CITY INFORMATION MODELING – A TOOL TO MAKE GERMAN CITIES AND CITIZENS MORE SUSTAINABLE?

An overview of sustainable behaviour inducing urban design principles, their application in Germany and an evaluation of the potentials of CIM fostering their application

Master Thesis by

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Preface

The following thesis was written in collaboration with the Fraunhofer-Institute for Industrial Engineering IAO in Stuttgart, Germany. The organization provided additional supervision ("fachliche Betreuung") through the research associates Claudius Schaufler, part of the team Smart Urban Environments and Edith Schwimmer, part of the team Smart Urban Environments until May 2019, now part of the team Building Culture Innovation. Furthermore, the author was working throughout the whole completion of the thesis as a student research assistant at the Smart Urban Environments team, which enabled her, with the consent of the supervisors, to utilize infrastructure and working facilities at the research institute for the completion of the thesis, such as e-mail correspondence for example.

Furthermore, the author aims to develop a journal article out of her thesis which shall be submitted to the journal *Sustainable Cities and Society (SCS)* by ELSEVIER after the final exam at the end of June 2019. The journal "is an international journal focusing on fundamental and applied research aimed at designing, understanding, and promoting environmentally sustainable and socially resilient cities" which is why it was chosen for submission of the article. The guidelines of the journal imply preferably not to hand in more than 20 double line spaced manuscript pages including tables and illustrations. On the contrary, the AAU curriculum expects 10.000-12.000 words for theses that are handed in within the journal format. As these criteria do not match one hundred percent, the author is aware that the final hand in needs final editing before submission. Furthermore, the article is not formatted in the journal style as guidelines for authors request no specific formatting, except double space, a font size of 12, and a main structure including Abstract, Keywords, Methods, Results, Discussion, Conclusion and references. Tables and figures are ought to be placed with a caption within the text instead of placing all of them in the end.

The thesis is organized around the journal article, which constitutes the main body. The section "additional material" provides supporting material for the thesis. Prior to each material it will be outlined to which section within the journal article the material relates to.

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Summary

Increasing urbanization and Climate Change put pressure on urban settlements and create a need for more “inclusive, safe, resilient and sustainable” cities as stated in the Sustainable Development Goals by the United Nations. Adaptation to and mitigation of the impacts have become paramount for cities. One possibility can be a change in the modal split from individual motorized vehicles to emission-free modes of transport like walking or cycling. This is of particular importance in Germany, as private vehicle ownership has been rising over the past decades, offsetting emission savings from environmental measures in the engines. Therefore, this research examines sustainable urban design principles that encourage citizens to increase their sustainable modes of transport, i.e. walking and cycling. An online survey among practitioners from the field of urban planning, especially among urban planning departments of German municipalities was carried out to investigate the state of the art of the application of such principles in Germany. Furthermore, the digital planning tool ‘City Information Modelling’ (CIM) was evaluated through the survey for its potential benefits and disadvantages when applied in German planning procedures and its capability to foster the application of sustainable urban design principles that encourage citizen to walk or cycle. An invitation to participate was sent to 868 practitioners from the field of urban planning, two third of that being urban planning departments of German cities. 110 responded to the survey, of those 37 partially. Additionally, eight interviews were conducted with experts from the fields of 3D city modelling, smart urban environments, Building Information Modelling and urban planning procedures in Germany. The results indicate that some sustainable urban design principles, like mixed-use land types or the expansion of bicycle road network, are applied but that there is still a lot of room for increasing sustainability within urban settlements in Germany. Moreover, the results clearly show many benefits that could be utilized through the application of CIM in planning procedures once the technology is fully developed. The combination of a 3D-model, GIS-data and information modelling can aid planning processes through visualization, simulation and analysis, thus making decisions in planning more evidence-based and potentially more economically sustainable as intervention could be more impactful for the same investment. Generally, the experts saw more potential in the utilization of CIM than the participants of the survey. The respondents estimated the potential benefit for their organization through CIM to be only somewhat to moderate. Possible explanations for this, like the lack of knowledge about CIM or potential inhibition of the development and spread of digital planning methods through German laws and regulations, are discussed.

Lastly, the functions of CIM could also help to foster the application of sustainable urban design principles and in consequence potentially increase the modal split of walking and cycling within cities as well, thus increasing ecological sustainability. The vast possibilities for participation through CIM could help increase social sustainability within the built environment.

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Journal Article

Title:
City Information Modelling – a Tool to Increase Sustainability Within German Cities and Among Their Citizens?

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Abstract

Urbanization and Climate Change put pressure on urban settlements. Adaptation and mitigation have become paramount for cities. One opportunity can be a change in the modal split from motorized vehicles to emission-free modes of transport. In Germany, private vehicle ownership has been rising, offsetting emission savings from environmental measures. This research examines sustainable urban design principles (SUDP) that encourage citizens to increase their sustainable modes of transport, i.e. walking and cycling. Practitioners within urban planning were surveyed online to investigate the current application of such principles in Germany. The digital planning tool City Information Modelling (CIM) was evaluated through the survey for its potential benefits and disadvantages for German planning procedures and its capability to foster the application of SUDPs. Additionally, expert interviews were conducted. The results indicate many benefits for German planning procedures through CIM. The combination of a 3D-model, GIS-data and information modelling can aid planning through visualization, simulation and analysis, making decisions more evidence-based and potentially more economically sustainable. CIM could be used to increase application of SUDP and thus potentially increase the modal split of walking and cycling. Vast possibilities for participation through CIM could help increase social sustainability. An application of CIM with regards to German laws and regulations for planning are discussed.

Keywords: City Information Modelling, CIM, sustainable urban design principles, Germany, walking, cycling

Introduction

Urbanization is increasing throughout the world (United Nations, 2014) and urban settlements in Europe are shaped to a major extend through the concepts and plans of urban planners. Especially in Germany, it is the municipal urban planners who define the basic layout of cities, e.g. by assigning land types to zones, restricting the height of buildings or favouring the car as mode of transport. The composed layout aggregates to the unique complexity of a city, which then impacts and influences the behaviour of its inhabitants who in turn impact and influence the urban environment. This raises essential questions in the domain of planning: How should the urban environment try to shape the behaviour of its citizens? What principles should guide the development of urban environments?

The United Nations gave clear answers when publishing the 17 Sustainable Development Goals (SDGs). In particular, goal number 11 ‘Sustainable Cities and Communities’ is directed at the urban environment, as it declares “to make cities inclusive, safe, resilient and sustainable” (United Nations General Assembly, 2015). Also, Danish architect and scholar Jan Gehl has been emphasising the importance of a “lively, safe, sustainable and healthy city”, that focuses less on cars and single buildings but caters to the needs of humans through a liveable urban setting, e.g. through well-designed public spaces and alternative modes of transport like walking and biking (Gehl, 2010; Gehl & Svarre, 2013). German researcher Tran (2018) argues in favour of increased walkability to create environments that are human-scale and wholesome and that do not prioritize car-friendliness. To create such urban environments, input and action is needed not only from urban planners but also from the domains of politics, economics, sociology and technology within a city. The introduction of a congestion fee, the priority of cleaning bicycle and pedestrian lanes before car lanes in winter or the art policy in a city are examples for entities, that can influence citizens behaviour and choices, although they are not physically present in the built environment (Gehl, 2010). However, there is great potential in

how the physical urban environment can impact and influence the behaviour and choices of urban populations. Denmark's capital Copenhagen prioritized and invested in infrastructure for bicycles, which recently resulted in 41 % of all trips to work and study to/from Copenhagen are done by bike (Cycling Embassy of Denmark, 2017). Similar can be observed in the German city Münster in North Rhine Westphalia, informally known as the cycling capital of Germany ("Stadt Münster," n.d.). These are just two of many examples that show that the built urban environment can encourage sustainable behaviour among its citizens by making cycling a convenient option to travel within the city.

Within the past years, German municipalities and cities gradually shift their focus to sustainable urban development. For example, by April 2019, nineteen German cities had joined the network ICLEI – Local Governments for Sustainability (ICLEI Local Governments for Sustainability, n.d.). Yet, there is a strong need to incorporate sustainable design principles into all urban planning activities to help reduce local greenhouse gas emissions and possibly mitigate global Climate Change. Already in 2013, Bott and Grassl see an opportunity to cater to this issue in the emerging technological solution City Information Modelling: the parametric planning tool, combining GIS data and information modelling, bears potential to optimize urban planning according to sustainable principles (Bott & Grassl, 2013). But how exactly can this tool foster the development of more sustainable cities? This research aims at investigating a piece of the pie by answering the research question: How are sustainable behaviour inducing urban design principles applied in planning procedures in Germany and how can City Information Modelling (CIM) help to foster the application of those design principles?

1.1. Sustainable behaviour

Sustainable behaviour is defined in this paper as behaviour by citizens in the outside urban environment, that reduce greenhouse gas emissions. Walking and cycling as an alternative to motorized vehicles are focussed. Pedestrians and bicycles use fewer resources and affect the

environment less as emissions are very minor to zero (Gehl, 2010). In Germany, the amount of private motorized vehicles has risen 21% from 1995 to 2016, thus partially offsetting saved emissions by environmental measures in motorized traffic (Umweltbundesamt, 2018). Motorized traffic was responsible for 17,4% of Germany's greenhouse gas emissions in 2010. Cycling and walking can save 138g CO_2 per passenger kilometre. Up to 30% of the trips in private motorized vehicles could be replaced by walking or cycling (Umweltbundesamt, 2016). Thus, this paper focusses on ecological sustainability. However, research has shown that walking and cycling have positive impacts on social sustainability, e.g. personal health benefits (Freeman et al., 2013; Lund, 2002; Neun & Haubold, 2016; Rundle & Heymsfield, 2016; Umweltbundesamt, 2016; Villeneuve et al., 2017) or the development of social capital (Leyden, 2003). Moreover, cycling has proved itself to be economically sustainable as well, e.g. by contributing to revenues of shops in the city centre or savings in the health sector (Neun & Haubold, 2016). A high walkability of an area is even used as an argument to buy or rent houses in the USA by the company Walk Score® (Walk Score, n.d.-a).

1.2. City Information Modelling (CIM)

The basic idea of CIM is a digital model, similar to a digital twin of a city. It combines the 3D-model of a city with data from a geographic information system (GIS) and information modelling (Bott & Grassl, 2013; Mignard & Nicolle, 2015; Müller, Broschart, & Zeile, 2016). The crucial part is, that besides the visualization of geometric objects, like buildings and city furniture, the relationship of these objects can be defined in such a model within a data base (Xu, Ding, Luo, & Ma, 2014). More precisely, according to Hägglöf and Salminen (2015), "CIM would make it possible to see the relationship between objects and how they are effecting each other. It will also be possible to see future plans and with algorithms make analyses which would facilitate the planning process." This is also the major advantage in CIM compared to solely visualizing the urban environment in 3D, because these visualisations lack relevant

information on for example building regulations or development constraints (Gil, Almeida, & Duarte, 2011). Urban planning is “multi-dimensional and complex” which leads to challenges within the decision-making processes (Acuto, Parnell, & Seto, 2018; Hamilton et al., 2005), one of them being to gather and combine the extensive amount of relevant data for planning, e.g. “2D map, 3D urban model, thematic information, historical data, national statistics, local survey, various policies and regulations”(Hamilton et al., 2005) or more generally data “from all the sciences – natural, engineering, and social, as well as the arts and humanities” (Acuto et al., 2018). An integrated information model could support these processes and even improve efficiency (see also Stojanovski, 2013). Not only would the information be easier accessible to urban planners, but rather democratize knowledge among all stakeholders and thus also allow for more collective and better decision-making (Correa, 2015; Maxwell, 2018a, 2018b; Thompson, Greenhalgh, Muldoon-Smith, Charlton, & Dolník, 2016). Knowledge silos could be eliminated through the centralization of information, making data more accessible and available. This could also help to increase collaboration and cooperation and improve possibilities for participation of citizens and informing further stakeholders in the process (Bott & Grassl, 2013; Correa, 2015; Maxwell, 2018b; Thompson et al., 2016). Another major advantage of utilizing CIM in planning procedures would be the visualization and simulation of different scenarios or planning proposals (Bott & Grassl, 2013; Stojanovski, 2013). Furthermore it could enable analysis and simulation of traffic flows and congestion, but also energy and environmental impacts, like floods or storms (Khemlani, 2016, 2017; Müller et al., 2016).

1.3. About the research

The purpose of this research is to understand the potentials for sustainable urban development in Germany through utilizing the digital planning instrument City Information Modelling, specifically in the domain of fostering the application of urban design principles that cause citizens to behave more sustainably, i.e. increasing the amount of walking and cycling among citizens. With regard to this, this research aims to generally evaluate CIM in the field of urban planning in Germany. Although there are some international case studies of projects utilizing and evaluating CIM (see for example Hägglöf and Salminen (2015) in Sweden and Thompson et al. (2016) in the UK), an assessment based on German practitioners and experts from the field is missing. Combining sustainable urban design principles, their application in Germany, and an evaluation of CIM for German planning produces, the research was guided by three sub-questions:

1. What research backed design principles cause urban dwellers to behave more sustainably in the outside urban environment?
2. What is the status quo of the application of sustainable design principles in planning procedures in Germany? And how do German practitioners and experts from the field of urban planning generally evaluate CIM?
3. How can the application of sustainable design principles be fostered through the utilization of City Information Modelling (CIM)?

