.

The detection of on-street parking spaces is one of the biggest challenge for parking sensors. For the detection of parking bays parallel to the road, which offer parking space for more than one car the usage of ground sensors can be less efficiently. Vehicles do not necessarily park in predefined gaps. the possible number of vehicles that can be parked in a parking strip depends largely on the size and position of the vehicles. Often, overhead sensors (e.g. camera-based optical sensors) are used in on-street parking areas. The installation of such sensors requires an installation possibility at a certain height in order to detect parking bays efficiently. Especially lamp posts as existing infrastructure in cities are predestined as sensor carriers. The facades of buildings could also be used. The usage of camera-based optical sensors almost always requires a permanent or battery charged power supply.

In conclusion, the detection of parking space should be implemented by a combination of different sensor types, since no parking sensor is suitable for all application requirements and locations. For example, if camera-based sensors may not be able to detect all parking bays, a combination with ground sensors may be useful. It also may be useful to detect parking spaces that are equipped by balancing methods, special parking spaces (e-loading, disabled, family and/or women's parking spaces) additionally with other sensor technologies. The possibility of interoperability of different sensors types therefore must be feasible especially in the back-end structures.

b) Data

When choosing sensors, the data transmission of the respective sensors must also be considered. In particular, the three aspects of data access, data quality and data content need to be examined with regard to the predefined goals and added values want to be achieved.

Relating to data access the manner of the provision of data by the sensor provider has to be considered. One possibility is data access via an Application Programming Interface (API) provided by the provider. There may be costs associated with setting up the API interface. In this way the data can be integrated e.g. into the municipal data platform. Many sensor providers offer an own web portal or the integration into a third-party web portal. When using different technologies and providers, it is always important to ensure that the web portals allow the integration of other providers and other interfaces, because a parking management system needs a holistic data concept. In the ideal case, an urban data platform is used for the entire city, in which all sensors but also already existing data can be integrated via interfaces. Data should be normalized and then either after analysis and processing or directly transferred to end applications. In addition, all data must be stored in a data storage structure.

The data of sensors should be delivered in the required quality depending on the use case and the defined goal. Parking data is required in real time for many applications, e.g. for a parking guidance system or for a correlation between the occupancy status of an electric parking space and its charging status. However, as described the data should also be saved so that the historical data can be used for long-term analyzes and forecasts. In parking guidance systems and routing applications, it is important to indicate the number of parking spaces expected to be available on arrival. For this purpose, the real-time data (possibly in combination with historical data) must be processed in prediction algorithms. For a parking guidance system, predictions of parking space occupancy should therefore be based on real-time and historical data in combination with other sensor data, such as traffic counts. Also, it might be important e.g. to display parking time for the public order office to detect all park changes (even very quick changes) to identify parking offenders, so the data quality needs to be reliable.

The content of the transmitted data should be checked for the information it contains. A reliable sensor system requires, for example, regular information about the battery status or a keep-alive messages. Based on the keep-alive data, a sensor management tool in the back-end can check the functionality of the sensors.

Overall, the central administration of the data in one platform as well as the connection and combination with other data of the city is necessary in order to be able to exhaust the maximum added value of the data. Data sovereignty should remain as far as possible within the city in order to exclude dependencies on third parties.

c) Visualization

The classic way of visualizing parking space occupancy is using signs on the street. These can be static as well as dynamic signs. Due to the increasing digitization of vehicles and the permanently available mobile internet e.g. smartphones offer options for conveying parking information. The information must be prepared and visualized accordingly for the target group. Overall, the way of visualization is also dependent on the goals and added value that are to be generated. Depending on the goal definition, the city administration requires an automatically analysis of parking data and a statistical overview of it, in order to make use of them, for example, for structural decisions or price structuring. A real-time display on parking violations could provide a data basis for public order office. The integration of newly collected parking data into existing systems (e.g. geo information system) could be a requirement of the city.

The creation of further added value through the linking of data and the formation of correlations between sensor data could be important. It must be agreed which data may be used for which purposes and who should have access to it (e.g. within the city administration). For example, data on the utilization of parking spaces can be a valuable support for city planners. [2]

The information about parking space occupancy should reach as many people as possible, so that it is not advisable to provide the data in a city-specific app alone. For specific use cases with specific user group, such as resident parking, a local app could be useful. Information on the public parking space should be made available for residents, visitors and tourists of the city. An integration of the parking information data in common navigation apps, navigation systems and vehicle functions would achieve the greatest range. Cities would have to make data available to providers or integrate the data into the apps via interfaces. This might also be a profitable business model to sell the data. In addition to the information on the free parking space, information on parking fees, payment options, parking times or function of parking spaces can also be forwarded. A navigation calculation should not only use the current number of free parking spaces, but also historical data to calculate forecasts for the occupancy situation depending on arrival time. Input options in the navigation calculation could optimize the search for parking space, because maximum parking times of parking spaces can only be included in the calculation if the information is available about how long the driver plans to park. The possibility to select parking preferences such as "Cheaper parking fee beats distance to the destination" or "priority is the arrival time at the destination, therefore parking fee is unimportant" would offer added value for the user and optimize the navigation.

The information for the driver via information boards at the road should be introduced out in parallel with the integration into parking apps or navigation systems. The information boards should function as a parking guidance system, which means that parking and traffic information should be dynamically combined through intelligent algorithm. A forecast of the available parking space should also be calculated and displayed for parking guidance systems depending on distance to parking lot and amount of traffic.

The transmission of parking information in a city should be communicated to citizens and guests of the city via various channels. The drivers who are deliberately guided to the next free parking space at the destination address should be reached, but also those who know the city well and move around it without navigation.

D. Business Modell

The goals and added values defined in A must be translated in business models. An open approach is important in order to exploit the potential beyond previous possibilities. The basis is the target customer research, from which personas can be derived that can be used in workshops for business model development. It is advisable to introduce customer validation steps in the early phases of business model development [9]. Prototypes can be made available for customers e.g. via Klick Dummies and be validated as an intermediate step in the development auf business models.

When implementing business models, as with the choice of sensor technology and data structure, care should be taken to ensure that future expandability and flexibility is maintained. A vendor lock-in combined with dependencies should be avoided. In some cases, the processes and procedures within the city administration have to be redefined for newly implemented or changed business models.

IV. Application of the Concept

In order to ensure the transfer of the concept and to validate its applicability, this concept was used to build up an IoT parking management system in the city of Paderborn. The area for the implementation of the project is limited to the inner ring of the city and thus offers comparable conditions to medium-sized cities. Paderborn has set itself the goal of making the parking process more pleasant for road users through digital parking management and at the same time contributing to air pollution control in the city. The responsibility for the parking management of the city of Paderborn lies with the "Abfallentsorgungs- und Stadtreinigungsbetrieb Paderborn" (short: ASP), which is significantly involved in the development process.

A. Goals and Added Values

In order to take into account, the goals and added value of a future parking management system from the very beginning, the relevant stakeholders were involved in the process of developing the solution. Here, the focus was on three superordinate groups of stakeholders, which were addressed in different formats: internal city actors, retail and city management as well as residents and tourists. The first format addressed the stakeholder group of the city's internal actors. In this context, these included the Road and Bridge Construction Office, the Public Order Office, the Urban Planning Office, the Digitalization Department and the ASP. As opening activity, a gallery walk gave impressions and impulses for possible values, achieved by implementing a smart parking system. Subsequently, the different needs were identified using a Value Proposition Canvas (VPC) and linked to solution approaches. The principle of VPC is to generate ideas for products and services based on the tasks to be performed and customer/user needs. The results of the workshop with stakeholders of the city were then clustered into the areas of operationalization/ management, planning and order/ parking violations and prioritized by an effort-benefit assessment. For example, transparency on parking availability and occupancy duration, digital payment processes with dynamic pricing, adaptable parking guidance system with inclusion of traffic situation and navigation option with forecasting were identified.

In a separate workshop, the same procedure was used to identify the added value in the area of retail and city management. A broader format was developed for the citizens. Flyers and social media campaigns were used to draw the attention of citizens and visitors to the city of Paderborn to a survey, which investigated the current problems and needs of parking space management. The results from all three activities were consolidated and create the framework for the further development of parking management.

B. *State Analysis*

For a detailed state analysis of the city's parking situation, the information in the current city map material was updated in cooperation with the Geo-Information Office and supplemented by additional external profiles. In the course of a detailed city inspection, the individual streets were checked and documented according to the criteria shown in Fig. 2. Information, such as number of parking spaces or type of parking lot, could be partially integrated directly into the city map material. Additional information was prepared for the project documentation in the form of the profile for each street as shown in Fig. 3. Subsequently, the contents of the cartography were transferred into requirements, in order to accomplish a founded market and technology research on it.

C. *Park Management*

The content of parking management is divided into three parts: sensors, data management and data visualization. In addition to the intensive examination of hardware-related issues, a data platform and corresponding dashboard were established in this implementation project.

a) Sensors (Market Research and Pilot Project)

Due to the dynamic and fast-growing market of suppliers, a new market research and intensive coordination with different manufacturers despite the already deep previous knowledge from the living lab in Lemgo has been carried out. Different areas of requirements have been identified and the research was also structured accordingly and divided into the technological focus areas ground sensor technology and camera based optical sensor technology for individual parking spaces and for balancing. After an initial cost and performance evaluation, a pilot implementation was carried out with selected manufacturers. Here a typical road situation was selected, which is characterized by cobblestones, low street lights and tree population. Besides on-street parking situations, off-street parking situations were also part of the pilot projects. Intensive targeted test phases were carried out as part of the pilot project. In addition, the collected data was evaluated over longer periods and examined for abnormalities. The challenges and situations identified here were important components for a subsequent performance and service catalog for potential providers.

b) Data and Visualization

As part of the pilot project, an urban data platform was built. The base of the data platform is an open system, which can integrate any kind of urban sensors and is therefore very flexible. The platform enables data storage, data retention and data management. By using the data platform, both the historical and the real-time data could be examined and important insights could be gathered. For example, the detection accuracy or the reaction speed of the sensors could be determined. A dashboard was connected to the platform to visualize the data. The visualization is primarily used for acceptance tests with users and citizens.

D. *Next steps*

The results from the workshops, the survey, the cartography and the pilot phase will all be taken into account in a performance and service catalog for corresponding providers. In this way it can be ensured that the invitation to tender meets the requirements of the city of Paderborn. An implementation of different sensor combinations will be carried out in the inner city area. Based on this, the city will in future deal with the question of a suitable parking management system and displays as well as corresponding business models. Thus, a sustainability of the parking management system can be guaranteed.

