Using Conceptual Modeling to Support Innovation Challenges in Smart Cities

Dominik Bork, Robert Buchmann, Igor Hawryszkiewycz, Dimitris Karagiannis, Nikolaos Tantouris and Michael Walch

Published in:

14th IEEE International Conference on Smart City, 12.-14-12-2016, pp. 1317 - 1324, Sydney, Australia

Using Conceptual Modeling to Support Innovation Challenges in Smart Cities

Dominik Bork*, Robert Buchmann†, Igor Hawryszkiewycz‡, Dimitris Karagiannis*, Nikolaos Tantouris* and Michael Walch*

*University of Vienna, Research Group Knowledge Engineering, Waehringer Street 29, 1090 Vienna, Austria
Email: firstname.lastname@univie.ac.at

†Babes-Bolyai University, Business Information Systems Department, Str. T. Mihali 58-60, 400591 Cluj-Napoca, Romania
Email: robert.buchmann@econ.ubbcluj.ro

‡University of Technology Sydney, Faculty Engineering and Information Technology
Broadway, NSW 2007, Sydney
Email: igor.hawryszkiewycz@uts.edu.au

***Abstract*—The digital transformation of cities towards Smart Cities proposes many opportunities, e.g., related to services, security, waste and energy management, and infrastructure management. These opportunities come with manifold innovation challenges, not only from a technological perspective but also for public authorities and citizens. The paper at hand introduces conceptual modeling as a means towards handling the complexity of Smart City planning, management, and operation. This paper presents multiple scenarios, indicating possibilities of bridging between the challenges of Smart Cities on the one hand and the opportunities of applying conceptual modeling on the other. Evaluation results and experience gained from two years of teaching such scenarios at the Next-generation Enterprise Modeling Summer School (NEMO) indicate a strong positive impact on student's motivation and learning success. The aim of this paper is therefore to emphasize on the benefits of adopting conceptual modeling in Smart Cities by exemplifying possible application scenarios.**

***Index Terms*—Smart City, Conceptual Modeling, Model Query, Model Simulation.**

1. Introduction

Smart Cities are an emerging field in research and development, proposing a lot of new possibilities and opportunities for its citizens and managers. Transforming a city into a Smart City requires: changes in the way enterprises, public authorities, and non-profit organizations interact with their customers; changes in the established business models; and changes in the services that need to be designed and implemented. In consequence, Smart Cities are considered a highly relevant research, application, and learning domain.

This paper investigates the possibilities of utilizing domain-specific conceptual modeling [1] in Smart Cities. In this regard, conceptual modeling enables managing complexity by applying abstraction in different contexts of Smart Cities. The focus of this abstraction is on socio-technical aspects of such cities. The paper reports on a teaching case presented at the *Next-generation Enterprise Modeling in the Age of Internet of Things 2016 Summer School (NEMO)*[1]. The teaching case is composed of three scenarios, addressing the innovation challenges as stressed in [2]: *Smart City Planning*, *Smart City Management*, and *Smart City Operation*.

Each scenario describes concrete challenges faced in Smart Cities. Besides the description of the scenarios, the paper discusses experience from presenting the teaching case at the 2016 edition of the NEMO Summer School. Evaluation of the teaching case is performed twofold: first, quantitative results of a survey conducted one week after the summer school are reported; second, a comprehensive SWOT analysis is performed by reflecting on the experience and by contrasting this experience to the experience of teaching conceptual modeling in regular university courses without the Smart City as an application domain.

The aim of the paper is to emphasize on i) the benefits of deploying the abstraction effort of modeling method engineering in order to raise awareness on challenges from the emerging domain of Smart Cities, and ii) the evaluation results we obtained from this teaching case. The rest of the paper is organized as follows. Section 2 positions the work within the research context. The theoretical foundation as well as the organizational frame of the research are delineated in Section 3. How conceptual modeling can address innovation challenges in Smart Cities is then discussed in Section 4. Evaluation results are presented in Section 5 before the paper is concluded in Section 6.