Methodology

To find answers to the proposed research questions, a mixed-method approach was taken. A thoroughly literature review was carried out to summarize urban design principles that increase chances of sustainable behaviour, walking and cycling in particular, among citizens within the urban environment. With regards to CIM articles and blog-posts from online magazines were considered additionally to literature originating from scientific journals, because it is rather an upcoming topic in the field of urban planning and present scientific literature is exhaustive. To gather an understanding of the status quo of the application of sustainable urban design principles, a survey was conducted among potential players in the field of urban planning in Germany: public planning departments, private planning offices, construction companies, consulting companies offering services in the planning sector, associations (the so called "Verbände" or "Kammern"), and investment companies. Furthermore, the recipients were asked about their usage of (digital) planning tools, and their evaluation of the (potential) usage of City Information Modelling for their planning processes. Potential influencing factors, like the size of a city, the number of employees, delays in planning procedures, or the intensity with which the organisation pursues the goal to encourage sustainable behaviour among its citizens etc. were also surveyed. The software SPSS was utilized to analyse answers to the survey, using methods from descriptive and inference statistics. Linear regression models where calculated using categorial variables with 5 or more points on the Likert-scale. This is an established procedure in the empirical social science (Urban & Mayerl, 2018). Answers to open-ended questions were clustered and categorized. In total, 868 potential participants were contacted, thereof 533 invitations to participate were sent to official e-mail addresses of planning departments of cities all over Germany, which were researched via the official websites of the municipalities. If possible, the head of department was contacted. It was made sure, cities of all sizes were contacted.

To deepen the findings of the survey and to get a professional estimation of CIM in Germany and whether it could foster the application of sustainable urban design principles, semi-structured expert interviews were conducted. In total, 8 experts from the fields of 3D city modelling, smart urban environments, Building Information Modelling and planning procedures in Germany were interviewed in person or via telephone. The questionnaire was e-mailed to them approx. a week before the interview took place. Interviews took part between 12.04.2019 and 06.05.2019. With permission of the interviewees, interviews were recorded and later analysed for key messages that provided an answer to the main research question. Quotations of German speaking interviewees were translated to English by the author. All interviewees gave their consent to be quoted non-anonymously.

Results

2. Sustainable urban design principles

2.1. Walking

How does the urban environment encourage or discourage walking? Many interruptions (e.g. high density of traffic lights) on the route of pedestrian are perceived as a barrier to walk (Ferrer & Ruiz, 2018; Gehl, 2010), which is supported by Kim et al., (2014), who found pedestrians to be less satisfied once they have to cross multiple intersections on their way. Moreover, it was found that large intersections and roadways discourage walking, but the connectedness of a street network (intersection density) is important to support walking (Appleyard, 2016; Cervero, Sarmiento, Jacoby, Gomez, & Neiman, 2009; Ewing & Cervero, 2010). Gehl (2010) discusses the "tiring length perspective", i.e. a long, straight and endless seeming walk, and obstacles on the sidewalk (e.g. pillars, streets lights, traffic sign, bollards) as discouraging urban elements for walking. People are usually willing to walk distances of approximately 200 to 500m or pursue walks of 10 to 20 minutes to their destination (Ferrer & Ruiz, 2018; Gehl, 2010), whereas particularly the elderly appreciate proximity in their neighbourhood (Alidoust, Bosman, & Holden, 2018) and places to rest along the walk increase the perceived walkability of an area (Rantakokko, Iwarsson, Mänty, Leinonen, & Rantanen, 2012). The walk to destinations has been combined into measures of walkability of the urban environment. Frank et al. (2010) used residential density, retail floor area ratio, intersection density (as a measure for accessibility), and land use mix to quantify the walkability of an area via the walkability index (see also Bucksch and Schneider, 2014; Leslie et al., 2006; Reyer, 2017). WalkScore® is a US-based company that developed a similar measure, namely the WalkScore®. The measure estimates the walkability of a certain address by analysing the routes to nearby amenities, population density, block length and intersection density. The more amenities are in walking distance, the higher (range 0-100, 100 being very walkable) the WalkScore® (Duncan,

Aldstadt, Whalen, Melly, & Gortmaker, 2011; Reyer, 2017; Walk Score, n.d.-b). Ewing and Cervero (2010) support this and the measure of a walkability index, as they found that "walking is most strongly related to measures of land use diversity, intersection density, and the number of destinations within walking distance." Li et al. (2018) found that walking is associated with "street greenery and the enclosure of the street canyons" that vary with different land use type and suggests considering adding streetscape variables to further improve walkability measures. Similar has been found by Alidoust et al. (2018) and Gehl (2010), who emphasise the importance of greenery and soft edges/ the design of facades at eye level in leisure related walking activities whereas hilly, steep terrain, the presence of stairs and ill-maintained walkways can lead to a decrease in walking in general (see also Ferrer and Ruiz, 2018; Gkavra et al., 2019). Lastly, the width of the side walk needs to be able to cater to pedestrians flows to allow for a good and enjoyable walking experience (Gehl, 2010).

2.2. Cycling

Research has shown, that cyclists go out of their way to increase the proportion of travel on bicycle paths (Dill, 2009; Krenn, Oja, & Titze, 2014; Krizek, El-Geneidy, & Thompson, 2007; Winters, Teschke, Grant, Setton, & Brauer, 2010). This clearly indicates the need for an extensive and well-connected cycle network to encourage cycling, which has also been stressed by other scholars (Akar & Clifton, 2009; Broach, Dill, & Gliebe, 2012) and has been confirmed by a survey of cyclists in Hamburg, Germany (Meyer-Wellmann, 2018). Yet, cyclists do prefer direct routes, especially when commuting (Akar & Clifton, 2009; Appleyard, 2016; Broach et al., 2012; Cervero et al., 2009; Wahlgren & Schantz, 2012; Winters, Brauer, Setton, & Teschke, 2010) which is supported by findings that areas with a high land-use mix are considered as bike-friendly (Krenn et al., 2014) and thus encourage cycling whereas "parking lots create unfriendly environments to pedestrians and bicyclists" (Appleyard, 2016). Appleyard (2016) also found a positive relationship between available bicycle parking at a transit station and the

odds that people would cycle. Furthermore, cyclists tend to avoid traffic lights and crossings (Krenn et al., 2014) but "cyclist-activated traffic lights" were associated with increased likelihoods for cycling (Winters, Brauer, et al., 2010). The importance of uninterrupted cycle rides has also been stressed by Gehl (2010). Cycle routes that included bus stops and thus heavy pedestrian traffics were avoided (Z. Li, Wang, Liu, & Ragland, 2012) and associated with negative experiences (Snizek, Sick Nielsen, & Skov-Petersen, 2013). Moreover, the quality and design of bike paths influence cyclists. Unsafe routes, where cyclists are forced to cycle between parked cars and traffic or on busy roads with no extra bike path increase a feeling of a lack of safety and discourage cycling (Chataway, Kaplan, Nielsen, & Prato, 2014; Evans-Cowley & Akar, 2013; Meyer-Wellmann, 2018) or lead to the avoidance of main roads with heavy and fast traffic and usage of calmer and more bike-friendly streets, e.g. with clear signage for cycling (Krenn et al., 2014; Pereira Segadilha & Sanches, 2014; Wahlgren & Schantz, 2012; Winters, Brauer, et al., 2010; Winters, Teschke, et al., 2010). The ‚Copenhagen-style' cycle path (i.e. a segregated cycle lane between parked cars and the sidewalk) (Chataway et al., 2014; Snizek et al., 2013) or other clearly marked cycle path are highly valued by cyclists, and even encourage the use of cargo bikes for transport of goods (Mertens, 2016). Another important quality of a cycle path is its width and a smooth surface. Wide paths encourage cycling as they allow for safe cycling in times of heavy bicycle traffic (Dazzo, 2015; Evans-Cowley & Akar, 2013) and increase the individuals' comfort during a the ride (Z. Li et al., 2012). Gehl (2010) recommends a minimum width for bicycle paths of 2.5m, with a range from 1.7m to 4.0m. The consultancy Ramboll reports to use a minimum width of 3.0m for one-way lanes and 4.0m for two-way lanes in one of their latest projects on cycling in Berlin (Ramboll, 2019). Insufficient lighting along the bike paths can act as a barrier to cycle at night (Akar & Clifton, 2009; Pereira Segadilha & Sanches, 2014). Steep slopes or hilliness was found to be associated with less cycling (Broach et al., 2012; Cervero et al., 2009; Int Panis et al., 2011; Krenn et al., 2014; Z.

Li et al., 2012; Winters, Brauer, et al., 2010). Greenery along the trails is valued (Snizek et al., 2013; Stefansdottir, 2014) and seems to stimulate cycling for commuting purposes (Wahlgren & Schantz, 2012) and in general (Krenn et al., 2014).

3. Survey: descriptive statistics of the respondents

110 recipients replied to the survey, of those 76 departments for planning, 21 planning offices, 1 construction company, 2 consulting companies, 4 associations, 0 investment companies and 6 classified as "other". 73 recipients completed the whole survey, 37 partially. Table 1 shows the distribution of the respondents across the German provinces. Table 2 depicts the sizes of the cities in terms of inhabitants, for which the 76 urban planning departments responded. Table 3Table 3 gives an overview of the number of employees of the organisations.

Table 1. Distribution of respondents across German provinces

Province (Bundesland)	**Absolute frequency**	**Relative frequency (in %)**
Baden-Wuerttemberg	11	10.0
Bavaria	14	12.7
Berlin	2	1.8
Brandenburg	6	5.5
Hamburg	3	2.7
Hessen	11	10.0
Mecklenburg-Western Pomerania	3	2.7
Lower Saxony	8	7.3
North-Rhine Westphalia	26	23.6
Rhineland-Palatinate	4	3.6
Saarland	1	0.9
Saxony	6	5.5
Saxony-Anhalt	3	2.7
Schleswig-Holstein	6	5.5
Thuringia	5	4.5
Total	110	100

Table 2. Size of a cities, measured in inhabitants of cities, that the 76 urban planning departments work for

Inhabitants of city	Absolute frequency	Relative frequency (in %)
> 500,000	9	11.8
100,000 – 500,000	8	10.5
50,000 – 100,000	14	18.4
20,000 – 50,000	26	34.2
10,000 – 20,000	12	15.8
5,000 – 10,000	6	7.9
< 5,000	1	1.3
Total	76	100

Table 3. Number of employees of organisations that responded

Number of employees	Absolute frequency	Relative frequency (in %)
< 10	36	36.7
≤ 11 to 50	35	35.7
≤ 51 to 250	13	13.3
≤ 251 to 500	5	5.1
≤ 501 to 1,000	4	4.1
≥ 1,001	5	5.1
Total	98	100

94.4% of the planning offices stated to participate in regional tendering, 55.6% to participate in national, and 33.3% in European tendering. None participated in international tenders. The construction company stated to be only regionally active. One of the consultancies stated to pursue only business in the region, whereas the other stated to be consulting only internationally.

Almost 80% of the respondents (N = 98) stated to use geoinformation systems (GIS). Three quarters use computer-aided design (CAD). Roughly more than half utilize graphical

programmes, like Adobe creative cloud, and 41.8% make use of physical 3D-models in their planning processes. Only 8.2% utilize simulation software, 2% use Building Information Modelling (BIM), 1% use City Information Modelling (CIM) and 4.1% named additional "other" planning tools, for example a 3D-model of the city. 2% claimed to not utilize any tools, as the type of organisation (association) does not require the usage.

A good third ($N = 98$) stated not to have delays in their planning procedures. Two thirds (62.2%) are experiencing delays. These delays are majorly caused because further steps are dependent on input by third parties (95%; "Abhängigkeit von Dritten"). Other reasons for delays are objections raised by the citizens (71.7%; "Einwände aus der Bevölkerung"), the lack of employees (66.7%; "zu wenige Mitarbeiter/innen") and objections raised by politics (65.0%; "Einwände aus der Politik"). Insufficient financial resources (36.7%; "zu wenig finanzielle Mittel"), objections raised by the local businesses (26.7%, "Einwände aus der lokalen Wirtschaft"), insufficient data (21.7%, "unzureichende Datengrundlage") and technical issues (10.0%, "Technische Probleme") were named less frequently. Technical issues were further specified as outdated hard- and software or as missing licences to access programmes. One department of planning named complying with noise control and Major Accidents Ordinance ("Bewältigung Lärmschutz, Störfallrecht") as reasons for delays caused by technical issues.

97 out of 98 stated to use 2D drawings. Only one department of planning reported to use mainly 3D drawings in their planning processes. Respondents ($N = 98$) reported that approximately half of their planning processes are digitalized ($M = 56.32$, $SD = 24.45$). Answers ranged from 0 to 100.

4. Application of sustainable design principles in Germany

On average respondents ($N = 84$) stated that their organisation moderately ($M = 3.48$, $SD = 0.96$) pursues the goal to increase sustainable behaviour among people in the urban environment ("How much does your organisation pursue the goal to foster sustainable behaviour among

citizens?" [Wie stark verfolgt Ihre Organisation das Ziel, nachhaltiges Verhalten seitens der Bürgerschaft zu fördern?]; 5-point Likert scale: (5)Extremely [sehr] – (4)Very [ziemlich] – (3)Moderately [mittelmäßig]– (2)Slightly [wenig]– (1)Not at all [nicht]). The strategical orientation of the organisations (N = 83) was stated to be influenced majorly by politics (88.0%), laws and regulations (65.1%), master plans (56.6%) and management (48.2%). Other influences were today's Zeitgeist (27.7%), financial incentives (24.1%), recent research (15.7%) and "other reasons" (8.4%), which were specified as the trend of digitalization or local circumstances, e.g. a high demand of residential and commercial areas, green roofs, or regional plans that one needs to comply with.

Table 4 gives an overview of the applied urban design principles by German departments of planning and planning offices. Yet, five respondents stated to use no sustainable urban design principles to foster sustainable behaviour among their citizens. Four respondents did not specify their answer.