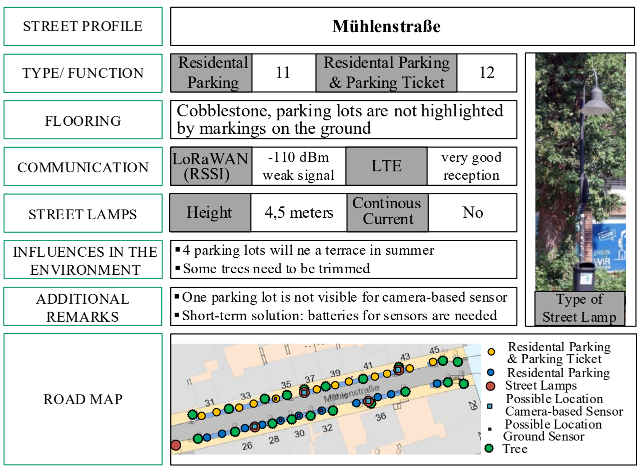

Fig. 3. Extract of the documentation of the state analysis.

V. Conclusion and Outlook

This paper introduces a holistic concept for the implementation of smart parking in small and medium-sized cities and describes its transfer to another city. The individual phases of the concept are described, from the definition of the goals and preparation of a state analysis to park management with sensors, data and visualization and finally to the development and implementation of business models.

A point that should not be underestimated in the context of smart city applications is the back-end and data platform. Here in particular, the involvement of all stakeholders in the city can be significant, because back-end and database structures should, if possible, be used holistically for many applications within the city, not just for smart parking. Therefore, it may be necessary and helpful to have an overall strategy process to establish a concept of data platform and back-end system for smart city applications.

The transferability of the concept is currently being verified in the city of Paderborn. Thereby it was shown that the state analysis is recording as an important component of the concept. In this paper, especially in the phase of park management, the acquisition of parking spaces with sensors and the visualization of the data has been investigated. The usability of the concept to other smart parking applications such as payment systems should be tested in a city. It is expected that the concept presented in this paper can be applied with minor modifications also in this context. When looking at the focus area, the division of the phase parking management should be kept, but instead of sensors the focus would be extended to software and other hardware related to payment systems and the visualization would incorporate other elements relevant for the user in this context. The subdivision of data would remain in the same form. In the future it would also be interesting to check the transferability of the concept to other IoT-based smart city topics. The positions considered in the state analysis would have to be partially adapted for this purpose.

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Smart Cities Using Social Cyber-Physical Systems Driven by Education

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***Abstract*—A smart city must be planned to efficiently manage its material and human resources to improve each citizen's quality of life. This paper proposes that the large amount of data generated daily by citizens could be collected, filtered, and processed by Cyber-Physical Systems (CPS) installed throughout several sectors in a smart city. However, it is necessary to have a better interaction between machines and humans. Intelligent agents in the CPS can add new social characteristics, morals, and ethics to enhance the smart city's performance and produce less biased decisions. Thus, this paper describes how smart city problems could be solved by considering both technical aspects and social features to potentiate the smart city's performance. The Cyber-Physical Systems (CPS) must become Social Cyber-Physical Systems (SCPS). Achieving an integral, efficient smart city necessarily integrates ethical principles and morality in AI in almost all engineering areas. The education issues surrounding this are discussed at the end of the paper.**

Keywords—Social Cyber-Physical Systems, SCPS, Smart City, Ethical and Moral AI, Cyber-physical World, Higher Education, Educational Innovation

I. INTRODUCTION

A smart city has been defined from various points of view. Many frameworks have been proposed to explain the elements comprising a smart city and its component relationships, or at least the critical ones. These frameworks include, for example, one that incorporates sustainability and livability in eight different factors [1]; another groups elements into six categories: natural resources and energy; transport and mobility; buildings; living; government, and economy and people [2]. There is also a framework to accommodate the relationship between university, industry, and government [3]. However, there is still not a unique definition for this complex concept.

A smart city's unified definition aims to use a high-level ontology with four main elements: architecture to sense, systems to process, policies to communicate, and sustainability [4]. The authors left the definition structurally open to adaptation, proposing a modular structure. In this work, we define a smart city as a sustainable city that can manage its resources. Our definition encompasses not only natural resources but also human capital, equipment, buildings, and infrastructure. The smart city envisioned is not harmful to the environment; decisions are made to optimize resources and upgrade the quality of life by leveraging technology to obtain full information about all the aspects of a city [5].

Smart cities should promote social and economic aspects that enhance the quality of life of their citizens. Therefore, it is necessary to figure out the best topology to build an effective structure in the smart city, leading to resolving its main challenges (listed below). Each of those challenges has some particular requirements [6]. For instance, transportation has specific needs for sustainable, inclusive, and multimodal transportation. The smart city's main challenges lie in:

- Health care
- Public safety
- Traffic and mobility
- Education
- Transportation
- Energy
- Safety

The smart city requires fast and efficient communication with the citizens. They must be able to send information about their needs and receive information about the required actions to address the problems faced by the citizens (locally) and the communities (globally). So, the smart city requires systems that can deal with physical and virtual conditions to support relevant decision-making and predict the consequences so the best solutions can be deployed.

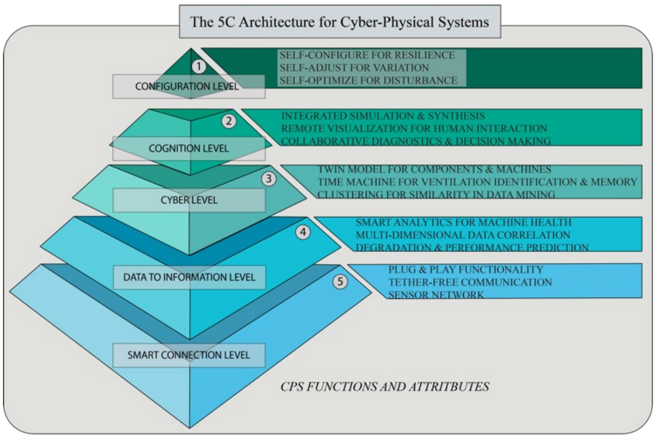

Fig. 1. CPS attributes and functions, taken from [10].

On the other hand, Cyber-Physical Systems (CPS) combine the virtual and physical worlds and cope with a significant amount of data. These systems monitor and control things, taking advantage of cloud storage and computational power so that artificial intelligence can interact with humans, proposing the possibility of fully automated complex systems [7]. As a result, the CPS can be

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implemented in a smart city as the fundamental elements that collect, process, manage information, and transmit the actions to be taken in the city. These systems have proven advantages in sensing, communicating, and processing both local and global information. The CPS can also represent real-world conditions in a virtualized environment that processes and acquires knowledge, becoming an integrated cognition process to select the most appropriate actions and implement them in the city; it is an intelligent and autonomous system [8]. Along these lines, we integrate artificial intelligence algorithms as the decision-makers in the CPS in this paper.

Therefore, CPS are systems that integrate the virtual world, that can be found on the cloud or a server, with the physical world representation using embedded computing, communication, and control technologies. As a result, the systems are represented and implemented to manage a sizeable amount of information, covering a large physical world area, collecting information, processing, and managing it [9]. Some actions that the CPS can perform are:

- Detecting events with sensors
- Affecting a physical process with actuators
- Communicating with other CPS
- Evaluating data
- Acting as human-machine interfaces

Fig. 1 illustrates a five-level CPS architecture according to Bagheri and Lee [10]. The five levels use the CPS as the interconnection between them. Level 2 could be considered a cognition level that acquires knowledge and makes decisions as its most important characteristics. Thus, it is essential to integrate moral and ethical aspects as social characteristics into the AI system. The social characteristics allow communication between citizens and devices and between products and other products to improve the quality of information collected and the decisions made [4]. Social features focus mainly on improving the communication between products and citizens; they are not part of the technical operation in products.

For instance, the way that a smart TV communicates and understands the user (through voice or keyboard) is defined as a social characteristic but adjusting the color and tuning a channel is not a social characteristic. The TV set might be designed to detect depression or another type of illness; thus, social features in the TV's artificial intelligence could improve citizens' quality of life.

The administration of a smart city in terms of energy requires decentralized micro-grids that can generate and transmit energy locally. The decentralized micro-grids could be modeled as a cyber-physical energy system that includes physical resources such as thermal and solar plants [11]. However, the micro-grids require changing some environmental conditions when power plants are installed, so social issues have to be included in the autonomous artificial decision engine. Making a decision based only on load demand is not sufficient for smart cities because this would not integrate equality of distribution in the smart city's entire population.

Hence, a smart city can be viewed as a large-scale CPS implementation. The author of [12] proposed five roles for the CPS in the smart city:

- Cyber Computing Infrastructure
- Smart Living and Governance
- Public Safety Systems
- Smart Transportation Systems
- Smart Street Systems

For example, a transportation system can be implemented for self-driving cars and optimization of traffic control by an AI methodology known as Adaptive Neuro-Fuzzy Inference System (ANFIS) to control the highways [13], [14]. The data is managed remotely and processed through machine learning algorithms. However, some sensors *perceive* the physical world while actuators, like autonomous cars or streetlights, *affect* the physical world. This solution is only partially sufficient since the driver's social behavior is not being modeled as part of the solution. Only the technical solution is included, so the driver could not change his/her driving behavior. Also, usually, social conflicts have to be resolved when someone is driving. These cannot be correctly solved if ethics and moral considerations are not included in automatic decision systems. Besides, it is essential to mention that biased AI programs could be running in smart city decision systems, so the smart city could not create an equalitarian place to live. As a result, unethical behavior could occur as the smart city addressed its main challenges (public safety, energy, education, etc.).

Accordingly, this paper proposes including a social component in the CPS to enable smart interactions in cyber, physical, and social spaces. This generates Cyber-Physical Social Systems or Social Cyber-Physical Systems (SCPS) in a virtual world. A CPS with social characteristics for enterprises was previously proposed by Wang [15], but ethical considerations were not integrated. The key duties of SCPS are therefore to satisfy the demands of human social interaction and to respond ethically to the physical world. However, implementing the SCPS also requires privacy because the sensitive data about citizens' lives could generate undesired impacts if made public [16]. This paper does not present a strategy about the privacy conditions in smart cities. Smart cities' social conditions are fundamental because social activities impact the smart city environment [12]. Moreover, some social features help knowing better the citizens, communities, and cities, expressed in social terms [17]–[21].

A. Social computing

The capacity to sense social experiences derives from the collection of information from a large number of individuals. For example, Google uses mobile GPS data to detect traffic jams for their *maps* application. Another example is the patterns of mobility that aid in predicting diseases for the health service [22], [23].

B. Context-awareness and management

Context-awareness and management are found in any application in which contextual data provides information or services to the user. It is common to use knowledge-based machine learning algorithms to sense a specific situation and decide in the user's favor. For example, user types are analyzed to understand the users' preferences [4], [13], [24], [25].

C. Human-Machine Interface

Human-machine interface (HMI) refers to the interactions between the users and the CPS. The goal is to make this interaction more user-friendly. The most popular design is user-centered. These include tailored HMI based on the user's profile and behavior within a gamification structure that provides feedback for adjustments to teach, motivate, and engage the end-user to perform specific goals [18]–[20], [26], [27].