2. Research context and contribution

"Although there is an increase in frequency of use of the phrase 'smart city', there is still not a clear and consistent understanding of the concept among practitioners and academia. Only a limited number of studies investigated and began to systematically consider questions related to

1. Next-generation Enterprise Modeling (NEMO) Summer School: http://nemo.omilab.org, last visited: 05.08.2016

this new urban phenomenon of smart cities" [3, p. 2289]. Planning, management, and operation of Smart Cities requires innovation and abstraction to cope with the given complexity and design novel solutions to upcoming needs. Modeling plays a vital role in this regard (cf. the smarter cities innovation framework proposed by [2, p. 36]).

The exercise scenarios described in this paper contribute to the Smart City research framework proposed by [3], [4] in the fields of *technology*, *people and communities* and *natural environment*. Following the smart city vision of [5], this paper contributes to the *intelligent transport systems, smart mobility, logistics and technology*, *quality and sustainability of living*, and *ecosystem: sustainable environment, renewable energy and other resources*. Considering the research challenges stressed by [6], this paper proposes teaching cases and an evaluation of scenarios towards: i) *"how governmental agencies may use the IoT to serve citizens in the smart city of tomorrow"* [6, p. 1538], and ii) *"What human behavioural changes are likely to occur due to pervasive diffusion of smart devices and smart products connected to the IoT?"* [6, p. 1536].

[2] proposes innovation challenges for Smarter Cities. The paper at hand perceives these innovation challenges as a special form of wicked problem [7], [8], originally admitted to the area of design thinking. A wicked problem is mostly related to a wicked system - in this case the Smart City - that *"introduce new challenges because of a much wider problem space and greater problems complexity, open for interpretation, characterized by competing or conflicting opinions for solutions, and unlikely to ever be completely solved"* [9].

The industry is of course also taking up on the challenges and (economical) possibilities of Smart Cities. Global enterprises like IBM, CISCO, Microsoft, Oracle, and SAP work on providing tools and methods to support the transformation of cities towards smarter cities [10], [11]. Most of the endeavors extensively use modeling approaches.

Smart Cities raise both run-time challenges (management of sensor networks, large-scale data processing etc.) but also design-time challenges (design analysis, "what if" simulations). Considering run-time aspects, several works have already been published, e.g., related to crowd sensing in combination with social media [12] or real-time Smart City decision support systems [13]. The scope of the hereby proposed approach is limited to design-time analysis and sense-making, where smart cities research is less prominent and the application of design science largely overlooked [14]. The paper proposes a first step towards bridging the gap between conceptual modeling and Smart Cities. It contributes to this bridging by proposing several scenarios following the design science research (DSR) paradigm [15]. Considering the DSR knowledge contribution framework [16], this paper contributes to the exaptation area as the solution maturity (i.e., conceptual modeling) can be characterized as high but the application domain maturity (i.e., Smart Cities) is considered to be very low. The scenarios spotlight the possibilities of applying domain-specific conceptual modeling in Smart Cities.

3. Foundations

3.1. Domain-specific Conceptual Modeling

Conceptual modeling *"is the activity of formally describing some aspects of the physical and social world around us for purposes of understanding and communication"* [17]. Existing systems and human beings are limited when it comes to planning, management, and operation of Smart Cities. Conceptual modeling approaches are candidates for taking their place or supporting them, respectively. These approaches not only facilitate coping with the increasing complexity by providing structuring, planning, and analysis processing qualities for human beings. Moreover, if based on a formal specification [18], they can be used as knowledge bases or the model-driven development of complex systems [19].

The creation of valid models is guided by modeling methods. As defined by [20], three building blocks constitute a modeling method: The *modeling language*, defining the syntax of the modeling method, i.e., the elements and the rules constraining allowed combinations thereof. For a complete modeling language specification, one needs to define also the semantics, i.e., the meaning, and the notation, i.e., the graphical visualization for each syntactic element; The way modelers are intended to utilize a given modeling language, thereby creating valid models, is specified in the *modeling procedure*; Further model processing functionality is specified in *Mechanisms & Algorithms*, e.g., simulations, model transformations, model queries, model validation.