Table 4. Sustainable urban design principles that are applied by German municipal departments of planning and planning offices. Results are in no particular order

Category	**Applied design principle**
Cycling	- Improvement of bicycle infrastructure - Expansion of cycle road network (local and regional) - Offer bike sharing (normal bikes and cargo bikes) - Open one-way streets to cyclists in both directions - Increase number of bicycle racks - Expand designated cycle lanes on shared roads - (planned) revision of regulations regarding the amount of cycle racks ("Fahrradabstellanlagensatzung")
Walking	- Improvement of walkways - Maintenance of walkways - Improvement and/or expansion of pedestrian zone in the inner city
Public spaces	- Make public spaces multifunctional in use

	- Ensure public spaces have a high quality of stay - High quality facades - Improvement of urban furniture (e.g. benches) - Install trash cans - Accessibility for all citizens
Individual motorized traffic (cars)	- Reduction of parking spots - Traffic calming and prioritization of slow traffic modes (cycling and walking) - Parking guidance system - Car-sharing, ride-sharing - (Planned) revision of current regulations regarding the amount of required parking spots ("Stellplatz- und Garagensatzung") - Develop a concept for the parking-space management of stationary traffic ("Parkraumbewirtschaftungskonzept für den ruhenden Verkehr")
Mobility	- Incorporate mobility needs into planning procedures - Develop, establish and implement a sustainable mobility concept or strategy - Expansion of e-mobility and integration of charging stations
Public transport	- Expansion of public transport (railways and/ or busses) - Good design of stations - Maintain stations - Increase density of stations - Assign building plots along existing public transport routes
Structure of districts	- Favour mixed-use land types (→city of short distances) - High urban density and densification of existing buildings - Reduce and minimize sealed surfaces - Development of inner city before development of outskirts - Accessibility - Expansion and maintenance of green infrastructure - Requirement of greening as part of the building permit - Give away free fruit trees to building plot owners

	- Incorporate public spaces to encourage and strengthen local communication within the community
Energy	- Funding of renewable energies - usage of renewable energy - Supporting and consulting of private developers in the field of energetic restructuring measurements - Apply measurements of local energy strategy
Participation	- Inform citizens via local newspaper, websites, social media or information displays - Surveys, discussions, workshops, talks among and with citizens - Extensive participation processes on different levels (neighbourhood or citywide) - Digital 3D city model - Establishment of a citizen committee to ensure cross-generational participation
Education	- Offer environmental education ("umweltpädagogische Angebote")
Administration	- Install position of a climate protection officer - Install position of a sustainable mobility agent - Discussion of design principles and the culture of building within a city - Establishment of a youth parliament and elderly parliament

Experts were also asked for an estimate of the application of sustainable urban design principles in Germany. In summary, there has been a shift towards sustainability in the urban environment in the past decades and there are good examples in Germany but alternatives to the car are not always prioritized and the paradigm of car-friendliness manifests itself in regulative incentives as well:

> With regards to most topics, I would say we are a bit lagging behind the trends or spirit of our time. Where one now – maybe because of the automobile industry, that has quite a strong lobby in Germany – is a little scared, to put somebody off or to threaten jobs. And thus, shy a little bit away from declaring new pedestrian areas. Or really massively

> taking away infrastructure for cars and make room for public transport or cycling within the city. […] Surely there are single cities that are a role model, also when it comes to trash. But generally everything is done like it has always been done. Often it is also a question of costs, because municipalities are often very cost-driven, as the law requires them to use taxes sparingly. (M.Sc. Philipp Groß)

> Very difficult. I believe, it is considered, of course. In the end we have principles for all our planning. The most obvious principles which we have here in Stuttgart, is the principle of a car-friendly city. […] Cycling is an example that shows, that this is changing a little. Until recently there have been no bicycle lanes or one would drive on the streets. This has changed a lot in the past decades. […] Besides, we have other design principles or paradigms that we plan according to, for example the commuter allowance ("Pendlerpauschale") and housing allowance ("Eigenheimzulage"). I.e. residential areas are placed outside the city, that is also a design principle of our cities. (Dipl.-Ing. Mike Letzgus)

5. City Information Modelling as a tool for urban planning procedures

Before participating in the survey, three quarters (N = 76) have heard of Building Information Modelling (BIM) comparing to 27.6% who have heard of City Information Modelling (CIM). A similar impression is gathered from the estimation of the experts. Nationally in Germany, but also internationally, CIM is still in its early development and just starting to be known of in the circles of professionals. However, there is development and some provinces and cities utilize 3D-models:

> So, I would say it's still extremely early. Building information modelling has now been formally launched in 2000 and there are some folks who are still doing things the old way, using drawings. Even though they know that there is a better way to do things. I think it takes a long time to transition. I think, it's going to be the same with CIM. I mean, it's been like three or four years since we started hearing about CIM in the professional circles. So, I would say it would be at least 10 years before it actually becomes something that is commonly known and accepted. (Dr. Lachmi Khemlani)

> It's non-existent, right? I'd say globally it is non-existent. […] Depends kind of on your definition. According to my definition, you have large numbers of datasets, real time datasets. But one could say, well, a 3D-model of the city is already a City Information Model. […] But according to my definition it needs to have the complexity and the multi-layered aspect for it to be one. Which doesn't exist yet. (B.Arch MAUD FRSA Euan Mills)

> Regarding the usage in planning processes, I cannot say. It is still like a small sprout, which is about to rise. 3D is a set standard in the land surveying administrations („Vermessungsverwaltungen“) all over Germany. They can have single, all-encompassing models, at least as part of LOD1, as rough averaged blocks. Sometimes one needs to pay per block or it’s open data like in the province NRW, or Berlin offers a download platform. […] But we see, that the urban planning departments are the next in line where development will take place. […] One can tell, that they start talking to each other; urban planning, urban development, urban land-use planning. So, all planning departments are considering themselves with 3D-models and they see the benefit. (Dr.-Ing. Stefan Trometer)

5.1. Evaluation of CIM in Germany

Participants were asked to rate the importance of CIM with regards to its contribution to the future viability of their organisation and Germany in general (“Als wie wichtig bewerten Sie den Einsatz von City Information Models (CIMs) für die Zukunftsfähigkeit von (Stadt)-Planungsprozessen in Ihrer Organisation? / in Deutschland insgesamt?”, 5-point Likert scale: 1 – unimportant [Gar nicht wichtig], 2 – somewhat important [Etwas wichtig], 3 - quite important [wichtig], 4 – very important [Sehr wichtig], 5 – extremely important [Äußerst wichtig]). CIM was considered more important for the future viability of Germany (M = 2.93, SD = 1.01) than for the future viability of the respondents’ organisation (M = 2.56, SD = .99). A t-test for paired samples revealed that this difference is significant, $t(72) = -4.41$, $p < .001$. This difference remains significant, when considering answers by planning departments only, $t(55) = -3.61$, $p = .001$.

Respondents (N = 74) rated the potential benefit using CIM higher in general (M = 2.82, SD = .83) than for their own organisation (M = 2.51, SD = .90). A t-test for paired samples shows that this difference is significant, $t(72) = -4.41$, $p < .001$. This difference becomes insignificant, when only analysing the answers of the departments of planning, $t(56) = -1.70$, $p = .095$. Furthermore, the rating of the potential benefit for the organisation did not differ significantly between departments of planning (M = 2.58, SD = .87, N = 57) and planning offices (M = 2.33, SD = 1.07, N = 12), $t(67) = 1.03$, $p = .314$.

Explorative analysis using a linear regression model indicates that the size of the organisation, measured in number of employees, seems to influence the rated utility of CIM within the organization ($F(1,72) = 10.948$, $p < .001$). Large organizations seem to see more value within their organization due to CIM than smaller ones ($\beta = .229$, $p < .001$). 12% of the rating can be attributed to the size of the organization ($R^2 = .12$). On the contrary, the size of the city seems not to be associated with the rating of value created through CIM for the organization, as the results of the model are not significant ($F(1,55) = 7.355$, $p = .009$). However, the size of an organization and the size of a city correlate significantly ($r = .441$, $p < .000$, $n = 71$). According to Cohen (1992) this would be a mediocre to strong effect. Moreover, delays in planning procedures did not have in impact on the rating of the value of CIM for the organisation, $X^2(3, N = 74) = .075$, $p = .995$.

A relationship between the rated benefit generated by CIM for the organization and the factors guiding the strategic orientation of an organization seem to be significant, $X^2(24, N = 74) = 47.452$, $p = .003$. The more benefit was attributed to CIM, the less organizations named politics and regulations as factors that determine their strategical organization. Furthermore, organizations who stated their strategic orientation was determined by masterplans rated potential benefit through CIM higher. Management was found as a factor on all ratings [low to high] on benefit created through CIM. However, one needs to interpret all of these results with caution, as the number of cases is rather small, and some cells do not provide enough cases.

The usage of different types of planning tools is not associated to the rating of benefit created through CIM in the organization. The test was not significant, $X^2(24, N = 74) = 32.394$, $p = .118$.

Furthermore, the perception of advantages through the usage of CIM seems to be associated with the rating of the benefit generated through CIM for the organisation, $X^2(48, N = 74) = 126.871$, $p < .001$. The more benefits perceived, the better the rating of CIM appears to be.

However, one needs to interpret these results with caution, as the number of cases is rather small, and some cells do not provide enough cases.

5.1.1. Advantages of CIM: Findings from survey

When asked, what benefits could be generated in their organisations using CIM, 69,4% of the participants (N = 72) chose the simulation of planning projects in the (digital) urban environment ("Simulation von Planungsvorhaben im (digitalen) Stadtbild"). Other major benefits identified were easy access to a digital urban model (66.7%), central access to data (58.4%), consistent data standards (50.0%) and a better collaboration between different departments involved in planning, like civil engineering department, traffic department and the department for greenery (51.4%). Potential was also seen in the design of participation processes, making them more interesting (48.6%) and more efficient (41.7%). One third also saw benefits in CIM as this could speed up planning procedures (38.9%) and reduce multiple data storage (37.5%). Other benefits were only identified by a quarter of the respondents or less: "time travel" in the digital urban model (29.2%), analysis of planning project through algorithms (23.6%), more efficient processes after planning is completed (maintenance; 19.4%), ensure competitiveness (16.7%), reduction of errors (12.5%), long-term financial savings (9.7%), and others (6.9%), who stated that communication with external parties involved in planning procedures would be made easier and more convenient.

Moreover, respondents stated that on average 24,6 percent (*SD* = 21.36) of the time could be saved in planning procedures in their organisations when using CIM. Answers ranged from 0 to 80 percent.

5.1.2. Advantages of CIM: Findings from expert interviews

The interviewees saw enormous potential in the usage of CIM during urban planning processes, because in a nutshell "it makes planning more evidence-based. So less about politics and more about science" (B.Arch MAUD FRSA Euan Mills). This assessment was shared by other experts, supporting the arguments from Acuto et al. (2018), Bott and Grassl (2013) and Hamilton et al. (2005):

> Everything can be streamlined. […] you could decide, where the services can be most efficient […]. If you have the data, that can help you make better decisions about what to put where. (Dr. Lachmi Khemlani)
>
> I think also, that the risk of wrong decisions will be reduced, and time efforts will be less. […] Further, I think the possibilities of forecasting will improve. When I state, what will change due to the plan. (Dipl.-Ing. Stephan Kaczmarek)
>
> […] basically, that one can deduce consequences much better. No matter where I intervene in the city organism, I could deduce the consequences relatively fast or have them depicted. If you truly work on scenarios and variations, you can arrive quite fast at an estimation […], which will probably play a role when conclusions/findings are conveyed. Politicians are always interested in knowing this: what are the implications, if I decide like this or like that? (Dipl.-Ing. Martin Hunscher)
>
> What we are lacking today is a consistent understanding of digital information. […] a digital chain of processes on different levels, that can be utilized as a basis for decisions making. That is, of course, also on the level of neighbourhoods. That means, if I know, how energy is managed in the neighbourhood, how many people live there, how traffic flows are; then I can control, manage and optimize these streams of any kind. […] Nowadays, we don't have all this information, so we make general solutions. And general solutions don't always target the issue. (Prof. Dipl.-Arch. Daniel Mondino)
>
> A city is a complex structure and it will become more complex. […] If you utilize the capabilities of such digital models, this can help you to deal better with this complexity. […] it is kind of a core system like a heart, not to replace all the other systems, but to aggregate everything digitally at a central place, to then discuss the complex challenges with all their many facets at and within the model. (Dr.-Ing. Stefan Trometer)

The aggregated data builds the foundation of a City Information Model but also describes one of its key values for planning procedures, namely accumulating (existing) data from various

fields. A project engineer from the field draws on his experience and supports the problem of data gathering put forward by Hamilton et al. (2005):

> One must note that many of the cities already have these information present. The information is just not synchronized most of the times. (Philipp Groß)

Moreover, the aggregation and densification of data is crucial to be able to perform simulations. The simulation of alternative planning proposals marks an essential component of CIM in future planning procedures as CIM also makes "planning more agile" (B.Arch MAUD FRSA Euan Mills). In times of short innovation cycles, simulations in CIM can help to shorten the planning procedure and adjust the processes to the fastening of innovation cycles:

> If you think about it, it can take up to four to five years until a building plan is finished. If we now look at innovation cycles within the city, i.e. the speed with which a technological innovation establishes itself, these cycles are below five years today. That means, if we already need a time horizon of five years to finalize a plan, in times where everything already changes during the planning process, we see the problem at stake. CIM can help us here, because we can simulate alternatives beforehand. (Dipl.-Ing. Mike Letzgus)

Furthermore, simulations could help predict potential effects of Climate Change on the built environment, like cloud bursts or flooding (see also Khemlani, 2017, 2016). Other simulations could investigate effects of greenery, evaporation and their effect on the microclimate of a neighbourhood or how the grid needs to be altered to support the trend of electromobility:

> Right now, the grid could not support it, if everyone was moving on electricity. Here, a CIM could help to localise energy demand and identify locations for energy storages or energy hubs, where the electricity will be distributed. (Dipl.-Ing. Mike Letzgus)