II. PROPOSAL

The main idea is to have social devices that allow cities to integrate social factors, to design devices that understand and interact with citizens to address their technical and social needs. Since social needs are sometimes not considered an essential condition of technical needs, technical solutions per se cannot be implemented in smart cities [4], [28], [29]. A trade-off between social and technological requirements in a city must be fulfilled as a fundamental factor. If the CPS only deals with technical data using sensors to monitor, validate, and manage the city, it could not achieve the desired result. Besides, AI, as the engine of CPS, requires meeting three conditions throughout its life cycle. The three components, according to the European Commission [30] are as follows:

- Condition 1: Lawful AI that complies with all applicable laws and regulations.
- Condition 2: Ethical AI that ensures adherence to ethical principles and values
- Condition 3: Technically and socially robust AI, due to AI systems can cause unintended damage even with good intentions.

On the other hand, when laws delimit AI systems, the AI system is constrained in its actions. Some actions cannot be done. Thus, finding solutions for the smart city's needs is limited, but a solution found could be accepted and implemented.

Hence, the cyber-physical system must be redesigned to integrate social capability because it has to integrate special sensors to detect social activities and human behavior. Fig. 2 depicts the general proposal where the physical world's inputs rely on adaptive, dynamic interfaces that receive and send stimuli to the citizens. The citizens actively interact with the interface. However, the information read through that interface in the physical environment comes from social cyber-physical systems. Using AI allows getting information from citizens to find correlations between stimuli and outputs that fulfill the citizen requirements. Besides, the CPS becomes a social cyber-physical system (SCPS) that can interact with citizens using social interfaces. So, SCPS can be defined as a set of social systems that combines the virtual and physical worlds into social environments, integrating the information from a conventional CPS into the system. Still, the priority of SCPS is to improve the communication with humans drastically and understand their needs and expectations to provide social and technical solutions accepted by citizens and cities.

The term social interface refers to the sensing, modeling, managing, and interoperating social factors. If the social and technical requirements are aligned, an optimization system can figure out the best solution to implement in the city. Furthermore, other aspects to consider in the city include the inclusion of disadvantaged groups as the senior groups; in [26], Méndez, et al. proposed the inclusion of Alexa and cameras to track the older people and check their daily status and mood improve their quality of life. In [27], Méndez, et al. proposed social interfaces to aid older people by using tailored interfaces with game elements to guide them in their physical activity and avoid social isolation.

When smart cities are deployed, the smart communities' architectures could be modeled as cooperative blocks in which information flows dynamically from citizens to local and global governments. This networked community has elementary blocks (homes) that can be defined as multi-sensors since they can sense several conditions in terms of safety, health care, and other public conditions. The proposal to use homes as multifunctional sensors is presented in [31]. When the networked community receives information from each cooperative block, local and global solutions are sought. However, the solution search is delimited by the moral and ethical restrictions, or AI algorithms that are biased might have been implemented so the social issues will not be resolved. One way of preventing learning algorithms from acquiring unethical biases is to provide citizens with ethical and moral competencies since they have to evaluate the AI systems that make the decisions. The evaluation of ethical and moral issues is a complex task that must be performed by citizens and governments under the best conditions. Cultural factors also have to be considered, and these depend on each country, affecting how the AI systems make decisions. Also, continuous evaluations about the deployed AI algorithms must be conducted, as presented by Mehrabi, et al.[32].

A. Smart Education helping Smart Cities

Smart Education helping Smart Cities is a model of learning adapted to the new generations of digital natives. It is an immersive, collaborative and visual model intended to enhance student interaction and allow teachers to connect to student skills, desires and learning needs. [33]. For instance, The Tec21 Educational Model of Tecnologico de Monterrey [34], [35] developed from the need for a change in the teaching-learning processes in educational institutions worldwide to adjust to today's changing and globalized world. The goal of the Tec21 Model is to provide comprehensive preparation to enhance the competitiveness of students in their professional fields by improving the skills needed to become leaders in facing the challenges and opportunities of the 21st century [36].

Tecnologico de Monterrey considers seven transversal competencies that guide the student in their curriculum development; these include self-knowledge and management, innovative entrepreneurship, social intelligence, ethical and citizen commitment, complex reasoning, communication, and digital transformation. This paper focuses on ethical and citizen commitment. This competency comes from implementing projects to transform the environment and improve common benefits with ethical awareness and social responsibility. Thus, the smart city citizens could be evaluated in those terms because they have pertinent knowledge of ethical considerations. If the citizens are not prepared to evaluate ethical AI systems in smart cities, it becomes challenging to construct an integral smart city structure.

B. Ethical and citizen commitment competence

The aim of the *ethical and citizen commitment competency* is to ensure that the graduates of the Tecnologico de Monterrey professional careers are in a position to face, with moral height, the ethical and social challenges facing today's society. This structure continuously includes ethics and morality in the solution to community problems. The educational intention is to generate in students the ability to implement projects that transform the environment and common benefits with ethical awareness and social responsibility. This means developing the attributes, qualities, skills, and values that distinguish an excellent professional: being sensitive and considerate of others, making ethical decisions, respecting human rights, being aware of the consequences of actions, taking responsibility for them, and acting with integrity and responsibility. Table I displays a list of ethical competency skills.

TABLE I. ETHICAL SKILLS FOR UNDERGRADUATE PROGRAMS AT TECNOLOGICO DE MONTERREY

Competency skills	Characteristics of the skill
Ethical and citizen commitment	Implement projects aimed at improving the environment and the collective well-being, through an ethical conscience and social responsibility.
Recognition and empathy	Respect the personal dignity, rights, contributions and circumstances of others; present constructive and supportive solutions to other people's situations.
Ethical argumentation	Solve problems in various areas of life, with ethical conscience, arguing from principles and values.
Integrity	Solve situations in academic, professional, and social life, complying with laws, regulations, and ethical principles.
Citizen commitment to social transformation	Build enduring, sustainable solutions in solidarity, taking on social problems and needs through strategies that strengthen democracy and the common good.

C. Artificial Intelligences Ethics

Artificial means something done by humans; thus, responsibility resides with us [37]. AI is only created with specific purposes by one or more members of society. AI ethics is about technological transformation and its impact on individual lives. Therefore, Education plays a vital role in ensuring that awareness of AI's potential is widespread so that people can shape societal development based on diversity and inclusivity. Many countries in Europe have proposed a new set of ethics guidelines for a human-centric AI approach. These guidelines consider the following ethical principles [38]:

- *No harm principle*: AI algorithms must avoid discrimination, manipulation, negative profiling and must protect vulnerable groups such as children and immigrants.
- *Justice principle*: Developers and implementers of AI need to ensure that individuals and minority groups maintain freedom from biases against them.
- *Explicability principle*: AI systems must be auditable and understandable by non-experts.

Inclusion, diversity, and AI access are necessary for ongoing diversity in AI development teams and professionals. A more diverse student population can include, for instance, the broadening of engineering education curricula to cover the humanities and social sciences, which are imperative to guarantee the responsible design and development of AI. [37]. For instance, engineers could learn to do things that ordinary citizens do and vice-versa [38]. The *ethical and citizen commitment competency* impulse by the Tec 21 Model exemplifies this approach [34].

D. Cyber World (Fig. 2)

a) Data Management Modules: Consist of storage media and electronic devices and appliances. These modules bridge the gap between the dynamic environment and the data sensed by the multi-sensor system. Besides, this module uses the Next Generation Internet to forward the collected information.

b) Next Generation Internet: This is the ability to plan and optimize strategies to fulfill specific goals such as promoting energy reduction or improving community ethical skills. This dynamic level of internet service is required to design a Social Cyber-Physical System that presents applications offering strategy choices to each user.

c) Secured Database: The Next Generation Internet's information should protect against hackers or criminals and avoid sharing personal information with other providers.

d) Service Aware Modules: These recognize and send data to the available services by using decision-making systems.

e) Application Modules: These modules deploy services to interact with the Next Generation Internet and save and secure the databases' information in local and cloud storage.

E. Physical World (Fig. 2)

a) Social Sensing Modules: Multi-sensor systems collect the data and process environment awareness from the physical world. Then, this information is provided to the cyber world through the Data Management Modules. Social sensing modules collect the following information:

- Virtual description of citizen stereotypes.
- Levels of happiness and sadness in citizens.
- Facial expressions of emotions.
- Social body language.
- Sentimental analyses that describe social conditions.
- Tone and voice used by citizens in social activities.
- Meaning of linguistic expression between citizens and machines in social environments.
- Social space outside of pandemic conditions.
- Social modeling of citizens and communities.
- Virtual social environments.
- Digital twins for social communities and social cities

b) Sensors and Actuators: They are electronic devices that interact with the Physical World and the end-user.

c) Smart Community and Smart City: The consumers socially interact with the physical and cyber worlds. They feed both worlds through the interactions with devices such as Human Machine Interfaces or interactions with other consumers in physical spaces.

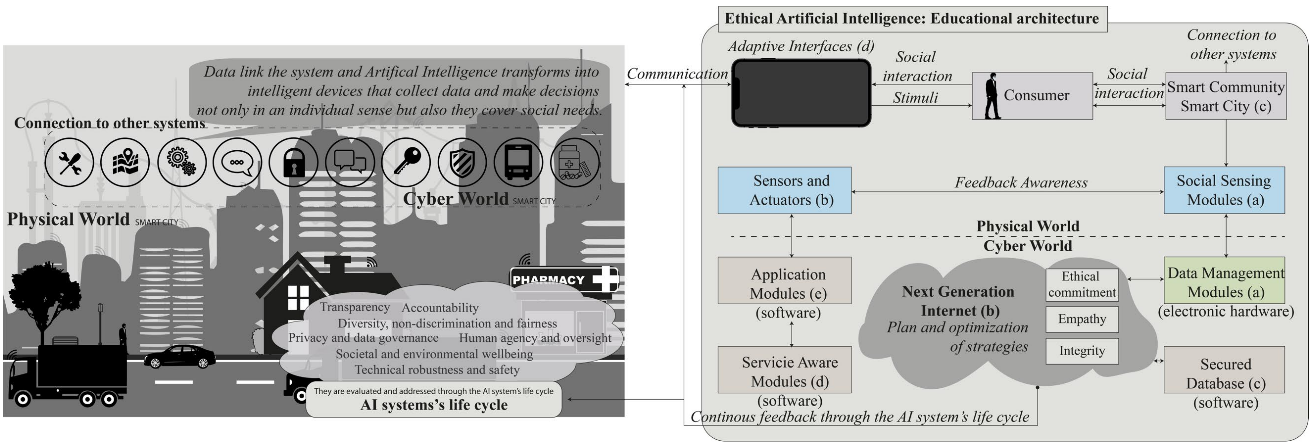

Fig. 2. General view of a smart city and SCPS with social and ethical features.

d) Adaptive Interfaces: The consumer receives stimuli through an interface to interact with both worlds. Consequently, the adaptive interfaces should provide strategies aligned with the Next Generation Internet that promote specific goals such as improving ethical background and interacting with other community members or the city.