Standard modeling languages like BPMN and UML are widely used and accepted in industry for pre-defined application scenarios. With emerging and upcoming domains like Smart Cities, however, such standards are not adequate for all domain-specific requirements and their necessary depth of conceptual specialization. Hence, modeling language, modeling procedure, and mechanisms & algorithms need to be adopted to the specific requirements of Smart Cities. Modeling methods in this regard *"represent a clearly more productive instrument for describing and analyzing problems as well as for designing systems"* [21, p. 155].

3.2. OMiLAB Method Engineering & Prototyping Environment

The Open Models Laboratory (OMiLAB) [22] is a virtual and physical environment for modeling method engineering and modeling tool development following the Agile Modeling Method Engineering (AMME) approach [23]. AMME covers all aspects of method conceptualization, i.e., starting with the design of modeling languages until the implementation of the corresponding modeling tools. The whole approach together with a development life cycle and a case study is published in [23] and [24], respectively.

The OMiLAB is meant to establish an international community of modeling enthusiasts interested in developing novel modeling methods following the OMiLAB lifecycle and using the meta modeling platform ADOxx (http://www.adoxx.org). ADOxx is the technological enabler for the OMiLAB. It is an open use platform that everyone in academia can freely use in order to develop his/her modeling tool. The platform has proven its feasibility in numerous national and international research projects.

AMME and ADOxx are specifically designed to capture required domain-specificity of modeling methods. In consequence, both enable and facilitate fast prototyping of modeling methods and corresponding tools, also employed for the teaching case described in Section 4. A modeling method, as described in Section 3.1 is the output of the engineering approach advocated by OMiLAB. Dissemination and validation of these methods can take place as part of the Next-generation Enterprise Modeling in the Age of Internet of Things Summer School (NEMO). NEMO was initiated in 2014, aiming to provide an educational forum for international Master and PhD students interested in foundations and applications of domain-specific conceptual modeling. Each year 50 to 70 international students participate in lectures and exercises focusing on foundations, applications and technologies of conceptual modeling. Theoretical lectures are comprised by exercises, enabling the students to transform their theoretical knowledge towards practical application in challenging and interesting domains.

Since 2015, one exercise block comprising three sessions focuses on addressing Smart City challenges by means of conceptual modeling [25]. In the following, the Smart City exercises presented at the NEMO Summer School will be presented, describing how domain-specific modeling in the OMiLAB can be applied to Smart Cities.

4. Conceptual Modeling for Smart Cities

We considered the situation of a Smart City planner, responsible for planning, management and operating a Smart City. We specified multiple scenarios, focusing on tasks of the Smart City planner and aligned them to the research framework proposed by [2]. The underlying goals were: i) to familiarize students with the Smart Cities domain; ii) to guide them through an exercise of "abstracting" this domain, where they need to isolate some relevant concepts/properties for a given scenario; iii) to guide them through an exercise of formally and graphically representing this abstraction by designing a domain-specific modeling language; iv) to make them aware of different means of how the model contents may be processed (queries, simulation) and how this processing depends on a formal meta model; and v) to guide them through implementing all these in a dedicated platform that allows fast prototyping as well as agility (cf. [23]). As a meta-goal, this paper aims to evaluate how the students perceived all this effort in terms of various metrics like understandability, motivation and time.

One scenario we want to elaborate throughout the rest of the paper is the **Smart City Marathon Scenario**. The following sections will use the scenario of planning, management, and operating a marathon within a Smart City.

Marathon Planning. The first session covered all aspects related to the design of a marathon. After a brief introduction to meta modeling and conceptual modeling, the students were asked to think about relevant concepts of a Smart City that should be included in a modeling language supporting a Smart City planner. The outcome of this session was an extended version of the Smart City Modeling Language.

Marathon Management. The second session used the modeling language defined in the first session to answer non-trivial questions related to managing a marathon in a Smart City. Most marathons include a relay competition where groups of e.g., four runners participate. One question in this session was how to prevent the runners from waiting in the wrong relay section and/or omit unnecessary waiting times. As an outcome of this session, students were enabled to use model query functionality to answer domain-specific questions using domain-specific conceptual models.