The experts also saw potential in CIM to support the investigation and identification of new urban design principles within the city:

> The more information one adds to an extensive city model, the more multidimensional one can develop concepts and strategies. (Dr.-Ing. Stefan Trometer)

Another expert illustrates this potential referring to the simulation of cloud bursts and potential flooding:

> A City Information Model, where I have the reality depicted and can operate simulations, to then see, which design principles I need to develop to curb the masses of water. (Dipl.-Ing. Mike Letzgus)

Despite the possibilities of CIM to simulate, it also bears great advantages for analysing the existing mark up of a city:

> I would think that once the technology is more developed, you can actually build sustainability analysis tools. You can check a City Information Model for meeting whatever, like carbon standards, or like how far away is this neighbourhood from a public transit area? (Dr. Lachmi Khemlani)

> The biggest leverage [for energy transition] is within the existing buildings. With a digital twin that has information about the condition of the buildings, cities would have a helpful tool to assign new areas for refurbishment, for example. […] In Hamburg, they analysed [using GIS analysis] which buildings have potential to carry another one or two stories, without the building's substance giving in or generating unbearable costs, because one would have to invest into the structure beforehand. They came across a gigantic potential within the city. (M.Sc. Philipp Groß)

Moreover, the possibilities to inform other project partners, decision makers, politicians and the public were perceived as a benefit of using CIM, as "it makes planning more transparent and inclusive" (B.Arch MAUD FRSA Euan Mills). Information could be accessed easily by citizens, e.g. to inform themselves about traffic flows or affordable housing in the area. This is congruent with arguments put forward by Correa (2015) and Thompson et al. (2016). Additionally, people who are involved in the planning process could gather necessary information more quickly:

> If they [specialised municipal departments] would have a common platform to exchange themselves with one another, they could communicate easier, could exchange information easier. […] For example, if I need information for a certain development plan or an urban study, then I would have a certain planning platform to turn to. And with the digitalization of these planning platforms, e.g. Geoserver Hessen, it has become much easier to access the relevant information. (Dipl.-Ing. Stefan Kaczmarek)

When asked about potential time savings generated through the usage of a City Information Model, the increased availability of information was identified as a potential during a planning

process. However, resources required for maintaining a CIM were thought to be similar to present levels:

> I think we will not talk about a safe in resources regarding time [in the maintenance], personnel or money. The question is, if we have time saving in the process of development or in the process of informing: I think so, yes. […] It could be that we would generate substantial advantages in time with such processes. […] an intelligent model, which fundament is the basic data, that are maintained, from which the responsible agents can generate a substantial advantage. It could be, that this will bring advantages to the resources of day-to-day business in planning department. But I cannot pinpoint the actual extend right now. (Dipl.-Ing. Martin Hunscher)

> If everyone knows the method and truly all planning and adjustments are carried out digitally, the required software and tools would exist, that are all connected to a central data base or different sub data bases, then the effort will be relatively small. […] But if the processes are really in line [with CIM], then the effort can be disregarded, in my opinion. (M.Sc. Philipp Groß)

Furthermore, the digital twin and especially its ability to visualize the existing, and potential future, environment could aid in participation processes, as has also been mentioned by Bott and Grassl (2013). The process could be shortened, more efficient and planning proposals more tangible for citizens:

> From my point of view, a crucial part could be the sharing of plans and their consequences with the public. […] Participation can be tenacious […] and you're not as fast that you have immediate results, that can be evaluated. It is an iterative process. I could imagine that you could work with it [CIM] more strikingly, including quicker feedback and evaluations for the planners and municipal administration. (Dipl.-Ing. Martin Hunscher)

> If I can show planning proposals to citizens in a 3D-environment, in which they can navigate themselves like in Google, this is a lot of help. […] These models also assist, because they objectify discussions and can activate a vast majority of users due to easy web-based access. On the one hand to the decision-making committee, on the other hand to the public. (Dr.-Ing. Stefan Trometer)

Lastly, CIM could be a tool to reach out to the younger generation and integrate them more into participation processes. Also, the access barriers to participation processes would be lowered by using the digital tool:

That you try, with a digital city model in which you can comment and discuss, to take the working younger generation by the hand and incorporate them into these processes, because often they do not fancy to sit in a sticky gym after they finished work. (M.Sc. Philipp Groß)

Thinking of informing citizens and participation, I think the digital methods and web-based solutions will provide a good possibility to activate people. You don't have to attend meetings, you don't have to go vote somewhere, you don't need to write a letter to somewhere. Through this you lower barriers of access enormously and thus create better informing and participation. (Dr.-Ing. Stefan Trometer)

5.1.3. Disadvantages of CIM: Findings from survey

Some respondents stated that they do not see any disadvantages by using CIM. Approximately 14 respondents chose to "not specify" their answer when asked about potential disadvantages. Others named the following disadvantages in no particular order:

- extensive need of resources for maintaining CIM
- amount of resources needed to roll-out CIM
- costs
- non-sufficient education of employees
- mismatch of effort and utility/benefit (in small administration units)
- additional time resources needed
- extended need for personnel
- Loss of creativity
- High focus on digitalization
- Contract issues
- Quality of data

5.1.4. Disadvantages of CIM: Findings from expert interviews

Generally, experts saw more benefits than risks in utilizing CIM in planning which showed once they were asked about the risks:

> Risks are hard to grasp for me with regards to this topic, to me it offers many, many chances. (M.Sc. Philipp Groß)
>
> I thought about it – and nothing really came to my mind. Or you need to help me, giving a direction in that I should think. (Dipl.-Ing. Martin Hunscher)

However, most of the interviewees also saw potential risks related to data security, yet stating that these are those risks that always occur once technology is used:

> The risks are those, that we always have once we gather data. That means, that are always risks regarding data security. Which information do we have? Which information do we not have? Which information should be accessed through the public? […] I.e. I always have this problem: I have personal data that I need to extract in a way that they are not related to the person anymore. (Prof. Dipl.-Arch. Daniel Mondino)
>
> Security is paramount. They should be careful about that kind of data. […] If you really should be doing it and then you should be taking care of security and the sensitive stuff, just like emails. It's convenient, right, but then it opens you up to the possibility of spam and cybercrimes and so on. (Dr. Lachmi Khemlani)
>
> Actually, rather few [risks]. The biggest disadvantage, that I can think of, is that everything will be broken down to the individual or user level. So to say, that personal rights are violated. […] I would not like to see this, i.e. the inference to households or persons. (Dipl.-Ing. Stefan Kaczmarek)
>
> There always occur side-challenges with regards to data security. It can be the case, that data protection officers prohibit to use mapping materials or raw data that consist of a higher point density than 20cm difference in between, because if a person is depicted one could not guarantee, that they are not identified. The good thing is, that there are data protection officers that recognized this issue and work on it. (Dr.-Ing. Stefan Trometer)
>
> Who has the rights regarding the data? It’s also a discussion about open data. For example, all data that the City of Frankfurt collects or gathers, is mostly accessible. Regarding data privacy I don’t see any problems or risks, if we don’t talk about persons. (Dipl.-Ing. Martin Hunscher)

In a nutshell, experts identified the risks related to data security and protection but do not perceive this as an unsolvable issue, but more as issues that "are the risks associated to a technocratic system" (B.Arch MAUD FRSA Euan Mills). To a certain extend one would rely on technology using CIM. However, this dependency is relative and can be managed:

> Generally: everything that is digital – just as paper can catch fire – has a certain dependency on the functionality on the system. I think this is a fundamental difficulty that one needs to face. (Dr.-Ing. Stefan Trometer)

The risks become more severe when talking about the potential of biases that could be incorporated into a CIM, if the science behind these data was false or incorrect conclusions were drawn:

> What if the data that we put in wasn't true? Or if we interpreted them wrong? Then our planning won't be correct anymore. That means regarding data, I call it the blood that runs through the veins of a City Information Model for now, is the biggest risk. Other than that, I have to say I see more possibilities and benefits than risks. (Dipl.-Arch. Mike Letzgus)

> There is a clear risk, that you could get caught up in unimportant details or set the wrong focus, for example. (M.Sc. Philipp Groß)

> I guess more room for inbuilt biases as well. […] because we would be standardizing a system, any errors would be across the whole system. So, any bias will be across the whole system. Whereas today it might be that you have an individual planner who has a particular bias, that there is one particular way. Any mistakes, that are done are going to be bigger and more impactful. (B.Arch MAUD FRSA Euan Mills)

Related to this is also the concern that there would be less room for innovation and creativity when using CIM, i.e. let the technical system govern all the decisions that are made:

> It should not go as far as that one creates constraints that restrict the political creative will or drive. So, for example saying, "Here are so many cars, it is impossible to promote bicycle traffic." There must always be a political will, that stands above the system and that can influence the system from above. That one does not create a bureaucracy that does not accept design ("Gestaltung"). It sometimes occurs, the "that's not possible". Well, if it is not possible I have to think about what needs to happen, that it is possible after all. It always works out somehow. The difference being that I will be able to estimate the effort really well with the mean of a good system. (Dipl.-Ing. Stefan Kaczmarek)

Moreover, the experts saw further problems, but no risks, related to the implementation of a City Information Model. One reason for this being that transition or change is often a difficult task in itself, another reason being that German laws are currently not providing regulations for, and sometimes even inhibit, the use of these new digital tools (e.g. BIM):

> There is the problem of how to implement a new system. Which technology do you need? Is the city capable of managing it? Do they have the money for it? Do you need to train and educate the people, that are using this information model? These are things I wouldn't define as risks but rather as problems. (Dipl.-Arch. Mike Letzgus)

> Exactly, not seeing it [CIM] as competition, but as a helpful tool, that can make life much easier. And when applied correctly, similar to Building Information Modelling, it does not mean additional work. It means a shift in paradigm, it means, that planning can not be done like it used to be done and that one must adjust. But if you carry it out in the correct scale, then you can actually just gain through these types of planning processes. (M.Sc. Philipp Groß)

> This is not a risk but rather an obstacle. New methods and new planning always require change, at least with regards to the collaboration within the public authorities. Maybe even change concerning the structure of single public authorities/ departments and processes. New processes are difficult of course. […] It [the digital tool] is not depicted in any kind in the fee scale ("Honorarordnung"), which they all life according to. Actually, they would need an additional specialised discipline that starts work on BIM simultaneously once the architect starts to work. One somehow really needs a revision of the HOAI[1], so this can be depicted. And then the processes need to be aligned and adjusted with and to one another. From my point of view, this challenge is way bigger than the previous ones, concerning the usage of 3D and City Information Modelling. (Dr.-Ing. Stefan Trometer)

This required change, or shift in paradigm, was pointed to in educational institutions in Germany as well:

> From all that we know, the paradigm shift, this urban planning 2.0 or whatever you want to call it, the digital planning tools, the topic of BIM, has not completely found its way into education yet. (M.Sc. Philipp Groß)

Despite the necessary change and many benefits that could be utilized using CIM, experts also warn to envision a City Information Model as a solution to all urban problems:

[1] HOAI: "Honorarordnung für Architekten und Ingenieure", the German fee scale for architects and engineers

> I believe, that the media coverage and internet of things, digital twin, that this is more of a hype in the beginning, that first will be followed by disappointments before it will actually integrate sustainably into processes. One of the dangers is, that one puts all one's confidence in these modern methods, thinking they will solve all the problems. And not having confidence in the old, established procedures that have worked for over 50 years and enabled what we have today. I believe some overestimate the potentials of these possibilities. And do not realize that there are solid and established procedures for almost all fields that one must consider as well. (Dr.Ing. Stefan Trometer)

In addition to this, another expert saw possibilities of overengineering the model into an enormous data base that fails to cater to its causes and could only be operated by highly specialised workers:

> So, to inflate a model, that contains possibly all data that one has, and create a data monster in the end. Which can be only operated by experts, because only single persons involved can actually work with such a City Information Model. One needs to make sure, that especially in the municipal administration all people involved are taken along. So actively involve each department, the heads of department, but also train the executing personnel. (M.Sc. Philipp Groß)

5.1.5. CIM and sustainable urban design principles

The respondents of the survey saw somewhat to moderate potential in CIM fostering the application of sustainable urban design principles (M = 2.73, SD = .99) ("Wie sehr könnte CIM dazu beitragen, dass nachhaltige urbane Design-Prinzipien vermehrt Anwendung in Planungsprozessen finden?", 5-point Likert scale: 1 – not at all [Gar nicht], 2 – somewhat [Etwas], 3 - moderate [mittelmäßig], 4 – very [Sehr], 5 – extremely [Äußerst]). An explorative analysis using a linear regression shows that the pursue of the goal to foster sustainable behaviour among citizens is not associated with the estimation whether CIM could help foster the application of such sustainable urban design principles. The model was not significant ($F(1,71) = .095$, $p = .759$). Neither associated are the factors that were said to guide the strategic orientation of an organization as the results for the model were not significant, $X^2(32, N = 73) = 42.693$, $p = .098$.

However, the perception of advantages through the usage of CIM seems to be associated with the estimation whether CIM could help foster the application of sustainable design, $X^2(64, N =$

74) = 86.553, p = .032. The more benefits perceived, the better the rating of CIM appears to be. However, one needs to interpret these results with caution, as the number of cases is rather small, and some cells do not provide enough cases.