On the other hand, developing the SCPS requires considering the ethical principles of no harm, justice, and explicability. For instance, in a smart city environment, the sensors collect information from surveillance, transportation, security systems, messaging systems, and healthcare, among others, through physical devices. Since a primary concern is ethics in the data gathering, it is suitable to apply the no harm, justice, and explicability principles and provide security to the whole system. In an educational environment, surveillance cameras in the academic and administrative community could collect data to analyze compliance with laws, regulations, and ethical principles and show the application of ethical skills.

III. Discussion

CPS is included as a critical element for improving technical capabilities in manufacturing systems. However, this paper describes how CPS must become SCPS to fulfill citizens' needs and expectations in smart cities. Suppose the cyber-physical systems do not interact well in social terms with humans and machines. In that case, they could limit the achievement of citizens' expectations and needs; the smart cities would only solve technical problems, which would be unacceptable. Besides, the solution could be biased by the designers. Thus, social factors must be included in the cyber world using the physical information from the CPS. Special social sensors have to be integrated into the CPS to convert to SCPS and detect ethical and moral behavior. Besides, social processing and managing must be a fundamental element in the creation of smart cities. Moreover, the concept of SCPS has to be included in human-machine interactions and machine and machine interactions. Each module of a solution proposal inherently requires teaching the consumer ethical principles and how to improve their ethical skills.

A first approach could occur in an Education context in HEIs such as Tecnologico de Monterrey. The Tec 21 Educational Model proposes the inclusion of the *ethical and citizen commitment competency* and the transversal skills necessary for the professional degree. This competency applies to all careers, including engineering.

Hence, ethical thinking development must begin in early childhood and be strongly promoted in undergraduate programs. In AI courses, the goal is to apply solutions based on AI algorithms. Still, these are limited when social features are not integrated into them. During their professional lives, students could succeed in implementing AI to solve real complex problems. However, they would not understand that smart cities also require social solutions based on moral and ethical principles. Hence, an introduction to ethical thinking should be a subject of any AI course regardless of the educational level or academic degree. AI programmers have an in-depth knowledge of programming but need ethical thinking to improve ethical skills to consider the implications of AI decisions.

Although this paper does not present a strategy for privacy conditions in smart cities, further research should focus on strengthening smart cities' potential and linking it with the social concept proposed in this paper.

IV. Conclusion

This paper proposes using AI algorithms in an SCPS structure that is based on ethical principles.

This proposal argues to profile and know every citizen better to develop efficient problem-solving strategies and promote ethical awareness throughout the community. An example of how ethics can be applied in the current educational system is provided through the Tec 21 Educational Model. This paper sets the scene for social processing and managing as fundamental elements in creating smart cities with dynamic interfaces.

As many European countries have proposed guidelines to diminish potential dangers for all the data collection gathering, these guidelines must become adopted in other parts of the world as privacy concerns, so an unbiased AI/IT decision making could be performed without violating privacy or personal data.

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Modelling Circularity in Bio-based Economy Through Territorial System Dynamics

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***Abstract* — We deploy territorial system dynamics as a methodology to analyze stock and flow diagrams (SFD), identify the circularity in the value chain management of bioeconomy, the strengths and limits of circular economy incorporating symbiotic links between multi-products supply chain. Complex systems theory, supply chain management and the geographic economy constitute the frameworks conceptualizing the closed loops supply chain management of industrial symbiosis. Our outcomes draw up three scenarios proposing simulations for 2027, which are able to integrate the complexity of multi-products and by-products allocation (sugar green juice, low quality syrup, CO2, and stillage) in the model. The strategic decisions engaged in the Scenario 2 trigger a less resilient industrial network in comparison with baseline scenario 1, standing out the lack of resilience in the biorefinery platform to an exogenous tension like climate change resulting in extreme periods of rain or drought. Scenario 2 results from a decrease in sugar beet production by 5%, in sugar beet production will trigger a fall of almost 50% on sugar production by 2027 in comparison with the baseline scenario. Furthermore, scenario 3 (COVID-19) shows strong negative effects just after 2020 crisis for agro-industrial ecosystems in cities, but they can maintain value chain functionality which is not the case for climate change effects in scenario 2, entailing a faster network recovery that in some extent can be explained on the bases of the value chain circularity of industrial symbiosis.**

Keywords—biorefinery, system dynamics, value chain, circular economy, industrial symbiosis, bioeconomy

I. Introduction

Circular management of resources became a key driver in fighting against resource depletion and/or waste overproduction. Even when we already have global recycling circuits trying to tackle this challenge, they cannot give full satisfactory answer. Limitations of circular economy such as biophysical degradation through entropy, products durability and lifetime spend in the economy, spatial system's boundaries, rebound effects, path dependencies and waste cultural influence result in a partial answer to this challenge that in some cases could be triggered into negative trade-offs. Circular economy is promoted as one of the transition models encouraging models of human development to reinvent themselves based on the circular management of raw materials' flows and stocks and the creation of synergetic exchange opportunities. We claim in this paper that Circular economy and supply chain management literature have many similarities. The aim of this paper is to improve our systemic understanding on how actors' decisions and exogenous impacts at resource flows/stocks influence the overall industrial ecosystem, to analyze the alternative scenarios of allocation decisions influencing the ecosystem. Our research question examines how the systemic relationships in the bio-based value chains should be coordinated in the industrial symbiosis when balancing the demand and supply of wastes over the years. To better answer this question, we use the methodology of Territorial System Dynamics (TSD), allowing us to link biophysical flows and strategic decisions. This provides a decision-making tool for addressing collective action problems that could not be solved individually by any single member of the network [1].

Territorial system dynamics (TSD) attempts to better depict the value chains integration in the industrial symbiosis through the modelling of value chain complexity in an industrial network. In comparison with other mainstream forecasting methodologies, (i.e. statistics trend extrapolation, expert panels or decision trees, among others.) TSD methodology identifies pathways according to current behaviors in the network of actors, integrating the material flow and stocks relationships in the supply chain, but at the same time is able to integrate the socioeconomic and environmental constraints in the model. TSD opens up the discussion about the complexity of synergic decisions in the industrial symbiosis. The more actors embedded in a network the more complex the supply chain became, because of the challenges stemming from the cooperation with multiple waste suppliers/receivers.

We identify the biorefinery as one of the most successful examples of bio-based industrial symbiosis pursuing circular and sustainable goals. Once established that value chain integration in a territorial approach represent a valuable asset to overcome complexity and develop cooperative relationships based on trust in the bio-based industrial symbiosis. Bio-based industrial symbiosis takes place in the form of synergic exchanges in the value chain (reverse supply management, closed-loops supply management, synergic relationships, etc.). Trade-off in the bio-based industrial symbiosis mainly lies in how much effort to unbundle the material at the harvesting point versus the cost and ability to use the undesirable structures such as seeds husks, hulls, stillage, syrup, CO2 or pods. The biorefinery case study we analyze in this paper is the Bazancourt-Pomacle platform (BPP) located near Reims city (department of La Marne) in France. Our findings in the BPP case study are discussed in light of the IS's strengths and limits, with the aim of providing tools for research and policy implementation. Agro-industrial models is one of the best examples of complex value chain models where the TSD methodology can be settled integrating complexity from biophysical and strategic decision makings actors in their scope. The simulation model was set up around Cristal Union sugar cooperative, which plays the role of anchor tenant [2] and three ancillary players that contribute to IS success. The three ancillary players are: Cristanol, the distillery part of the Cristal Union consortium, the starch and sugar lab ADM (ex. CHAMTOR), as well as Air Liquide, the industrial gas specialist in charge of transforming carbon dioxide as an input for the soft drink industry.

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II. Methodology

We perform systems dynamic modeling in this study, for the sake of data gathering needed to build up the model we used data from secondary sources, including: 1) institutional reports and action plans, 2) official and non-official communications from stakeholders, local counties and regions, and 3) academic literature. Institutional reports and action plans include the Executive Board Reports [3] and the French national guidelines for the circular economy [4], as well as the Methodological Guide for the development of regional circular economy strategies in France; the guidelines of industrial and territorial ecology; how to manage territories [5] among others. Among official and non-official communication, we have also included in the model relevant information obtained from the semi-structured interviews with consultants with deep knowledge and expertise over the technical and business management of the biorefinery platform.

Among all the previously identified methodologies able to study complex agro-industrial ecosystems as a subset composing the sustainable cities system and referred in the literature review, we recognize System dynamics (SD) can better integrate complexity from biophysical and strategic decision-makings actors in their calculations. When SD is adapted to a mesoscale analysis that highlight the territorial dimension, setting the actors relationship in the network, and the supply and distribution strategies in the heart of modelling efforts we call this TSD. Territorial system dynamics (TSD) is an analytical tool that allows causal loop identification, balancing or reinforcing impact throughout the system (stocks – flows model). One of the advantages of TSD simulations is the possibility to test impacts and effects of resource allocation, TSD also has the advantage of providing a larger scope for territorial management in complex agro-industrial ecosystems, where the exogenous and endogenous variables are identified, focusing on the drivers on which the system's actors have control. Drivers like the strategic allocation decisions on final products and/or by-products, investment on R&D, infrastructure and technology among others. Territorial system dynamics (TSD) includes in the analysis of the system the territory influence. Territory influence can be defined as the political, administrative, social, economic and environmental framework in which a system has to be implemented. System's pathways display the ability to anchor itself in the present and propose meaningful and sustainable pathways to the future. Therefore, uncertainty in the medium- and long-term claims for a methodology able to propose different scenarios coming from different pathways, which provide a wider realm of possibilities produced by the model, which gain in political relevance as political decision-making tools.

Identifying and understanding behavioral changes and the impact of those changes is essential to analyze the circular management of biowaste in a territorial dimension. We build up the model of our biorefinery case study with a systemic approach that offer a comprehensive understanding of circularity in the bio-based value chain from the extraction of bioresource to the end of life of the finished products and then closing the loop. The model developed in this study depends on previous years' conditions (stocks), including current performance (flows), and allocation decisions made by different players (rates) in the industrial symbiosis process. Thus, after defining the starting conditions and assumptions, we define the model equations that will structure the system in 2017 (period t) and its trajectories until 2027. The complexity found in agro-industrial ecosystems as a subset composing the sustainable cities system is indicative of the struggles to find the pathways to engage circular economy transition in the bioeconomy field. TSD method bring new insight to the circular modelling of biorefineries, allowing a systemic understanding of the horizontal and vertical collaboration within actors in the bioeconomy network. TSD opens the room to analyze systems resilience through endurance of supply and demand of input and output contracts, which evaluate the endurance of the relationship between entities.