Marathon Operation. The third exercise session focused on how to operate a marathon by means of managing all volunteers and drinking stations. It was focusing on questions like how many volunteers are required at which time and which drinking station, and how many drinks need to be prepared at the different drinking stations. The outcome of this session was that students learned how to customize and execute model simulation functionality on conceptual Smart City models in order to answer such complex domain-specific questions.

The fundamental idea behind the teaching scenarios was twofold. First, students should be enabled to understand why and how to utilize domain-specific conceptual modeling. They should learn, that in some circumstances, standards and de-facto standard modeling approaches lack domain-specificity and are therefore unfavorable. Second, students should experience that models serve only limited value by themselves. In contrast, using conceptual models as knowledge bases for model processing by means of model queries and model simulations increases the model value remarkably.

4.1. Smart City Planning

In order to support the Smart City planner in designing a marathon, concepts of a Smart City that are relevant for the marathon need to be integrated into a conceptual modeling language. This includes e.g., sensor data that tracks the quality of the air, the traffic volume on the streets, and data about the pedestrians (volunteers, participants, spectators).

The exercise teachers showed the students how to create new modeling concepts in ADOxx, how to realize static and dynamic graphical visualizations and properties for these elements, and how they can be used by the modeler. Within minutes, students were able to extend a pre-defined modeling language with relevant Smart City elements, thereby creating a Smart City Modeling Language (SmartML). SmartML comprised streets, crossings, buildings, runners, common air quality index (CAQI) sensors, marathon relay sections, infrastructure elements etc. Afterwards, students