With regards to the experts, they saw general potential in CIM to help foster the application of sustainable urban design principles. Precisely, experts estimated that CIM could help through its analyses, simulations and especially visualization to foster efficient development of cycle lanes or public space in general, for example. This is congruent with estimations from Bott and Grassl (2013):

> I believe City Information Modelling could aid already just through the visualization and analysis of cycle-networks. And maybe through the visualisation of data help to raise the right questions of provide answers. Just show the city "Ok, look at this, here is a great potential to foster bicycle traffic. Why aren't you making use of it? Or, very precisely, for example, where do you have which types of streets and how many cyclists are on that road?" […] I think that City Information Modelling could also contribute, through the connection of different data and conclusions, to apply solutions or interventions at the right place. The places that are particularly prone to it, not because it is very cheap and easy to implement, but because there is a need for it. (M.Sc. Philipp Groß)
>
> The beauty is, that you have a model, that knows itself. That knows what it is. The data base allows for database queries. […] You could definitely analyse, because you would have single section, road sections, single lanes. Those would be in your system and you could just run a database query. That works quite well. But it is not the case that we all start to become urban planners all the sudden. One should not underestimate the urban planning – they might be a bit sluggish – but they are sluggish because these are very complex processes. (Dr.-Ing. Stefan Trometer)
>
> I can imagine that you could check the way public spaces work. Where we have long discussions now, we could compare. Once something is built, planners or the cities sometimes note, that it is not as well used as anticipated, or only with criticism. People say, they didn't picture it like this. I can envision that this would be quite a helpful tool in this field. (Dipl.- Ing. Martin Hunscher)
>
> A City Information Model, as far as I understand it, can mainly contribute by providing information, but that then can influence decisions. If you simply depict and visualize something, the people will understand "Ah, my behaviour has or could have these consequences." […] For example, when which public spaces are used, how heavily they are used, what are the important connecting paths, where are public services or how high

> is the demand for parking spaces, etc. […] Where is it worth it and where not and where do I reach the most people? Through analysis and simulation, I can estimate the consequences of my intervention. (Dipl.-Ing. Stefan Kaczmarek)

Altogether, these potentials are connected to the advantage of CIM to make decisions more evidence based and scientifically. In general, a City Information Model can help planners to truly understand the complexity of a city, its sustainability and potential causes and effects of their plans. Furthermore, it can help to leverage sustainability within the built environment of a city:

> I think so, because the complexities around sustainability are so big that it's very hard for us as individuals to be able to really understand the impact, right? […] we're not very good at measuring, really understanding the full impact. With technology we can start understanding that a lot better. We can understand the cause and effect and we can basically validate a lot of the assumptions that we have early on in the planning process. […] We don't measure the success of what we're trying to do. And with things like City Information Modelling or any kind of digital technology, we will be able to do that much better. […] in essence, through City Information Modelling and we can close the learning loop. So, we can validate the assumptions that we had before we build something, but after we built something. And then change the regulations to respond to that. So, we can build in feedback loops, that allow us to tweak and change the principles and the regulations. (B.Arch MAUD FRSA Euan Mills)

> We are in a constant transition process, i.e. that we as urban planners start to understand more and more that we set the agenda for development and that we plan a development. And this fixed final state of a city will never exist. That means, we need to think about the design principles and how static they are and how flexible they are. And to capture this complexity and to simulate, visualize, playing with principles, the tool that virtually depicts the reality can help us, of course. (Dipl.-Arch. Mike Letzgus)

> I believe that sustainability, resource efficiency and building ecologically, all these topics, have not had the success in the past years that we actually need, to really be sustainable in the future. I think that a big part of this is also due to that the processes, that we use for planning and building, have not really allowed for other factors, further aspects, e.g. like sustainability, to be truly integrated. I think that sustainability and digital integrated processes, BIM, CIM, all these, will function much stronger together. They will complement each other perfectly, because within these tools I can easily incorporate other criteria, that are very hard to integrate into conventional planning, because everything is already so complex there. (Prof. Dipl-Arch. Daniel Mondino)

5.2. Alternatives to CIM and suggestions for further development

The experts were also asked about alternative methods or tools that could foster the application of sustainable design principles in the urban environment and their suggestions for the further development of digital planning tools in Germany. The experts named the following alternative methods and tools that could be used to increase the application of sustainable design:

- Use existing digital tools to gather better data
- Depict and communicate the personal value of sustainable behaviour instead of doomsday predictions dominating the discourse
- Smart Citizens need to request sustainability from decision makers
- Inform better, give precise advice on behaviour and use best-practice examples

Further suggestions for the development of CIM in Germany included the following:

- More courage to try new methods
- Governments need to play a more active role
- Strong focus on usability
- Stronger incorporation of digital tools into education
- Open access to data paired with data security
- Usage of open data standards
- Develop better tools for analysis
- Rethink current planning processes and opt for more cooperation

Discussion

The literature review has shown that many urban design principles, that encourage citizen to cycle and walk more, have already been identified through research. A well-designed, connected and elaborate network of cycle lanes and routes, that caters to the needs of cyclists increase the possibilities of people to choose the bike as a mode of transport. Walking is encouraged through proximity of destinations within the neighbourhood, maintained and connected walkways without barriers and possibilities to rest, and an appealing streetscape. Results from the survey show, that some have recognized these principles and are applying them, for example by expanding cycle road networks, facilities for cyclists or pedestrian areas in the city. Moreover, some aim to create proximate destinations within the city by prioritizing mixed-use land types and densification in the inner city. Yet, the list of stated applied urban design principles was exhaustive and mostly the respondents did not include all of the presented principles. Furthermore, it became not clear if the application and knowledge goes down to specific design principles, like the width or location of a cycle path with traffic. As only 15.7% stated that their strategic orientation of the organization is influenced by recent research, one could arrive at the conclusion that there is room for improvement for research to find its way into application. Experts gave a similar estimation, stating that some practitioners in the field apply sustainable urban design principles but there is still a lot of room for enhancement throughout Germany.

The present research has shown that CIM could be used to foster the application of sustainable behaviour inducing design principles by providing extensive simulation and analysis of the present and future urban built environment. Identified principles could be translated into database queries and incorporated into analysis or simulations, for example. Through this, the benefits of sustainable urban design could be leveraged, i.e. interventions could be planned more specifically to the circumstances of the site instead of applying general solution that might

miss their full potential. Here, not only could ecological sustainability could improve but potentially also economic sustainability. Through CIM the effectivity of planning decisions could be raised as they potentially would allocate interventions more thoroughly. The investments would thus have more impact or put differently, a higher ‘return on investment’. In addition, CIM could increase social sustainability within planning processes as its ability to visualize in 3D, combined with web-based applications and open data standards improve and expand possibilities of participation and cooperation.

Furthermore, CIM could help to spread the application of sustainable urban design principles as they could be applied throughout the whole information model. Decisions could be based more on scientific research. However, this requires profound research of design principles as invalid data could lead to the incorporation of biases across the whole system. Thus, more research in the field is paramount to the further successful development and utilization of CIM. On the other hand, CIM could help identify new principles that lead to more sustainable behaviour among citizens.

Moreover, it should be noted that CIM can help foster the application of sustainable design in Germany but currently faces difficulties to find its way into practice. This on the one hand probably due to its development being rather in the beginning, on the other hand due to German laws and regulations that miss to cater sufficiently to new digital planning tools. Especially the national fee scale for architects and engineers (HOAI) regulates a lot of the planning process and does not offer sufficient regulation schemes for digital tools and processes, e.g. Building Information Modelling. This could also explain why still 25% of the respondents have not heard about BIM before participating and even more have not heard about CIM. Besides, the findings indicate that those with strong focus on laws and regulations evaluated potential benefits generated through CIM to be lesser. This seems reasonable as this could result in the perception of more barriers and hurdles than potential benefits through CIM. Additionally, experts

indicated German municipalities to be rather cautious, which could partially explain their rather conservative estimations regarding CIM as well. Another possible explanation for conservative ratings could be that many respondents originated from rather small organizations or cities and therefore rather focus on potential hurdles when it comes to the implementation, operation and maintenance of CIM. Resources in terms time, money and personnel are sparse, especially in smaller organizations.

Generally speaking, these findings suggest that planning processes in Germany require revision. Climate Change puts pressure on urban settlements and ways to mitigate and adapt must be found. The gathered data shows that digital planning tools, especially CIM, could help accelerate the process towards sustainable urban environments through gathering and aggregating data from all the different disciplines that are important to fully understand the complexity of a city. This includes data from civil engineering, natural sciences, social science, economics, arts and humanities. In times of the Internet of Things, Smart City and digitalization, with all of them constantly producing new innovations, CIM can be a tool to grasp and utilize these data faster and more efficiently. It should be noted also, that although CIM is likely to make decisions more scientific, it might also, to a certain extent, reflect the values of the society that uses CIM. Potentially urban planners would have used it 70 years ago to design car-friendly cities even better than they did up to now. Therefore, current paradigms in planning are likely to be reflected in CIM as well.

Conclusion

The utilization of City Information Modelling bears many advantages and manageable risks for planning procedures in Germany. There are many potentials and benefits, that could facilitate making cities and the behaviour of its citizens more sustainable. However, the technology is still being developed and not fully existent yet. It shall not be forgotten, that there are already cities that have cycling and pedestrian traffic above average. This has been achieved using present planning tools and methods. The effect of these could be leveraged and optimized using digital planning tools, City Information Modelling in particular. Experts call for more courage of German practitioners to test and embark on the potentials the digital planning tools offers. On a final remark, it shall be noted though that CIM, or any other planning tool, will not be the panacea to the challenges, cities face today. It is paramount to say that a sustainable urban society requires more than a digital tool optimizing sustainable urban design principles. However, CIM expands possibilities for cocreational, integrative, interdisciplinary and participative urban planning which can in turn support and encourage sustainable behaviour of the citizens. It can aid in fulfilling the Sustainable Urban Development goal of making cities more “inclusive, safe, resilient and sustainable.”

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Additional material

This section contains all material additionally used for this thesis, but which were not suitable to be incorporated into the journal article. In the beginning of each material it is outlined to which section in the journal article it relates to.

1.1. Additional Material A: Extended Methodology

The methodology section of the journal article provides limited room to elaborate deeply on methods utilized. In particular, this section provides further insight into how the survey and the interview questionnaires were designed and conducted. Moreover, limitations to the methodology are included. Grey text indicates text that has been used in the journal article. To ensure comprehensiveness and flow of reading it has been incorporated into this section.

To find answers to the proposed research questions, a mixed-method approach was taken. A thoroughly literature review was carried out to summarize urban design principles that increase chances of sustainable behaviour, walking and cycling in particular, among citizens within the urban environment. With regards to CIM articles and blog-posts from online magazines were considered additionally to literature originating from scientific journals, because it is rather an upcoming topic in the field of urban planning and present scientific literature is exhaustive. To gather an understanding of the status quo of the application of sustainable urban design principles, a survey was conducted among potential players in the field of urban planning in Germany: public planning departments, private planning offices, construction companies, consulting companies offering services in the planning sector, associations (the so called “Verbände” or “Kammern”), and investment companies. Furthermore, the recipients were asked about their usage of (digital) planning tools, and their evaluation of the (potential) usage of City Information Modelling for their planning processes. Potential influencing factors, like the size of a city, the number of employees, delays in planning procedures, or the intensity with which the organisation pursues the goal to encourage sustainable behaviour among its citizens etc. were also surveyed.

The survey was designed to have easy questions concerning type and size of the organization and the utilization of planning tools in the beginning. This was done to ensure potential participants did not lose interest and abort, because they were confronted with too complex questions up front. Afterwards, questions concerning sustainable urban design principles followed, as these should also be considerably easy to answer for participants. The question asking for the principles applied in their organization was purposely constructed to have an

open format for two reasons: it should be avoided to prime the respondents and therefore distort results and moreover, social desirability was intended to be excluded. When presented with potential design principles, participants might have just clicked many answers due to social desirability. When asking for ratings, the items were mostly constructed with a 5-point Likert scale as this would allow further linear regression analysis afterwards. A 5-point scale was chosen over a 7-point scale, as literature suggests that the scale with fewer options is less confusing and frustrating and thus increases potential response (Babakus & Mangold, 1992). When a question was ought to produce a clear positive or negative result, a 4-point Likert scale was chosen in order to eliminate the neutral middle value. An exemplary item in the survey is asking for potential benefits created through CIM at the organization or in Germany. The survey was designed to be completed within 10 to 15 minutes, so participants will not get frustrated by a survey that is too long. Also, this was anticipated with respect for their potential work load during business hours. Furthermore, the survey included a call for interviewees. If interested, participants could leave their e-mail address and be contacted for an interview on City Information Modelling and sustainable urban design principles. The full original survey is can be viewed in section 1.1.2. The software SPSS was utilized to analyse answers to the survey, using methods from descriptive and inference statistics. Linear regression models where calculated using categorial variables with 5 or more points on the Likert-scale. This is an established procedure in the empirical social science (Urban & Mayerl, 2018). Answers to open-ended questions were clustered and categorized. In total, 868 potential participants were contacted, thereof 533 invitations to participate were sent to official e-mail addresses of planning departments of cities all over Germany, which were researched via the official websites of the municipalities. If possible, the head of department was contacted. It was made sure, cities of all sizes were contacted. Moreover, 12 e-mail addresses from planning offices of each province were randomly selected via the websites of official associations for architects and urban planners (“Kammer”), where most German practitioners register their business contacts. In total, 192 practicing urban planners were invited to participate in the survey. Furthermore, the association of each province and the countrywide association for architects and planners were invited to take part in the survey. Invitations were also sent to the 50 biggest construction companies operating in Germany and to three randomly selected housing cooperatives from each province, totalling in 48 contacted housing cooperatives in Germany. Investment and consultancy companies with services targeted at city or urban development and German research institutes from the field were researched online. 7 consultancies, 28 investment companies and 10 research institutes from the field were invited to participate. The

invitations were sent from the author's e-mail account at the Fraunhofer IAO, as the Fraunhofer association is well-known and has a good reputation in Germany. Additionally, logos from Aalborg University and Fraunhofer IAO were incorporated into the design of the invitation e-mail with the intention to increase the perceived credibility of the survey and thus increase number of participants. Furthermore, participants could take part in a lottery to win one of five vouchers á ten Euros for the online store Amazon. Although it can be critically discussed if a voucher to an online store is a suitable incentive with regards to its implication for German retailers (Heide, Hofer, Kapalschinski, Kolf, & Weishaupt, 2018), it was decided to use it as in incentive, as potentially many participants could make use of such a voucher.