III. Results

The case study analyzed in this paper is the Bazancourt-Pomacle Platform (BPP), a biorefinery that entails an industrial symbiosis based on biomass availability, coming from the upstream process (agricultural cooperatives) and embedded within the system's boundaries [6]–[8]. The Bazancourt-Pomacle Platform entails the most remarkable example of successful industrial symbiosis in the bioeconomy field in France. The industrial symbiosis is composed of 10 actors, including Vivescia / Bletanol, Cristal Union, Cristanol, Chamtor, Givaudan Active Beauty, Wheatoleo, Air Liquide, European de biomasse, the Industrial research centre (ARD) and the European Biotechnology and Bioeconomy academic research center (CEBB). Within the sugar beet value chain systemic model, we identify the following products and byproducts:

- The commodities are green sugar juice and syrups derived from crystallization or distillation will result in products such as sugar, alcohol, and bioethanol.
- The by-products are stillage, low-quality syrup from crystallization, and CO2 resulting from distillation and crystallization.

In general, by-products in the model are looped within the boundaries of the platform; low-purity syrup is distilled into alcohol or bioethanol; CO2 is used to gasify drinking beverages; pressed pulps for animal feed; and finally, the scum from syrup production as well as stillage are reused as fertilizers.

A. *Baseline Conditions of a Dynamic Modelling*

Sugar beets represented 67% of agricultural production in the Marne region in 2017 [9]. Agricultural production in the Bazancourt-Pomacle area reached 3 million tons in 2014 [5]. Given this figure, we estimate total production for the 2017 at 3.36 million tons, and therefore, 2.25 million tons of sugar beets processed onsite. The area for growing sugar beets in the Marne increased annually by 3% between 2007 and 2017, oscillating between the ranges of -3% and +8%. The platform at Bazancourt-Pomacle has the infrastructure capacity to store 672,000 tons of sugar beet, or approximately 30% of annual production. The production of low-quality syrup in the BPP is calculated at 54,600 tons, and the stock of by-products from distillation is fixed at 101,929 tons (including available sugar beet biomass for distillation). The CO2 emission rate for sugar is 45% of overall sugar; the CO2 emissions rate from low-quality syrup projected for distillation is 25% of the overall volume; the stillage production rate for sugar is 6.5%; and the stillage production rate for low quality syrup is 5%. Stillage as output of non-food sources like the sugar beet pulp has generally poor nutritive quality, which restricts its use as animal feed [10] in the BPP. An alternative for stillage utilization in La Marne is its use for biogas production. The sugar beet pulp stillage has high concentration of organic matter and nutrients and its dry matter content reaches 83%, triggering a "dry digestion" often referred as "rocket fuel" for agriculture when compared with compost. Thus, it has earned his tag from its high available nitrogen content in sugar beet pulp stillage with an average concentration of 5.8% of nitrogen [10]. We can observe that the nitrogen fertilizer consumption in France goes from 80 to 100kg/ha of fertilized utilized agricultural area (UAA). The 20% increase in the nitrogen fertilizer consumption suggest that the commercial fertilizer's replacement volume for the sugar beet bio-fertilizer in the BPP stands between 1.4 and 1.7 tons of Sugar beet pulp stillage per hectare. We build the model simulations based on equations subject to the following model's assumptions linking the theoretical framework with the model's initial conditions.

B. *Territorial Systems Dynamic Modelling*

We develop stock and flows diagrams (SFD) that is displayed in Fig. 1, in the diagram the stocks are represented by square boxes, as in the stocks of available sugar beets. The double black arrows represent processes (production, use, sales) that determine the stocks of products and by-products e.g., the sugar stocks influenced by the stocks from previous year and production in current year.

The current year's production will depend on the technical efficiency crystallization rate. The available technologies and their efficiency are symbolized by rates, and the double black arrows represent them. We assume these rates can change over time. Curved blue arrows illustrate the variables influencing the rates. The stock is the accumulation of materials over a certain period (one year, in this case) and the rate refers to the changes in flows over time, i.e., the by-products reused for distillation. The dotted arrow represents the causal relations identified in the field, but which have not been modelled due to a lack of data, i.e., we observe that stillage improves agricultural yields, but we do not have data about it. With available and reliable data, this model can be extended in terms of actors, relationships, and rules regarding biomass, products, and by-products.

C. *Scenario's Simulations*

We simulate three stock and flow scenarios at the BPP systemic agro-industrial model presented in the analyzed case study where we sought to integrate quantitative and qualitative aspects to better understand the expected impacts and benefits. These scenarios are: 1) the baseline scenario; 2) strategic change in the sugar-beet outcome with small reduction in sugar-beet productive efficiency; 3) unexpected change in the sugar-beet production and consumption triggered by COVID-19 in 2020.

We develop a scenario-based approach to identify the best strategies to implement circular economy for organic waste management in industrial symbiosis. Our study establishes the based-scenario approach according to systemic understanding, describing each scenario by a set of specific economic, technological and social conditions from a territorial standpoint included in the model, those conditions have been previously displayed in the baseline conditions section. The scenario's simulations should encompass the set of specific values from the different stakeholders, regarding the political, economic and social perspectives. These

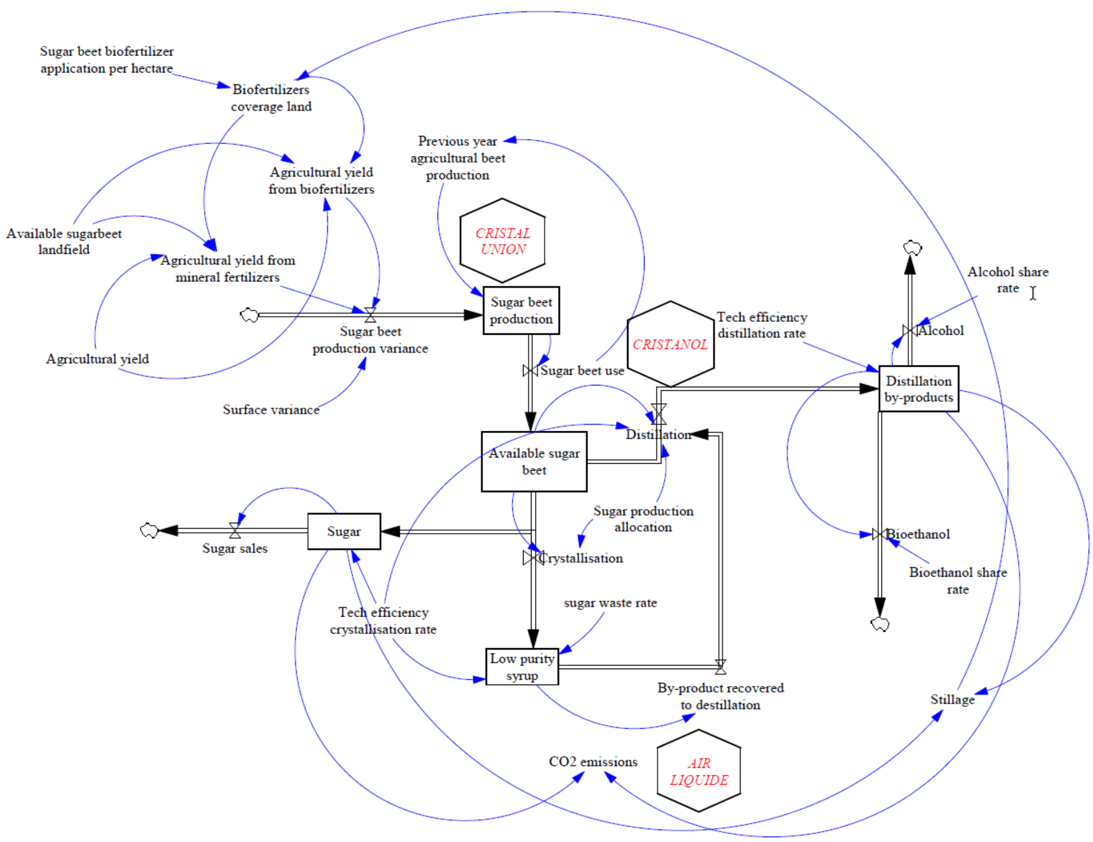

Fig. 1. Sugar beet flow and stock diagram of the BPP.

perspectives could be for example regulations stringency for organic waste management or resource scarcity increase, etc. For each scenario, different pathways to implement circular economy in the territory can be developed based on the understanding of interaction and drivers' behavior.

IV. Discussions

We decided to present three scenarios in this paper each one with different starting conditions, which can simulate the trajectories of the BPP sugar beet ecosystem from 2017 to 2027. Scenario 1, represent the starting conditions presented in 2017 foreseeing these same trends until 2027. Scenario 2 depict the rate of sugar and alcohol production changes from 50%-50% to 30%-70%, with an annual 6%, increase in the cultivated area because the attractiveness of the bioethanol market, resulting from a decision to specialize in distillation processes that provide more added value like the bioethanol. Scenario 2 also include the condition that sugar beet production will fall by 5% per year, that is, a lower deceleration than the 15% observed in France in 2010, 2011, and 2012. This scenario let us simulate the consequences of the strategic decision towards alcohol resources' allocation in the face of falling sugar prices and enables us to simulate the impact of climate change resulting in extreme periods of rain or drought. Scenario 3 introduce the COVID-19 scenario where the rate of sugar and alcohol production moves in 2020 to 20%/80% rate, with an annual 8% increase in cultivated areas resulting from the decision to get specialization in distillation, with added value processes like the bioethanol and sanitizing alcoholic gel. Scenario 3 keeps the baseline sugar beet yield with a 1.2% increase in production per year and set up an increase in the bio-fertilizer application per hectare from 1.55 tons to 2 tons, responding to an environmental transition effort. This scenario also considers a change in 2020 where 70% of the total distillate alcohol is supplied as input to the sanitizing alcoholic gel as a result of the increasing demand of cleaning and disinfectant products and only 30% designated to ethanol production.

Regarding the sensitivity analysis to evaluate the degree of uncertainty that the model can handle without compromising the stability of the IS, the model analyses the effect of external variables that are not submitted to strategic decisions, like the "Agricultural yield" in the Scenario 2 and the alcohol share rate in the Scenario 3. But some other external variables can also be subject to the sensitivity analysis in the model like the worldwide decreasing of bioethanol consumption resulting from the COVID-19 slow down effect in the economy, triggering a strategic decision in the model where bioethanol production decrease was traded-off by the alcohol production used to in the hydro-alcoholic gel for hands production. The plurality of local actors and the diverse and sometimes contradictory set of interests must be considered if we want to encourage dialogue between actors. The territorial governance policy is therefore important, because it creates the context that can favor activities more or less conducive to developing local bioresources.