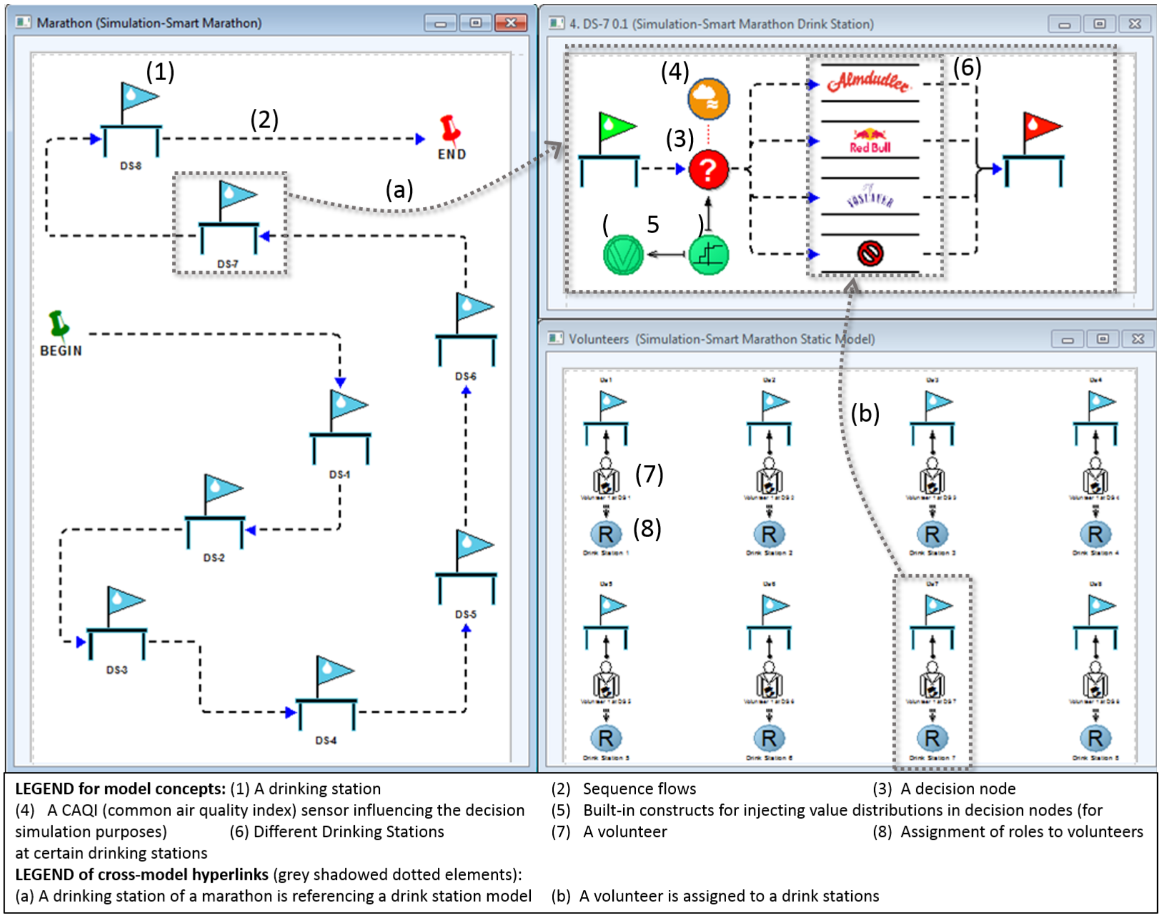


Figure 1. Modeling a marathon scenario with SmartML: *Smart Marathon* (left), *Drink Station* (top-right), and *Static Model*.

were asked to create visual models of a Smart City and create a marathon track (cf. Figure 1).

The general way of how students extended SmartML on ADOxx followed these steps: 1. Identification of relevant domain-specific concepts; 2. Identification of relevant domain-specific properties and relations for each concept, as required in envisioned queries and simulation; 3. Creation of language meta model, including cardinalities and constraints; 4. Creation of static notations for concepts and relations identified to be made available on a visual level; and 5. Identification of properties that should be visually reflected by means of a dynamic notation.

4.2. Smart City Management

The second exercise session introduced the students to model queries. Using the Smart City and the marathon scenario, students where asked to identify runners that are currently in the wrong relay section. A different scenario, the emergency scenario, was targeting at the question how can an injured person be supported with first-aid in the most efficient way and in the shortest time. Another scenario was centering the questions to find the healthiest (using the CAQI sensor data) and the fastest path through a Smart City.

Students used the conceptual Smart City models and the know-how on model queries to answer these questions after some examples shown by the lecturers. The students rather easy and fast approached possible solutions for the questions and where impressed by the power of model querying functionality. The students also learned, that multiple query strategies can lead to the same, positive result.

At the end of the sessions it was discussed with the students that such scenarios are already on their way. [26] investigates the possibilities of a Volunteer Notification System for decreasing the time until a person suffering a heart attack or cardiac arrest receives first aid. [27] recently investigated the possibilities of combining fuzzy logic with a Smart City infrastructure in order to reduce emergency services response times. According to [28], such systems might have a significant influence on the number of deaths caused by heart attacks. [29] showed possibilities of decreasing the travel time in a Smart City by using map matching techniques applied on sensor data.

4.3. Smart City Operation

In the third session multiple scenarios were discussed with the NEMO students. The goal of the scenarios was twofold: i) integrate concepts the students have realized and the experience gained throughout the first two sessions, and ii) teach students how to customize model simulation functionality to the Smart City domain. Additionally, students learned that multiple techniques, in this case model queries and model simulation, can answer the same question (in this case finding the healthiest running track).

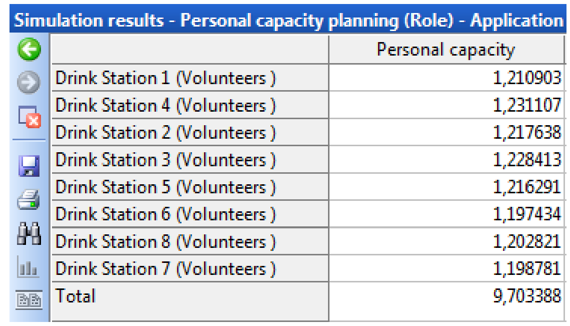
4.3.1. Healthy Running Track Scenario. The first scenario was concerning the question *what is the healthiest marathon running track in the Smart City*. Based on the common air quality index sensors (CAQI) and the path analysis simulation, students were enabled to answer this question by comparing the different path results considering the CAQI sensor value.