To deepen the findings of the survey and to get a professional estimation of CIM in Germany and whether it could foster the application of sustainable urban design principles, semi-structured expert interviews were conducted, as they are a suitable method to gather qualitive data on a specific topic (Brinkmann & Kvale, 2014).

This method was chosen as it leaves room for spontaneous alteration of the interview topic, i.e. clarification or further explanation of issues, if necessary. To ensure all relevant questions were addressed, a questionnaire was prepared in advance. The author utilized her competencies gathered in her psychological studies and designed explorative interview questionnaire. The questions at the beginning of the interview were deliberately formulated to ensure that they were easy to answer and not controversial. The central body of the questionnaire was designed to have more controversial and sensitive natured questions. To leave the interviewee with a good overall impression, less controversial questions were asked towards the end. Moreover, it was made sure that questions were open ended rather than closed. During the interview, the author used techniques such as paraphrasing to signal understanding of what the interviewees had uttered. An example of one of the interview guides can be viewed in section 1.1.4. To standardize answers across the interviewees, the same basic questionnaire was utilized for all of them. Specifically, introductory questions were formulated with respect to the professional background and expertise of the interviewee. In total, 8 experts from the fields of 3D city modelling, smart urban environments, Building Information Modelling and planning procedures in Germany were interviewed in person or via telephone. The questionnaire was e-mailed to them approx. a week before the interview took place. This was done as the purpose of the interviews was to gather many information. By sending it beforehand, interviewees could prepare themselves for the interview. Besides the questionnaire, interviewees were sent the standard information on data security from Fraunhofer IAO and declaration of consent to be signed and e-mailed back to the author. On the latter, interviewees also indicated whether their

quotes should be utilized anonymously or using their full name. Interviews took part between 12.04.2019 and 06.05.2019. Additional Material C, Table 5 gives an overview of the interviewees and their profession. An exemplary questionnaire is provided in Additional Material B. With permission of the interviewees, interviews were recorded, transcribed and later analysed for key messages that provided an answer to the main research question. Interviews were conducted in English or German, depending on the background of the interviewee. Quotations of German speaking interviewees were translated to English by the author. All interviewees gave their consent to be quoted non-anonymously.

1.1.1 Limitations of methodology

The online survey was designed with the intention to keep it rather concise to increase the rate of respondents. The response rate accomplished is 12.7% for N = 110, but only 8.4% for those who filled out the whole survey. To get a thoroughly overview of the application of sustainable urban design principles and a more diversified estimation of CIM in German planning procedures, it would have been favourably to have a higher completion rate. An alternative to the online-survey is to mail the survey to the postal address. Research showed, that response rates for such a methodology are often higher (Nulty, 2008). Furthermore, a personalized invitation letter can increase chances of response (Sauermann & Roach, 2013). However, due to a lack of resources these methods could not have been pursued, and potential participants received a similar e-mail with a general greeting in the beginning. Adjustments in the greeting were only made to the different types of potential participants, i.e. urban planning departments, planning offices, associations, housing companies, etc.

To gather a deeper understanding and to produce results that are more robust, these methods should be considered if to investigate this topic again.

1.1.2 Survey

This section gives an overview of the whole survey that was sent out to be completed. Information on data security were linked into the survey and could be read by participants. The possibility to leave one's email address to participate in an interview or for the lottery were linked to a different web page, so it was ensured that these data were kept separately from survey answer and therefore ensure that the participants and their answers stayed anonymously.

Sehr geehrte Teilnehmerin,
sehr geehrter Teilnehmer,

vielen Dank für Ihr Interesse an der Befragung für meine Masterarbeit zum Thema **„Nachhaltige urbane Design-Prinzipien und deren künftige Anwendung im Bereich City Information Modeling (CIM)"** am **Fraunhofer Institut für Arbeitswirtschaft und Organisation (IAO)** in Stuttgart und der Universität Aalborg (DK).
Ich befrage Sie und weitere Experten aus dem Bereich der Stadtplanung in Deutschland, um ein umfassendes Bild des Ist-Zustandes der angewendeten nachhaltigen Design-Prinzipien im urbanen Raum zu erhalten. Darüber hinaus interessiert mich Ihre Einschätzung der neuen Technologie CIM (City Information Modelling – die Weiterentwicklung von BIM (Building Information Modelling) auf Quartiers- und Stadtplanungsebene).
Die Befragung wird ca. 10 -12 Minuten in Anspruch nehmen. Als Dankeschön können Sie am Ende der Befragung an der Verlosung von 5 Amazon-Gutscheinen á 10 Euro teilnehmen.

Datenschutz
Vor Beginn möchte ich Sie über die Verwendung Ihrer Daten informieren. Ihre Angaben sind für meine Arbeit äußerst wertvoll. Selbstverständlich sind alle Daten, die ich in dieser Studie erhebe, anonym. Alle Angaben werden vertraulich behandelt. Die Teilnahme an der Umfrage ist freiwillig. Es steht Ihnen frei, die Teilnahme abzulehnen oder die Umfrage zu jedem Zeitpunkt abzubrechen. Dadurch entstehen Ihnen keine Nachteile. Die Daten werden für 10 Jahre archiviert, um die wissenschaftlichen Ergebnisse belegen zu können. Genauere Informationen zur Datenverarbeitung können Sie im angehängten PDF nachlesen, klicken Sie dazu auf den Link: Datenschutz

Bei Fragen oder Anregungen kontaktieren Sie mich gern!
Vielen Dank für Ihre Teilnahme.

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In welchem Bundesland hat Ihre Organisation ihren Hauptsitz?

(1) ❑ Baden-Württemberg
(2) ❑ Bayern
(3) ❑ Berlin

(4) ❑ Brandenburg
(5) ❑ Bremen
(6) ❑ Hamburg
(7) ❑ Hessen
(8) ❑ Mecklenburg-Vorpommern
(9) ❑ Niedersachen
(10) ❑ Nordrhein-Westfalen
(11) ❑ Rheinland-Pfalz
(12) ❑ Saarland
(13) ❑ Sachsen
(14) ❑ Sachsen-Anhalt
(15) ❑ Schleswig-Holstein
(16) ❑ Thüringen

Für welche Art von Organisation sind Sie tätig?

(1) ❑ Öffentliche Einrichtung (Stadtplanungsamt)
(2) ❑ Stadtplanungsbüro
(3) ❑ Bauunternehmung
(4) ❑ Beratung
(5) ❑ Verband/Kammer
(6) ❑ Investmentunternehmen
(7) ❑ Andere: _____

Wie viele Einwohner hat die Stadt/ Gemeinde, für die Ihre Organisation zuständig ist?

(1) ❑ > 500.000 (Großstadt)
(2) ❑ Zwischen 100.000 und 500.000 (kleinere Großstadt)
(3) ❑ Zwischen 50.000 und 100.000 (große Mittelstadt)
(4) ❑ Zwischen 20.000 und 50.000 (kleine Mittelstadt)
(5) ❑ Zwischen 10.000 und 20.000 (große Kleinstadt)
(6) ❑ Zwischen 5.000 und 10.000 (kleine Kleinstadt)
(7) ❑ < 5.000 (Landgemeinde)

An welchen Ausschreibungen nimmt Ihre Organisation hauptsächlich teil?
Mehrfachauswahl möglich

(1) ❑ Regionale Ausschreibungen
(2) ❑ Nationale Ausschreibungen
(3) ❑ Europaweite Ausschreibungen
(4) ❑ International/globale Ausschreibungen

In welchen Regionen realisiert Ihre Unternehmung hauptsächlich ihre Bauvorhaben?
Mehrfachauswahl möglich

(1) ❑ Regional
(2) ❑ National
(3) ❑ Europaweit
(4) ❑ International/global

Welche Kunden berät Ihre Organisation hauptsächlich?
Mehrfachauswahl möglich

(1) ❑ Regionale Kunden
(2) ❑ Nationale Kunden
(3) ❑ Europaweite Kunden
(4) ❑ Internationale/globale Kunden

In welche Projekte investiert Ihre Organisation hauptsächlich?
Mehrfachauswahl möglich

(1) ❑ Regionale Projekte
(2) ❑ Nationale Projekte
(3) ❑ Europaweite Projekte
(4) ❑ Internationale/globale Projekte

Nun folgen allgemeine Fragen zu Ihrer Organisation und den dortigen (Stadt)-Planungsprozessen.

Wie viele Mitarbeiter/innen sind in Ihrer Organisation tätig?

(1) ❑ ≤ 10
(2) ❑ 11 ≤ 50
(3) ❑ 51 ≤ 250
(4) ❑ 251 ≤ 500
(5) ❑ 501 ≤ 1000
(6) ❑ ≥ 1001

Welche Hilfsmittel und Programme werden in einem (Stadt)-Planungsprozess in Ihrer Organisation verwendet?
Mehrfachauswahl möglich

(4) ❑ Physische 3D-Modelle (z.B. aus Holz oder Styrodur)
(1) ❑ Computer-aided design (CAD-Programme, z.B. AutoCAD, StadtCAD, vektorworks)
(5) ❑ Grafikprogramme (z.B. Adobe Creative Cloud/ Suite)
(6) ❑ Geoinformationssysteme (GIS, z.B. ArcGIS, QGIS)
(11) ❑ Simulationsprogramme
(7) ❑ BIM (Building Information Modeling)

(8) ❑ CIM (City Information Modeling)

(10) ❑ Andere: _____

Nutzen Sie überwiegend 2D- oder 3D-Zeichnungen in Ihrer Organisation?

(1) ❑ 2D

(2) ❑ 3D

Wie digitalisiert sind die Planungsprozesse in Ihrer Organisation?
Angabe in Prozent 0 = nicht digitalisiert; 100 = vollkommen digitalisiert

_____

Gibt es Verzögerungen bei den Planungsprozessen in Ihrer Organisation, im Vergleich zu angesetzten Fristen/Terminen?

(1) ❑ Ja

(2) ❑ Nein

Was sind die hauptsächlichen Gründe für die Verzögerung von Planungsprozessen?
Mehrfachauswahl möglich

(1) ❑ Zu wenige Mitarbeiter/innen

(2) ❑ Zu wenig finanzielle Mittel

(3) ❑ Abhängigkeit von Dritten

(4) ❑ Unzureichende Datengrundlage

(5) ❑ Einwände aus der Bevölkerung

(6) ❑ Einwände von der lokalen Wirtschaft

(7) ❑ Einwände aus der Politik

(8) ❑ Technische Probleme, z.B.: _____

(9) ❑ Sonstige: _____

Im Folgenden stelle ich Ihnen Fragen zur Anwendung von nachhaltigen urbanen Design-Prinzipien in Ihrer Organisation. Es gibt dabei keine richtigen oder falschen Antworten, sondern Ihre Antworten helfen dabei, den Ist-Zustand der Anwendung solcher Prinzipien in Deutschland zu ermitteln.
Was sind nachhaltige urbane Design-Prinzipien? In dieser Befragung werden nachhaltige urbane Design-Prinzipien als solche Prinzipien bezeichnet, die nachweislich das Verhalten von Bürgerinnen und Bürgern so verstärken, dass sich ihr Verhalten im urbanen Raum nachhaltiger gestaltet.
Beispiele für nachhaltige urbane Design-Prinzipien und nachhaltigeres Verhalten seitens der Bürgerschaft wären:

Design-Prinzip --> **Potenzielle Folge**
Ausbau von Fahrradwegen --> Es wird mehr Fahrrad gefahren
Ausbau von Fußwegen/ Fußgängerzonen --> Es wird mehr zu Fuß gegangen
Ausbau des ÖPNV --> Öffentliche Verkehrsmittel werden stärker genutzt
Aufstellen von Mülleimern --> Weniger Müll wird auf die Straße geworfen

Wie stark verfolgt Ihre Organisation das Ziel, nachhaltiges Verhalten seitens der Bürgerschaft zu fördern?

(1) ❑ 1 - nicht
(2) ❑ 2 - wenig
(3) ❑ 3 - mittelmäßig
(4) ❑ 4 - ziemlich
(5) ❑ 5 - sehr

Welche Design-Prinzipien verwendet Ihre Organisation, um nachhaltiges Verhalten seitens der Bürgerschaft zu fördern?
Pflichtfeld - bitte geben Sie eine Antwort ein.

_____
_____
_____
_____
_____

Wodurch wird die strategische Ausrichtung Ihrer Organisation maßgeblich beeinflusst?
Bitte wählen Sie die 3 Möglichkeiten, mit dem stärksten Einfluss.

(1) ❑ Aktuelle (Stadt)politik
(2) ❑ Masterpläne der Stadt/ Gemeinde
(3) ❑ Gesetze und Regularien
(4) ❑ Führungskräfte
(5) ❑ Zeitgeist
(6) ❑ Aktuelle Forschungsergebnisse
(8) ❑ Finanzielle Anreize
(7) ❑ Anderes: _____

Nachfolgend interessiere ich mich für den (potenziellen) Einsatz von City Information Modelling (CIM) in Ihrer Organisation und Ihre Bewertung dieser Technologie im Rahmen von Stadtplanungsprozessen.

Vorab noch eine Beschreibung von CIM:
Die grundlegende Idee von CIM ist ein digitales Stadtmodell, ähnlich den digitalen Modellen für Gebäude (Building Information Model – BIM). Dabei werden BIM und GIS-Modelle zu einem **3D-Modell** des urbanen Raumes kombiniert, so dass ein **„digitaler Zwilling“** ensteht. Neben der reinen **geometrischen Darstellung** von Gebäuden und Objekten kann auch **deren Beziehung untereinander dargestellt** werden. Es ist beispielsweise möglich „versorgungsinfrastrukturelle Daten einzupflegen, objektspezifische Informationen zu hinterlegen und diese anschließend in automatisierten Prozessen auszuwerten und zu analysieren.“ (Müller, Broschart, Zeile, (2016)). Die Informationsbasis in CIM könnte die **Analyse und Simulation** von Verkehrsströmen und -staus, Energie, oder Umwelteinflüssen (z.B. Flut oder Stürme) ermöglichen.