V. Conclusions

This paper aims to clarify the way in which circular value chain principles work in a complex bioeconomic context. We identify territorial system dynamics (TSD) as the most suitable methodological tool to describe complexity, analyze, and model the dynamic stocks and flows, encompassing actors' behavioral effects in the system. The territorial approach related to the sustainable cities field in general facilitates the identification of the values and interests that govern the local structure in the agro-industrial ecosystem as component of a sustainable city, which is then integrated into a collective rational allocation of common resources among collaborative players. System dynamics methodology led us to combine the biophysical and socioeconomic influence of actors and their impact on the emergence and sustainability of IS platforms. As this study focuses only on material synergies between firms, energy flows are not considered in the analysis. Further research is therefore needed to investigate the energy potential of bio-based industrial symbiosis. Assessing material and energy aspects together will lead to a better understanding of IS contribution to sustainability.

The findings presented in this paper combine material stock and flow analysis with the distortions caused by interfirm relationships on a meso scale that strengthens a functional understanding of systems. The end of European quotas in 2017 and the production mix change (products and by-products) for sugar beet biomass resulting from the attraction of high value products markets like biofuels, medical and sanitizing care products is potentially addressed. Our results suggest that decisions to invest in the distillery led to a reduction in sugar production, and hence a reduction in the by-products that can be reused and made profitable via the synergies at the BPP, which could increase risk for such synergies. Simulations show that even in front of a stronger crash in the Scenario 3 (COVID-19) that took place in 2020, functional structures remain operational, and then the systems' resilience state their ability to get recovered from an external shock like the decrease in biofuels' demand and the shift in production strategies. However, when the drought and climate change effects are long lasting, they affect the agro-industrial ecosystem's functionality triggering a reduction in the territorial agricultural profitability. The vulnerability in the systems makes the recovery slower and external risk reduce resilience.

TSD models provide information on incoming and outgoing flows, and on the stocks and scenarios likely to improve the performance of the agro-industrial ecosystem as a subset of sustainable cities. It clarifies the role of local stakeholders in the circular bioeconomy strategies, and provides recommendations for public policy. Thus, TSD methods open up the room for discussions on alternative prospective tools able to raise a systemic understanding, thus defining strategic priority to circular economy actions according to the arrangement of sustainability and circularity goals. Regarding the research methods and conclusions, this study is not criticisms free, the robustness and validity of author's model could be questioned due to the difficulties in data gathering, because flow rates of waste materials are usually not measured or recorded. This study does not include the controversy regarding the weak/strong sustainability of the concepts of bioeconomy and circular economy that raise the question of economic growth suitability, but stand for their clarification and reciprocal integration of both concepts. However, the originality of this methodology relies on the loops introduction in the value chain, to better understand the impact of feedback effects in value chains and incorporate the CE and sustainability principles to build coherent tools and means capable to recognize and mitigate negative interactions (trade-offs) and maximize positive synergies to better address territorial resources allocation in a systemic and reproducible way.

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Model-based Systems Engineering of an Active, Oleo-Pneumatic Damper for a CS-23 General Aviation Aircraft Landing Gear

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***Abstract*—Model-based systems engineering (MBSE) is combining product development and project management with a focus on cross-domain, multidisciplinary projects in product development. In many application domains the engineering process and the quality gates are standardized and well defined in respective regulations. The goal of this contribution is to present a project design and engineering process which is compliant with aerospace regulations. As a case study, this paper deals with a detailed development process related to an active, oleo-pneumatic damper for a CS-23 general aviation aircraft landing gear (The CS-23 document is a construction and certification requirement for light weight powered aircraft published by the EASA). It is shown how system requirements are generated from use cases, environmental influences, failure conditions and stakeholder requirements, which finally result in the system architecture and shows how these work products are managed, especially when people from different domains are involved. Based on this, the domain-specific work products are generated, resulting in a list of hardware components, a software architecture and technical drawings for production. Furthermore, the approach illustrates how MBSE is used to incorporate safety assessment into product development.**

***Keywords*—Systems Engineering, Aircraft, CS-23, Model-based Systems Engineering, Active, Damper**

I. Introduction

Sustainable mobility is one of the major challenges both due to the complexity of the systems and the impact on society, ecology and economy. Therefore, mobility is a sector with a high demand for innovation and carefully engineered solutions which consider efficiency, but also concerns like safety. This leads to high quality requirements which are part of the engineering processes. Systems engineering combines the project management perspective and the engineering perspective. For complex solutions, it is very relevant to form multidisciplinary teams from different engineering domains, e.g. mechanical, electrical, software, which find optimum solutions by combining cross-domain design elements. MBSE uses formal and abstract models as a ”common language” for the work amongst the experts and for simulating the models with computers. This paper describes a MBSE process which is adapted to the requirements of the aerospace industry. It provides a combination of principles from configuration management, safety assessment and cross-domain modeling of solutions on different layers of detail. The case study of an active aircraft landing gear with oleo-pneumatic damper is used to illustrate the process.

Current airline standards require an aircraft to complete up to 90,000 cycles during its life cycle. A life cycle refers to takeoff, cruise and landing combined. In this context, 50% of accidents occur before or immediately after takeoff and landing [1]. Since the landing gear damper is a safety-critical component, the appropriate development processes are required as described in CS-23 [2] and associated documents [3]–[8][1]. These guidelines describe the requirements for managing, creating, formalizing, and deriving work products, but leave open a detailed hierarchy and structure. Furthermore, they do not address what specifically can go wrong in practice, for example, when ambiguous or not clearly defined language is used. Or more generally, what happens when the human

[1]The above guidelines for manned aviation are typically implemented with a commercial and often expensive software tools, e.g. *MATLAB* as a simulation tool or *Polarion* as a documentation tool [9].

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factor is involved in the execution of these processes? The safe integration of a new multi-domain system into an aircraft is essential and at the same time also a challenging development task. Therefore, it is important that all persons involved at the beginning of a development project gain the same understanding of the system in the shortest possible time. This can be a problem, however, because in a multi-domain project each person has a different understanding of the system. But that's not all: How can it be ensured that all knowledge remains in the project if, for example, one person leaves, or that a combination of development products from different domains will work reliably, or that there is a sufficient set of safety requirements, or that changes in the system that occur during the project do not lead to contradictions? These are just some questions that arise in a multi-domain project. This paper continues and gives a deeper insight into the execution of some processes by a case study and shows some points what to be aware of in practice. Furthermore, a way is shown how the CONSENS method (Conceptual Design Specification Technique for Engineering of Complex Systems) can be embedded in aerospace processes.

II. Development Case Study

Landing gears of CS-23 general aviation aircraft are in many cases equipped with passive oil-gas shock absorbers, which absorb energy at landing impact by forcing an oil chamber against an air or nitrogen chamber. This compressed gas behaves like a nonlinear spring under load, causing the pressure to increase with increasing damper deflection. The dissipated energy depends on the deflection velocity by forcing the oil through the implemented throttle openings. If the oil flows back too quickly after compression, a rebounce occurs, causing the main landing gear suspension to bounce back. If the oil flows back too slowly, high-frequency shocks that occur during rolling are not sufficiently damped because the shock absorber has not retracted fast enough into the static position [10]. To influence the damping behavior during landing impact, the conventionally used passive system is extended with an active and semi-active system part, as shown in Fig. 1.

In this context, semi-active means that the use of actuators can only change the amount of dissipated energy. In contrast, active systems can additionally transmit or extract energy in the system. By changing the cross-section area of the adjustable valve in the semi-active system part, the resulting hydraulic damping force due to the damper deflection velocity can be adapted by the system autonomously. For example, a larger opening cross-section area would be selected for ground travel in order to achieve softer damping. Depending on the variables measured online, such as pressure or damper deflection, the control law is used to calculate the current for controlling the degree of opening of the valve. For the active subsystem, a linear motor with cylinder pistons is used, which allows additional gas and oil to be pressed into the damper from a separate chamber, as shown in Fig. 1. Even a small change in the initial pressure level is sufficient to achieve a higher pressure level with the same high deflection

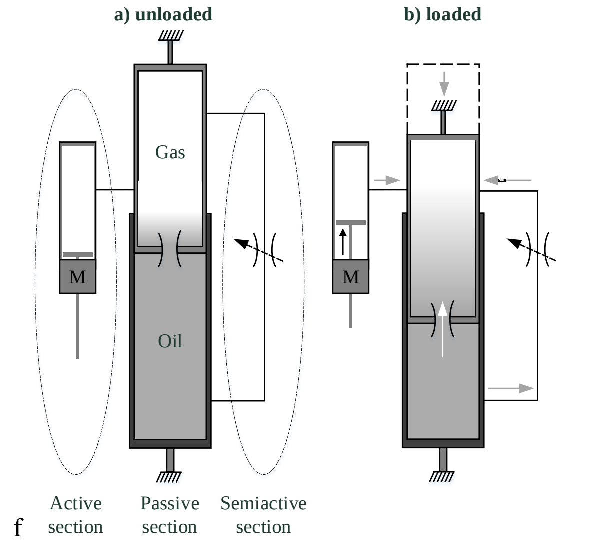

Fig. 1. Oleo-pneumatic damper with an active and semi-active section in a) unloaded and b) loaded state.

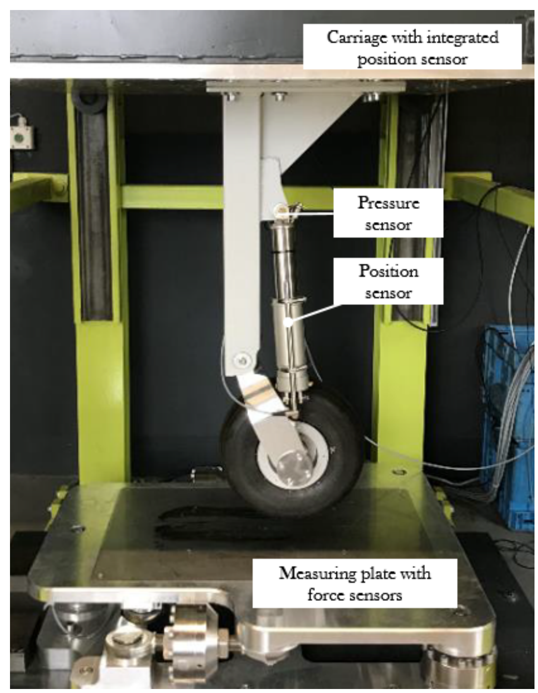

Fig. 2. Trailing arm landing gear suspension with integrated active damper on a droptest bench of the company HEGGEMANN AG.

($p \sim x^{-1.4}$, whereby x describes the damper deflection and p the damper pressure). This allows an internal pressure to be set as a function of the estimated weight force on the aircraft landing gear to receive an optimal reaction force of the damper. In Fig. 2, the damper is shown integrated in the drop test bench.

The drop test bench, shown in Fig. 2, is required to satisfy the top-level requirements (here defined as CS-23 work product related to Fig. 3) of paragraph CS-23-723 (Shock absorption tests) of CS-23 [2].

III. Configuration management

In the development phase of aircraft construction, configuration management has the task of creating transparency in product development and project management. In addition, traceability, change control and verification (in the specific case here CS-23) must be ensured at any point in the project. Here, a project structure is defined that hierarchizes and links the individual work products (e.g., requirements or architecture elements) based on the V-model. The guideline VDI 2206 recommends the V-model as part of the development methodology for mechatronic systems due to the increasing integration of mechanical, electrical and information technology components in mechatronic systems and the associated increase in complexity. All work products are distributed in total on four levels with a well-defined level of detail, as shown in Fig. 3. Each level is described in more detail in the following section V. Even if it is obvious to start the project at level 0: aircraft, Fig. 3 is not intended to imply a time progression from top to bottom, but only to show the relationships between work products. It is not surprising that even in the later stages of the project work is done at high levels, especially when change requests occur or iterations need to be done. Furthermore, only the traceability between the work products are shown, which can be implemented completely in text form in a tool, such as *Polarion* or *PTC Integrity*. In any case, traceability should be implemented bidirectionally so that it is possible to quickly jump back and forth between work products to improve the work flow. To keep overview, only one connection is shown between the work products in Fig. 3, even if a bidirectional trace is intended. For example, the transition path ”derived from” would automatically imply the return path ”derives” as well. Furthermore, the implementation itself, e.g. software code or test code or the realization on a test bench as work product, is not shown here. However, this does not suggest that there is no trace between the documentation and the realized implementation. In fact, such a track is quite necessary and is only left out here for the purpose of overview. To realize an interface, an additional software shall be used, which generates a bidirectional trace between two software development tools. As example, for the tools *Polarion* (documentation tool) and *MATLAB* (implementation tool) an interface, called *SimPol*, was already designed at the Technical University of Munich which generates a bidirectional trace [9].

IV. Safety Assessment Process

Here, only a basic overview of the necessary safety assessment processes can be shown that are performed during the development phase. For example, the Safety Analyses CCA (Common cause analysis), ZSA (Zonal Safety Analysis), PRA (Particular Risk Analysis), CMA (Common Mode Analysis), and so on are not discussed here as it is beyond the scope of this paper. For the implementation of each safety analysis, the reader is referred to common literature, especially to ARP-4761 [4] and AC23-1309-1E [8].

At level 0: aircraft, an aircraft FHA (Functional Hazard Assessment) is performed at the beginning of the aircraft/system

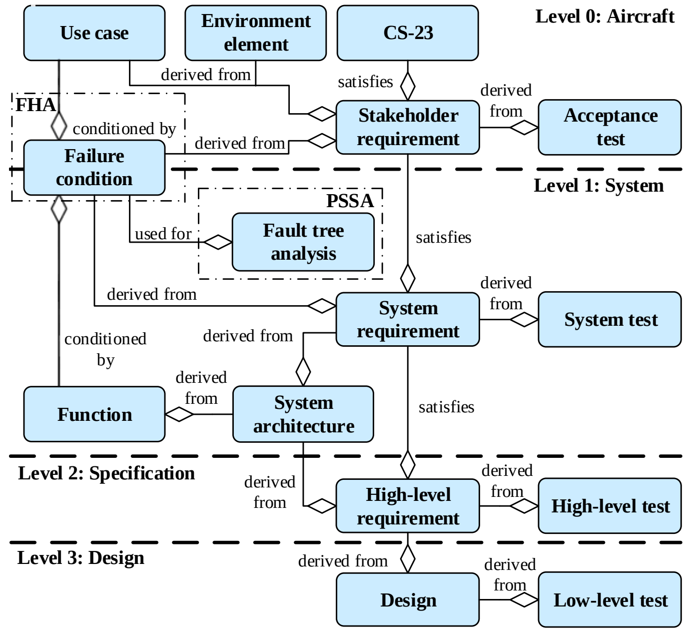

Fig. 3. Traceability between document work products.

development cycle and is defined as a systematic, comprehensive examination of functions to identify and classify failure modes of those functions according to their severity [11]. A FHA is performed at the aircraft level and at the system level. For this, failure conditions are associated with aircraft functions. This establishes the safety objectives on top level in combination with an aircraft FTA (Fault Tree Analysis) [4]. MBSE delivers the methodology to incorporate the safety assessment into the product development. The aircraft functions (high-level functions) are identified as use cases which are generated using CONSENS method [12]. That this method is suitable for an analysis of fault conditions in general has already been shown in [13], but so far not especially for the application in aviation. The failure conditions that arise lead to new (safety) stakeholder requirements. Analogous to the aircraft FHA, a system FHA at system level is derived from (system) functions. Furthermore, it is combined with a system FTA, which is usually used to perform the PSSA (Preliminary System Safety Assessment). However, there are other possibilities, such as a Dependence Diagram (DD) or a Markov Analysis (MA) [4], which can be used here instead. From the Failure Conditions, that are generated from (system) functions, new (safety) system requirements are generated to adjust or extend the system architecture, which leads to new system functions as well [14]. This iterative process is performed until the error probability (calculated with the application of the FTA) is below the specified threshold. Furthermore, the system FHA is processed down to design level 3, even though it is only shown at system level in Fig. 3.

V. Systems Engineering process

The starting point is usually a basic idea of the system with the respective use cases and environmental influences.

Especially in the early phase of a project, CONSENS provides a common understanding of the system for all project participants and the models support the transition to detailed development according to MBSE. From here, further detailing steps are taken to specify the development task.

A. Level 0: Aircraft

Use cases describe characteristic operating states of the system under development. They are defined by characteristic pairs of situations and states of the system [15]. Therefore, the reaction of a system or subsystem is a result of an action by one or more actors. Actors can be persons or other systems, which are not in the focus of development, but are coupled with the system to be developed. This system exists only as a black box. Therefore, the use case shall describe the behavior of the hole aircraft structure in which this system is embedded and from which further subsystem descriptions can be derived. For example, the use case with the title U1: "Reduce the body acceleration of the aircraft due to the landing impact" intends the desired aircraft behavior with the embedded system. For every system-environment interaction in combination with U1, a list of stakeholder requirements are derived, such as

> R0.1: "All electrical components of the system *shall* be able to operate with the given aircraft power supply."

This stakeholder requirement must be reflected in the environment model, which it also does through the interaction between the system elements "power transmission elements" and "electronic control unit", as shown in Fig. 4.

The environment model describes all interactions of the system as a black box with individual environment elements and specifies them in detail. Environment elements can be arbitrarily specified systems (also persons), which interact with the system to be developed but are not part of the system. How environment elements are distinguished from each other in detail is not particularly relevant. It is much more important that every employee in the project agrees with the nomenclature and receives the same understanding of environmental influences on the system [16]. The system itself may include various forms of solutions. In order to find out the best solution, it allocates the results from the use cases and environment elements to a defined set of stakeholder requirements. As easy example, the use case U1 in combination with the environment element "landing gear" and its interaction to the system "landing impulses" can be allocated to the stakeholder requirement

> R0.2: "The system *shall* be able to avoid rebounds of the aircraft after landing impact"

The occurrence of a rebound depends on the type of landing[2], the total weight of the load, and so on. Therefore, the implementation of R0.2 is a difficult and cost/time intensive process. In addition, it is necessary to perform each load and landing type configuration by testing. In reality, such tests would not be performed on level 0: aircraft with dampers implemented, because a failure of these acceptance tests would endanger human lives. Instead, the landing gear is previously tested (system tests) on a drop-test bench, for which the CS-23 provides the test criteria.

It is important to note that stakeholder requirements should not be derived from customer needs alone, as the customer may not know what frameworks need to be considered. For example, the document CS-23 may list specific requirements that apply to a particular use of the system in a particular environment. All stakeholder requirements derived from the CS-23 are written in a consistent form (syntax, prioritization, description, etc.) with the stakeholder requirements dervied from use cases and environment elements and highlighted as CS-23 stakeholder requirement. It must be taken into account that each requirement placed on a system must be unique, not overlap with other requirements or even contradict them. Furthermore, requirements must be formulated in such a way that they can be verified and validated on every detail level [17]. Especially contradictions in requirements can have various causes, whereby the following are especially obvious:

- Incorrectly derived requirements, resulting from a wrong understanding.
- Incomplete post-processing of the requirements after a change.

The first cause can be mitigated by clear project language. For this it is important that requirements have a clear syntax, as shown in this paper in numerous examples related to [17]. Text syntax is also required for the design of other work products, such as tests or architectural elements, and should be defined early in the project and supported by appropriate software tools. However, that is not all: Is there a difference between hardware and electronics, or is "mechanics" a separate domain? Which definition is the correct one does not matter. Instead, it is important that everyone on the project understands the same of the nomenclature used so that work products are not misallocated or misformulated [18].

The situation is different for the second cause. For example, the level 0 requirement

> R0.3: "If the electrical power supply fails, the system *shall* guarantee a safe landing."

will be changed in the current project. The level 1 requirement derived before the change is formulated as

> R1.1: "If the electrical power supply fails, the system *shall* be damped purely mechanically as in convention passive systems during landing."

The R0.3 is now changed to

> R'0.3: "The system shall be able to operate with self-sufficient electrical power supply systems to minimize the probability of failure to $10^{-6}\%$ during landing."

and therefore contradicts the old system requirement R1.1, since R'0.3 requires a self-sufficient electrical circuit, but R1.1

[2] Landing types differ mainly in different velocities on impact and load distribution if, for example, a wheel of the main landing gear touches down first.