Haben Sie in Ihrer Organisation bereits von Building Information Modeling (BIM) gehört, bevor Sie an dieser Befragung teilgenommen haben?

(1) ❑ Ja

(2) ❑ Nein

Haben Sie in Ihrer Organisation bereits von City Information Modeling (CIM) gehört, bevor Sie an dieser Befragung teilgenommen haben?

(1) ❑ Ja

(2) ❑ Nein

Wie groß bewerten Sie den potenziellen Nutzen durch den Einsatz von City Information Modeling im Allgemeinen?

(1) ❑ 1 – kein zusätzlicher Nutzen

(2) ❑ 2 – etwas zusätzlicher Nutzen

(3) ❑ 3 – mittelmäßiger zusätzlicher Nutzen

(4) ❑ 4 – großer zusätzlicher Nutzen

Wie groß bewerten Sie den potenziellen Nutzen durch den Einsatz von City Information Modeling in Ihrer Organisation?

(1) ❑ 1 – kein zusätzlicher Nutzen

(2) ❑ 2 – etwas zusätzlicher Nutzen

(3) ❑ 3 – mittelmäßiger zusätzlicher Nutzen

(4) ❑ 4 – großer zusätzlicher Nutzen

Welchen Nutzen könnte der Einsatz von City Information Modeling (CIM) in Ihrer Organisation generieren?
Mehrfachauswahl möglich

(1) ❑ Zentraler Zugriff auf Daten

(2) ❑ Einheitliche Datenstandards (z.B. Verwendung gleicher Dateiformate)

(3) ❑ Vermeidung doppelter Datenführung

(4) ❑ Beschleunigung von Planungsprozessen

(5) ❑ Analyse von Planungsentwürfen durch Algorithmen

(6) ❑ Leicht zugängliches digitales Model der Stadt/ Gemeinde

(7) ❑ Fehler werden reduziert

(8) ❑ Simulation von Planungsvorhaben im (digitalen) Stadtbild

(9) ❑ „Zeitreisen“ im digitalen Stadtmodell

(10) ❑ Langfristige finanzielle Einsparungen

(11) ❑ Bessere Zusammenarbeit unterschiedlicher Abteilungen (z.B. Tiefbau, Verkehrsplanung, Grünflächen, etc.)

(12) ❑ Effizientere Prozesse im operativen Bereich, nachdem die Planung abgeschlossen ist (z.B. Wartung und Instandhaltung)

(13) ❑ Wettbewerbsfähigkeit gewährleisten

(14) ❑ Beteiligungsprozesse effizienter gestalten

(15) ❑ Beteiligungsprozesse interessanter gestalten

(16) ❑ Sonstiges: _____

Wie viel Zeit könnte Ihrer Einschätzung nach durch den Einsatz von CIM bei Planungsprozessen in Ihrer Organisation eingespart werden?
Angabe in Prozent 0 = gar keine Zeitersparnis; 100 = vollkommene Zeitersparnis

_____

Welche Nachteile könnten sich Ihrer Meinung durch den Einsatz von CIM im Allgemeinen ergeben?

_____
_____
_____
_____
_____

Als wie wichtig bewerten Sie den Einsatz von City Information Models (CIMs) für die Zukunftsfähigkeit von (Stadt)-Planungsprozessen <u>in Ihrer Organisation</u>?

(1) ❑ 1 - Gar nicht wichtig

(2) ❑ 2 - Etwas wichtig

(3) ❑ 3 - Relativ wichtig

(4) ❑ 4 - Sehr wichtig

(5) ❑ 5 - Äußerst wichtig

Als wie wichtig bewerten Sie den Einsatz von City Information Models (CIMs) für die Zukunftsfähigkeit von Stadtplanungsprozessen <u>in Deutschland insgesamt</u>?

(1) ❑ 1 - Gar nicht wichtig

(2) ❑ 2 - Etwas wichtig

(3) ❑ 3 - Relativ wichtig

(4) ❑ 4 - Sehr wichtig

(5) ❑ 5 - Äußerst wichtig

Wie sehr könnte CIM dazu beitragen, dass nachhaltige urbane Design-Prinzipien vermehrt Anwendung in Planungsprozessen finden?

(1) ❑ 1- gar nicht

(2) ❑ 2 - etwas

(3) ❑ 3 - mittelmäßig

(4) ❑ 4 - sehr

(5) ❑ 5 - äußerst

Vielen Dank für Ihre Antworten. Im Folgenden ist Platz für Anmerkungen, Anregungen und Feedback zu dieser Befragung und/ oder den angesprochenen Themenbereichen:

_____
_____
_____
_____
_____

Für eine umfassendere Datenerhebung bin ich ebenfalls auf der Suche nach **Interviewpartnern/innen**, die mir Auskunft über den Einsatz von nachhaltigen Design-Prinzipien und City Information Modelling in Deutschland geben können. Wenn Sie Interesse daran haben, **Ihre Expertise in diesem Gebiet in die Forschung einfließen zu lassen**, hinterlassen Sie bitte hier Ihre E-Mail-Adresse unter diesem Link: E-Mail-Adresse für Interview hinterlassen

Wenn Sie am Gewinnspiel teilnehmen möchten, klicken Sie bitte auf diesen Link und hinterlassen Ihre E-Mail-Adresse:

Link zum Gewinnspiel

Vielen Dank für Ihre Teilnahme. Nachdem Sie auf "Fertigstellen" geklickt haben, werden Sie auf die Webseite des Fraunhofer IAO weitergeleitet.

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1.1.3 Interviewees

The following table gives an overview of the interviewees, their profession, the date on which they have been interviewed and the approximate length of the interview.

Table 5. Overview of interviewees and their profession

Name	**Profession**	**Date of Interview**	**Length of interview (in min)**
Dipl.-Ing. Stefan Kaczmarek	Practicing, self-employed urban planner in Darmstadt	12.04.2019	52
Dr.-Ing. Stefan Trometer	Managing director and responsible for business development at virtualcitySYSTEMS GmbH, a company that specializes in the development of system solutions for the collection, management, distribution, and, thus, ultimately for the use of 3D geodata. They provide system solutions for the modelling, management, and visualization of complex three-dimensional information spaces.	15.04.2019	80
Dipl.-Arch. Mike Letzgus	Research Associate at Fraunhofer-Institute for Industrial Engineering IAO, Urban Systems Engineering, Team Smart Urban Environments, with a strong focus on strategical urban planning.	15.04.2019	61
Prof. Dipl.-Arch. Daniel Mondino	Professor for digital integrated process management - Building Information Modeling and Planning at HafenCity University in Hamburg, and partner at the architecture office Core architecture, Kölln & Mondino GbR.	17.04.2019	34
B.Arch MAUD FRSA Euan Mills	Urban Futures Team Lead at Future Cities Catapult Ltd. based in London. Future Cities Catapult collaborates with and matches up industry, cities and government, and academia to define, create, test, and sell products and services for cities.	25.04.2019	33
Dr. Lachmi Khemlani	Founder and editor of AECbytes, an online magazine that is focused on researching, analyzing, and reviewing technology products and services for the building industry. She specialized in intelligent building modelling and consults and writes on AEC technology.	26.04.2019	28
Dipl.-Ing. Martin Hunscher	Head of the planning department at the City of Frankfurt am Main in Germany.	30.04.2019	32

M.Sc. Philipp Groß	Project Engineer working on integrated urban solutions at Drees&Sommer in Stuttgart, a leading European consulting, planning and project management enterprise.	07.05.2019	47

1.1.4 Exemplary interview questionnaire

This section depicts an exemplary interview questionnaire emailed to the interviewees in advance.

INTERVIEW QUESTIONS
25.04.2019, 15.00 – 15.45 pm UTC+1 (UK) [GER:16.00-16.45 UTC+2]
Euan Mills

AALBORG UNIVERSITY
DENMARK

Fraunhofer
IAO

Expert interview for master thesis »sustainable urban design principles and their future application in City Information Modelling (CIM)« (working title)

The master's thesis investigates urban design principles that encourage sustainable behaviour among urban citizens (buzzword: nudging) and their current application in Germany. Moreover, the thesis shall provide insight into fostering the application of such design principles by means of the digital planning tool City Information Modelling (CIM). For this purpose, an online survey among municipal urban planning departments, urban planners, associations and businesses from the building and financial industry is conducted. Additionally, expert interviews are carried out to gather thoroughly understandings. In the following you find the interview questions:

Introduction

1. What are your tasks as urban future team lead at Future Cities Catapult and what is the main business of the company?

City Information Modelling / digital twin of a city

2. How would you define City Information Modelling (CIM)?
3. What are chances for urban planning processes that are generated using CIM?
4. What are risks for urban planning processes that are generated using CIM?
5. How widespread is the application of CIM? In the UK/Europe/the rest of the world?

Sustainable urban design principles

In my thesis I investigate urban design principles that encourage sustainable behaviour among people in public spaces. The focus is on the built urban environment. For example, a good cycle road network can lead to more people choosing to ride the bike instead of driving the car. Pedestrian areas and a lot of green vegetation can lead to increased pedestrian traffic. A clever design of city trash cans can lead to a decrease in littering.

6. According to your estimation, to what extend are such design principles applied in Europe?
7. How could City Information Modelling foster the application of these design principles?
8. Which other mechanism/ tools could lead to an increased application of sustainable design principles in the urban environment?

Ending

9. What do expect from/wish for in the future development of digital planning processes/tools?

Thank you!

Laura Monika Arp
Urban Systems Engineering
Smart Urban Environments

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1.2. Additional Material B: Tables for chi-square tests

This section provides additional results for analyses conducted in the result section of the journal. Table 6 and table 7 supplement the chi-square tests in section 5.1. Evaluation of CIM. The test to investigate the effect of strategic orientation of the organization on the rated benefit of CIM for the organization lacks counts in the options ‘Zeitgeist’, ‘latest research’ and ‘other’ (refer to Table 6). The test to investigate the effect of the perceived benefits of using CIM on the rated benefit of CIM for the organization lacks counts in the options ‘analysis of planning proposals through algorithms’, ‘reduce occurrence of errors’, ‘long term financial savings’, ‘more efficient processes in operative tasks, after planning has been completed’ and ‘ensure competitiveness’.

Table 8 is related to section 5.1.5 City Information Modelling and sustainable urban design principles in the journal article. The test to investigate the effect of perceived benefits of using CIM at an organization on the rating of how much CIM could help foster the application of sustainable design principles lacks counts in the options ‘analysis of planning proposals through algorithms’, ‘reduce occurrence of errors’, ‘long term financial savings’, ‘more efficient processes in operative tasks, after planning has been completed’ and ‘ensure competitiveness’.

Table 6. Table for chi-square test, testing for the effect of strategic orientation of the organization on the rated benefit of CIM for the organization

		How do you evaluate the potential benefit from the application of City Information Modelling <u>in your organization?</u>									
		No additional benefit		Little additional benefit		Some additional benefit		Much additional benefit		total	
		Counts	Counts in column (%)	Counts	Counts in column (%)	Counts	Counts in column (%)	Counts	Counts in column (%)	Counts	Counts in columns (%)
Who or what influences the strategic orientation of your organization?	Politics	9	100.0	27	96.4	18	75.0	8	72.7	62	86.1
	Master plans	4	44.4	14	50.0	16	66.7	10	90.9	44	61.1
	Laws and regulations	9	100.0	17	60.7	15	62.5	6	54.5	47	65.3
	Management	3	33.3	14	50.0	11	45.8	5	45.5	33	45.8
	Zeitgeist	6	66.7	7	25.0	1	4.2	4	36.4	18	25.0
	Latest research	1	11.1	3	10.7	3	12.5	5	45.5	12	16.7

	Other	1	11.1	2	7.1	3	12.5	1	9.1	7	9.7
	Financial aspects	1	11.1	10	35.7	5	20.8	2	18.2	18	25.0

Table 7. Table for chi-square test, testing for the effect of perceived benefits of using CIM at an organization on the rated benefit of CIM for the organization

		How do you evaluate the potential benefit from the application of City Information Modelling <u>in your organization?</u>									
		No additional benefit		Little additional benefit		Some additional benefit		Much additional benefit		total	
		Counts	Counts in column (%)	Counts	Counts in column (%)	Counts	Counts in column (%)	Counts	Counts in column (%)	Counts	Counts in columns (%)
Which benefit(s) could the utilization of City Information Modeling (CIM) generate at your organization ?	Central acess to data	4	57.1	17	58.6	12	48.0	9	81.8	42	58.3
	Standardized data (e.g. usage of same data format)	3	42.9	13	44.8	13	52.0	7	63.6	36	50.0
	Avoid double data storage	3	42.9	8	27.6	9	36.0	7	63.6	27	37.5
	Speed up planning procedures	2	28.6	5	17.2	13	52.0	8	72.7	28	38.9
	Analysis of planning proposals through algorithms	0	0.0	7	24.1	5	20.0	5	45.5	17	23.6
	Easy access to a digital model of a city	1	14.3	20	69.0	19	76.0	8	72.7	48	66.7
	Reduce occurrence of error	0	0.0	2	6.9	3	12.0	4	36.4	9	12.5
	Simulation of planning proposals in the digital cityspace	2	28.6	20	69.0	18	72.0	10	90.9	50	69.4
	“time travel” in the digital model	0	0.0	5	17.2	10	40.0	6	54.5	21	29.2
	Long-term financial savings	0	0.0	2	6.9	1	4.0	4	36.4	7	9.7
	Better collaboration of different departments	1	14.3	16	55.2	11	44.0	9	81.8	37	51.4