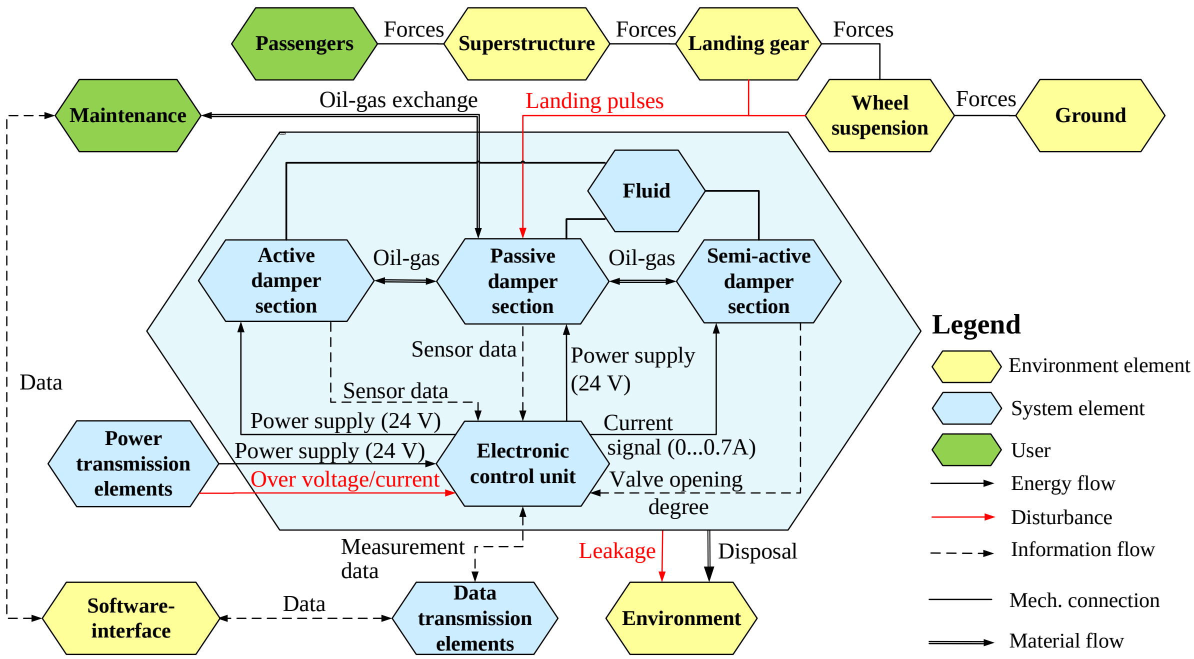

Fig. 4. Second layer of the CONSENS system architecture.

excludes this. To solve this problem for all levels in Fig. 3, tools like *Polarion* or *PTC Integrity* offer the possibility to mark changes to the related level as "suspect". If the changes were completed on a certain level, the next affected levels (connected by the bidirectional trace) are marked as suspect, too. This post-processing continues down to the lowest level of detail. Therefore, it is important to note that each change should be reviewed by other project members. This can be ensured by an approval/reviewer process [19].

B. Level 1: System

System requirements are derived from the stakeholder requirements in such a way that they can be tested and implemented as abstract system element on the test bench as interaction of hardware and software. For example, a derived system requirement from R0.1 can be written as

> R1.2: "To avoid rebounces, the controller *shall* control the oil and gas flow inside the system."

which in general suggest an open solution for this desired system architecture part. In that case, the (high-level) system architecture elements A1: "active damper section", A2: "semi-active damper section" and A3: "microcontroller software" are derived from R1.2. The hardware request part of R1.2 is solved by splitting the solution in two system elements A1 and A2. The software request part of R1.2 is satisfied by A3, as shown in Fig. 4. In addition, the system element A3 is part of the superior architecture element "electronic control unit", which contains the electronic system parts, such as "microcontroller" or "energy management system". It is important to ensure that the related system elements A1, A2 and A3 fully meet R1.2. It is obvious that not only actuators/sensors (hardware) are needed to control the oil and gas flow in the damper, but also the corresponding software must be implemented. Which actuators/sensors are especially required, however, does not necessarily have to be specified at the highest architectural level, but can be specified in more detail at the lower level. An example for a possible sub-architecture elements can be a "pressure sensor" or a "linear actor". Based on this procedure, the system architecture is created.

To keep costs and effort to a minimum, it is also important to avoid redundancy in the system architecture. For example, it should be checked whether the requirement (R1.2) is already fulfilled by A1 or A2 alone. Without going into detail, both system architecture elements (A1 and A2) are not exclusive in this development example, shown in Fig. 1, but complement each other advantageously.

At first view, the requirement R1.2 seems to be logical and easy to implement. However, it must be taken into account that all actuators, sensors and data processing units used require different current and voltage supplies, which must be adapted by a converter. A system requirement that derives the system element "converter" could be formulated as

> R1.3: "All needed supply voltages shall be provided by suitable voltage converters."

This formulation refers to all possible loads without going into detail about each load of the individual system part. In the same way, a number of system requirements are created for each stakeholder requirement, which finally results in a system architecture. It is important to note that a system requirement can lead to much more system elements than are obvious at the beginning of the project. These few examples clearly show that this results in numerous additional system requirements, which in return are divided into domain-specific software and hardware requirements. This process of decomposing cross-domain requirements into domain-specific requirements, supports the development of complex systems by involving domain-specific teams in the overall project and development process.

C. Level 2: Specification

Software and hardware high-level requirements are derived from system architecture elements and satisfies the related system requirements in more detail, as shown in Fig. 3. Example: The architecture element A2: Semi-active damper section is a combination of further architecture elements, such as A2.1: Adjustable valve, which is intended to control the fluid flow from the lower to the upper chamber of the damper (see section II) via a current signal from the energy management system. A possible derived hardware requirements could be formulated as

> R2.1: ”In the de-energized state, the adjustable valves *shall* close automatically.”

which satisfies only a part[3] of R1.1 (shown at the end of section V-A) before the change process takes place. Why a requirement is necessary should be explained in more detail in the description of each requirement. For example, R2.1 requires that no oil flows through the semi-active system part of the system in de-energized state. The damping shall only take place due to the passive part of the system. This realizes a fail-passive behavior in the de-energized state of the system.

Whenever possible, high-level requirements should include numeric values that better support hardware selection or design. For example:

> R3.2: ”The diameter of the adjustable valve *shall* be adjustable in a range from 0 cm to 5 cm.”

However, this is not always possible and also necessary, as the example based on R2.1 shows, because this requirement is also testable. Furthermore, requirements should also be specified that many people would assume to be trivial. For example, the software requirement

> R3.3: ”The cyclical measurement data buffer *shall* be large enough to map a measurement duration of at least 8 seconds.”

would not only give a clear restriction for the software to be implemented, but also affect the measurement process. The memory of a microcontroller is limited, so it is not desired that the memory is overwritten again after 8 seconds. This may be clear for many people involved in the project, but not for everyone who only has expertise in mechanical manufacturing, e.g. who has to perform the measurement process. Therefore, a ”common language” understood by all project members is needed to connect and synchronize development tasks.

[3]In the case of an electrical power failure, the active system part behavior is not considered in requirement R2.1

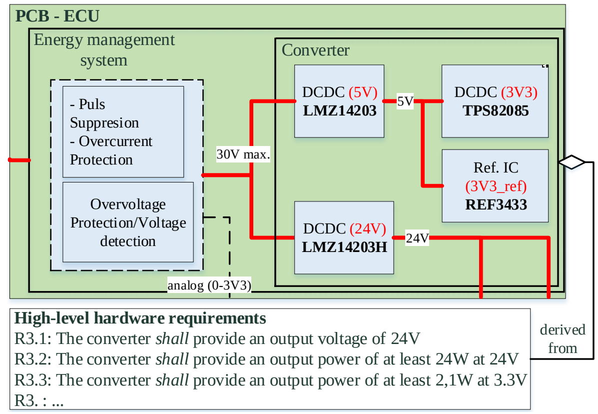

Fig. 5. Section of the overall hardware architecture (electronic part) with some related high-level requirements as example.

D. Level 3: Design

The hardware architecture is composed of individual hardware design elements. Tts design elements are derived from a defined set of high-level requirements, whereby each design element contains a concrete description of the object to be implemented. For example, this could be the documentation of a specific hardware component, technical drawings or circuit diagrams. This can also include more detailed product data, such as purchase price, manufacturer, technical details, etc. As example, in Fig. 5 a section of the hardware architecture is shown, which describes the system element ”electronic control unit” with its sub-systems ”energy management system” and ”converter” in more detail. Each component of the hardware architecture is derived from a specific set of high-level requirements, as can also be seen in Fig. 5.

The software architecture is composed of individual software design elements. These elements are derived from a defined set of high-level software requirements. A software design element would include the description of an implemented function or class, which in itself may be composed of further sub-design elements. An example of a possible software architecture may be an OCM (Operator-Controller Module) based software architecture that has been used for mobile robots in [20].

VI. Summary

This paper shows how work products are structured and formulated within a development project, with the objective of ensuring that the resulting knowledge is easily shared and understood by all project members. The ”common language” supports the cooperation, formulation and documentation of ideas and solutions. Therefore, if participants leave the project at a certain point in time, it is easy for new members to follow the ideas and implementations due to the traceability and consistent language of work products. In addition it is shown that a clear language and a consistent approach to the change process prevent work products from contradicting each other in terms of content.

Hierarchizes the work products on four levels ensures that combinations of domain-specific implementations can be validated by testing. But a complete test coverage of the system is nevertheless not possible, because the number of test cases becomes very huge, expensive and high-maintenance intensive [21]. Analogously, similar problems arise with the requirement of a complete coverage of safety requirements. The FHA improves completeness over the use of conventional hazard checklists, but there is only little detailed guidance in ARP-4754a on how to ensure completeness by considering failure classes [22]. In that case, whether a sufficient[4] quantity of safety requirements can be generated is equivalent in terms of meaning to whether all failures are detected by an FHA. Obviously, the answer is no, because some aspects of the FHA are based on empirical knowledge and may therefore be incomplete.

Further work should deal with the concrete implementation of the processes in more detail, i.e. ”how” and ”with what” shall something be carried out? The question of ”how” is addressed in some points in this paper, but still leaves some topics open. The standard formalism for requirements, as also shown in this paper, can still be improved, especially to further enhance understand-ability, redundancy, completeness, ambiguity, consistency, organization, conformance to standards [22]. For example, a more abstract language could further reduce the information content and leave no room for ambiguity. Such a language could also be understood more easily by computers, so that redundant parts could be recognized. Furthermore, project management could be seen as the management of additional work items, which can be directly linked to the structure in Fig. 3 and thus show measurable project progress in comparison to the time spent. Since iterative processes are involved, agile project management methods should be applied.

The question of ”with what” leads to the configuration of a tool chain and its interfaces based on the required processes. A suitable example for a (partial) tool chain would be *SimPol* as a specific interface between the cost intensive tools *Polarion* and *MATLAB*, as already mentioned at the beginning. Low-cost tools (possibly also ”open source”) would facilitate the access of many medium-sized aerospace suppliers/manufacturers here. This problem also affects the development of UAVs/UASs, as described in [23], outlining some alternatives.

Even though it is only intended as a case study in this paper, an open question would be why semi-active and active landing gears are not yet ready to enter the CS-23 based aerospace market, even though the state of the art in this area is more developed. The reasons may be complex, starting with comparatively low functional benefits compared to passive landing gears. However, the safety processes required for a multi-domain system development seems to be out of scope for the companies being referred to. On the other hand, compliance with the guidelines referenced in CS-23 [3]–[7] is not mandatory, but are seen as recommendations for development [22]. However, certification of an aircraft type is assured if these documents are strictly adhered to. Improving safety processes in development projects with multi-domain systems could therefore lead to simplified market entry by reducing development and tool chain costs. Of course, this should not lead to a loss of safety.

[4]Here, ”sufficient” means that the required failure probability of a fault is not exceeded

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