	More efficient processes in operative tasks, after planning has been completed	1	14.3	5	17.2	3	12.0	5	45.5	14	19.4
	Ensure competitiveness	0	0.0	3	10.3	4	16.0	5	45.5	12	16.7
	More efficient participation processes	1	14.3	9	31.0	12	48.0	8	72.7	30	41.7
	More interesting participation processes	0	0.0	11	37.9	15	60.0	9	81.8	35	48.6
	Other: _____	2	28.6	0	0.0	2	8.0	1	9.1	5	6.9

Table 8. Table for chi-square test, testing for the effect of perceived benefits of using CIM at an organization on the rating of how much CIM could help foster the application of sustainable design principles

		How much could CIM contribute to the application of sustainable urban design principles in planning processes?											
		Not at all		Little		Somewhat		Very		To a great extend		total	
		Counts	Counts in column (%)	Counts	Counts in column (%)	Counts	Counts in column (%)	Counts	Counts in column (%)	Counts	Counts in columns (%)	Counts	Counts in columns (%)
Which benefit(s) could the utilization of City Information Modeling (CIM) generate at your organization ?	Central acess to data		75.0	14	51.9	15	62.5	7	53.8	3	100.0	42	59.2
	Standardized data (e.g. usage of same data format)	1	25.0	10	37.0	16	66.7	8	61.5	1	33.3	36	50.7
	Avoid double data storage	1	25.0	10	37.0	10	41.7	4	30.8	2	66.7	27	38.0
	Speed up planning procedures	0	0.0	8	29.6	9	37.5	8	61.5	3	100.0	28	39.4
	Analysis of planning proposals through algorithms	1	25.0	7	25.9	4	16.7	4	30.8	1	33.3	17	23.9
	Easy access to a digital model of a city	2	50.0	17	63.0	17	70.8	10	76.9	2	66.7	48	67.6
	Reduce occurrence of error	0	0.0	1	3.7	4	16.7	3	23.1	1	33.3	9	12.7

	Simulation of planning proposals in the digital cityspace	1	25.0	20	74.1	17	70.8	9	69.2	3	100.0	50	70.4
	“time travel” in the digital model	0	0.0	7	25.9	7	29.2	6	46.2	1	33.3	21	29.6
	Long-term financial savings	0	0.0	1	3.7	2	8.3	3	23.1	1	33.3	7	9.9
	Better collaboration of different departments	0	0.0	12	44.4	14	58.3	9	69.2	2	66.7	37	52.1
	More efficient processes in operative tasks, after planning has been completed	0	0.0	3	11.1	7	29.2	3	23.1	1	33.3	14	19.7
	Ensure competitiveness	0	0.0	6	22.2	4	16.7	2	15.4	0	0.0	12	16.9
	More efficient participation processes	0	0.0	6	22.2	11	45.8	10	76.9	3	100.0	37	52.1
	More interesting participation processes	0	0.0	11	40.7	14	58.3	7	53.8	3	100.0	14	19.7
	Other: _____	0	0.0	1	3.7	2	8.3	1	7.7	0	0.0	12	16.9

1.3. Additional material C: Additional quotations from expert interviews

This section provides additional data from the interviews that results in the journal article are based on. Table 9 relates to section 5.1.3. Disadvanatges of CIM: Findings from the survey and shows the clustered answers of respondents to the question: Which disadvantages could derive from the application of CIM in general? The original German quotes have been translated by the author.

Table 9. Disadvantages using CIM named by survey respondents including quotes in English and German

Disadvantage	**English quote (translated)**	**Original German quote**
extensive need of resources for maintenaning CIM	"high effort to maintain the data base", "great effort for gathering of data and verification of completeness, data maintenance", "amount of work"	"hoher Aufwand zur Pflege der Datengrundlagen", "großer Aufwand für die Datenerfassung und Prüfung auf Vollständigkeit, Datenpflege", „Arbeitsaufwand"
amount of resources needed to roll-out CIM	"very high effort for setup", "high volumes of data for weak networks, hardware is not suitable → initial high investments for new hardware before roll-out", "problems in the beginning"	"sehr hoher Aufwand für den Aufbau", "hohes Datenvolumen für schwache Netzwerkstrukturen, nicht geeignete Hardware → zunächst hohe Investition für neue Hardware bevor Einsatz zum Tragen kommen kann", „Anfangsprobleme"
costs	"financial effort", "extra effort and expense", "high investment necessary"	„finanzieller Aufwand", „Mehraufwand, Mehrkosten", „hohe Investition erforderlich"
Non-sufficient education of employees	"employees are missing know how", "trainings", "acceptance of (older) employees"	„fehlendes Knowhow bei Arbeitnehmern", „Schulungen", „Akzeptanz (älterer) Mitarbeiter"
missmatch of effort and utility/benefit (in small administration units)	"too inconvenient for an administration", "effort and effect will be out of balance, especially in simple city planning processes in small municipalities", "especially in small organisational units there will be a high number of staff required compared to the overall number of staff"	"zu umständlich für eine Verwaltung", „Anwendung in einfachen stadtplanerischen Prozessen insbesondere kleiner Gemeinden, in denen Aufwand und Wirkung nicht im Verhältnis stehen", „Insbesondere bei kleiner Organisationseinheit sehr hoher Personalaufwand im Verhältnis zur Gesamtzahl der Mitarbeiter"
additional time resources needed	"additional time investments", „too time consuming"	"zusätzlicher Zeitaufwand"; "zu zeitintensiv"

extended need for personnel	„too personnel intensive“, „personnel placement is too high”	“zu personenintensiv”, “zu hoher Personaleinsatz“
Loss of creativity	“heavy losses on behalf of creative and artistic aspects (Stadtbaukunst)”, “new creative solutions in the urban environment will be hampered”	“starke Verluste auf Seiten der kreativen und künstlerischen Aspekte (Stadtbaukunst)“, „kreative neue Lösungen im Städtebau werden erschwert“
No disadvanatges	“none”, “no disadvantages”	„keine“, „keine Nachteile“
no answer	“I don’t know”, “not specified”	“weiß nicht”, “keine Angabe”
High focus on digitalization	„even higher dependancy on electronical systems”, “technization”, “digital surfeit”, “neglection of personal review/ site visits, to much dependency on digital data, neglection of qualitative analysis”	„Noch größere Abhängigkeit von elektronischen Systemen“, „Technisierung“, „digitale Übersättigung“, „Vernachlässigung von persönlicher Bestandsaufnahme/ Ortsbegehungen, zu viel Verlass auf digitale Daten, Vernachlässigung qualitativer Analyse“
Contract issues	“Similar to BIM, the contracts are complex. It is questionable, if the investment in the models will mayorly benefit the planners rather than other project partners and commissioners, without this being depicted in the fees”, noticeable more effort, because “the old way” will have to be planned through as well. A standard will have only established itself potentially after some years (see digital participation procedures – not fully established = double the amount of work)”	„Wie auch bei BIM sind die vertraglichen Beziehungen komplex. Es ist die Frage, ob der vorab in die Modelle zu investierende Aufwand den Planern oder nicht vielmehr anderen Projektbeteiligten und den Auftraggebern zu Gute kommt, ohne dass dies in den Honoraren abgebildet werden kann“ , „erheblicher Mehraufwand, da immer noch der "alte Weg" mit geplant/erarbeitet werden muss. Erst nach mehreren Jahren wird sich ggf. ein Standard einstellen. (Siehe digitale Beteiligungsverfahren - noch nicht vollständig etabliert = doppelt Arbeit)“
Quality of data	“wrong outcomes due to missing data”, “discrepancy between visualization and reality”, problems of interfaces, differences in the development of municipalities, country, planning and consultancy organisations”	„verfälschte Ergebnisse durch fehlende Daten“, „Diskrepanz zwischen bildlicher Darstellung und Realität“, „Schnittstellenproblematik, unterschiedlicher Ausbau bei Kommunen, Land, Planungs- und Beratungseinrichtungen“

Table 10 relates to section 5.2. Alternatives to CIM and suggestions for further development of the journal article. Depicted is the data utilized and clustered from the expert interviews. Table 11 relates to the same section and shows categories for further improvement and the relating data from the interviews.

Table 10. Alternative methods or tools that could be utilized during urban planning processes to foster the application of design that encourages sustainable behaviour among citizens

Alternative method/ tool	**Quotes from experts**
Use existing digital tools to gather better data	In actual fact, the building blocks behind that is just the use of digital technology in collecting better data. So, if we actually use some of the most basic tools that we have today, we can already start doing it, and be getting a lot of the benefits that City Information Modelling would give us. (B.Arch MAUD FRSA Euan Mills)
Depict and communicate the personal value of sustainable behaviour instead of doomsday predictions dominating the discourse	If you actually make a stronger case for the harmful effects of designing the way we are designing, it might have an impact, right? […] But it could be nice to also present the personal aspect of it. One of the things we talked about was building cities closer to public transportation, so people don't have to rely on cars. There's the sustainability aspect but there's also much more, like a social aspect to it. So maybe if we can focus more on how things could be actually emotionally better for people and their well-being, then that might be much more gripping to them. (Dr. Lachmi Khemlani)
Smart Citizen need to request sustainability from decision makers	Now we have the Smart City, but we forget that a city is not smart, sustainable, nothing. A city is a construct made from glass, concrete, which is stupid per se. What makes it sustainable are the citizens. So exactly your point of departure: "How to get people to behave more sustainable?" I believe the main mechanism is pressure from the outside, Climate Change, etc. We understand that if we continue, our children but definitely our grandchildren will face a huge problem. […] We need to change our way of thinking. I think it is our duty, as educated, mature ("mündig") citizens to inform ourselves and to direct requests at politics. So, like a bottom-up mechanism. (Dipl.-Arch. Mike Letzgus)
Inform better, give precise advice on behaviour and use best-practice examples	I think it is about information, the distribution of knowledge. That means, one needs to raise awareness for potential beginnings. And that works through examples – that one would possibly connect to digital

	tools – but they would show what is possible. (Prof. Dipl.-Arch. Daniel Mondino) I think we also need precise recommendations and call for actions. I think we need to think and act with the help of images. Because a lot is connected to the imagination of a thing. For example, if I want a place to change, I could compare it to other places, that are positive and have solved the problem in principle. And then evolve an image that can be a role model for a specific place. (Dipl.-Ing. Stefan Kaczmarek)

Table 11. Suggestions by experts for the further development of digital planning tools in Germany and in general

Suggestion	**Quotes from experts**
More courage (to try new methods)	More courage. The courage to leave the comfort zone and not – like we see in many projects, especially in ones on city level – act very cautiously, be worried, make everything like it used to be and shy away from trying something new. I think this is a crucial aspect that we just need in urban planning. From all parties involved, not just from the urban planners. (Prof. Dipl.-Arch. Daniel Mondino) From our perspective the difficulty is that the worries from administrations and municipalities are taken extra ordinally seriously and one is in a super cautious position, which inhibits digitalization in this specific cause to a certain extend. (Dr.-Ing. Stefan Trometer)
Governments need to play a more active role	I think the ownership and governance of them [digital planning tools] is probably the most important aspect. So, I think building these tools is great. But we have to get the ownership and the governance around them robust. Today Google knows more about your city than your planning department does. And that imbalance is a problem. So, I guess my wish is: can the public authorities, government take more of an active role in building their own tools rather than just relying on proprietary systems. (Euan Mills)
Strong focus on usability	Of course, usability. […] It is important that there are applications that are usable. This is an aspect every user, not only specific users or urban planners, is interested in. (Dipl.-Ing. Martin Hunscher)
Stronger incorporation of digital tools into education	I think if these things should really be used, this needs to be incorporated into the education very early. As a municipal employer, it is very important that young professionals come with other and new methods. It is

	hard to catch up on this in day-to-day business. […] One is dependant on younger colleagues which is why it is important for universities to embark early on these topics and impart knowledge. (Dipl.-Ing. Martin Hunscher)
Open access to data paired with data security	I would like to see that the data is accessible for everyone, as long as personal rights are not violated. That data is accessible free of charge and well prepared, easy for citizens to use. (Dipl.-Ing. Stefan Kaczmarek)
Open data standards	What we need in Germany? We need open standards – I mean we also don't give away our solutions for free. But we have specialized solutions, expert solutions, that work with open data standards and open interfaces. […] We need open interfaces, open data standards, that help spread the technology but also make it more economically efficient. If I don't have different solutions in Munich and Flensburg it becomes more economical. […] Of course, there is no perfect solution that fits all. But based on the cityGML standard, based on an open standard, we want to connect the different systems. (Dr.-Ing. Stefan Trometer)
Develop better tools for analysis	Definitely make better tools. […] we will need a lot of analysis tools for different aspects. […] they [the intelligent models of the cities] are going to be no use unless you actually have analysis tools which can study them, that can come up with recommendations or problems. (Dr. Lachmi Khemlani)
Rethink planning processes and opt for more cooperation	First: get the planners out of their ivory tower. Realize, that the urban planner can no longer plan the city by himself. We need co-creative building, participative planning tools. I would wish for us realizing that we need to plan interdisciplinary, cooperative, participative. And understand the city as a dynamic evolvement, in steady flow, in a steady change. Knowing this provides a different basis for future infrastructural projects. That means, the awareness for the different levels and the will to change the field of planning from its core. (Dipl.-Arch. Mike Letzgus) I think what we really need is cooperative working, a stronger cooperation. […] I think it is also about the administrations cooperating more with regards to urban challenges. So aggregate knowledge, integrate themselves more and not just focus on their own field

	and lobby for their own interest. (Prof. Dipl.-Arch. Daniel Mondino)

1.4. Additional Material D: Bibliography

The bibliography contains all sources that have been utilized for this thesis but not utilized for the journal article.

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