In order to perform a path analysis, several things need to be done. First, a conceptual Smart City model needs to be created. Afterwards, CAQI sensors need to be modeled and linked to street elements. The CAQI sensor value needs to be set according to either real-live data gained from the Smart City or an approximated distribution. Lastly, using the ADOxx simulation functionality, the CAQI sensor values need to be incorporated during the execution of the simulation. Students were then asked to execute the path analysis and investigate the multiple paths with all their values to decide which path is best suited as the marathon track.

4.3.2. Marathon Capacity Planning Scenario. After the successful path analysis, the NEMO students were challenged with more complex questions. The next scenario was targeting questions like *how many volunteers are required at each drinking station of the marathon*. Such questions can be answered in ADOxx with capacity analysis simulations.

For capacity analysis, three models need to be created. First, like for the path analysis, a conceptual Smart City model for the marathon. This model needs to be complemented by a static model comprising all resources and roles, and by a Smart City Drink Station. After these models have been created, drink stations need to be assigned to the marathon (cross-model reference (a) in Figure 1), and volunteers and roles to the drinking stations (cross-model reference (b) in Figure 1). Lastly, the simulation-specific parameters need to be configured. We configured the marathon to take place on the second of January from 9am until 5pm with almost 10000 participants. The starting time of the runners is distributed over the day. This is used as an approximation of the different times the runners need to run through the marathon in order for the simulation algorithm to work.

After executing the capacity planning simulation, ADOxx shows the simulation results in a result window. The students were asked to interpret the results and investigate the different simulation result perspectives the platform provides, i.e., *Process related*, *Person related*, *Working environment*, and *Capacity planning*. Figure 2 illustrates the capacity analysis simulation results after selecting the *capacity planning* perspective. It shows, that in the currently considered models with the current configuration at least two



Simulation results - Personal capacity planning (Role) - Application

	Personal capacity
Drink Station 1 (Volunteers)	1,210903
Drink Station 4 (Volunteers)	1,231107
Drink Station 2 (Volunteers)	1,217638
Drink Station 3 (Volunteers)	1,228413
Drink Station 5 (Volunteers)	1,216291
Drink Station 6 (Volunteers)	1,197434
Drink Station 8 (Volunteers)	1,202821
Drink Station 7 (Volunteers)	1,198781
Total	9,703388

Figure 2. Results of the marathon capacity planning simulation.

volunteers at each of the eight drinking stations are required to handle the workload produced by the runners.

The capacity planning simulation resolved the minimum number of volunteers at each drinking station. Using this information, the students adapted the resource model, created two volunteers and assigned them to the corresponding drinking stations. Re-executing the simulation enabled the students to immediately reflect on the impact of their changes on the simulation results.

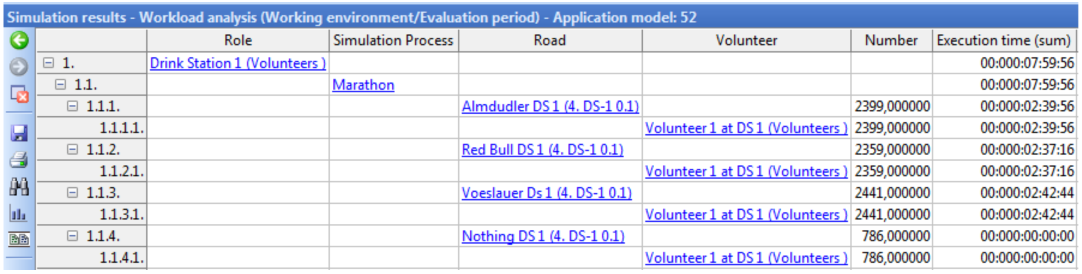
4.3.3. Marathon Workload Planning Scenario. In the last scenario of the simulation session, the students were asked to answer questions like *how many drinks of a certain taste are required at a certain drinking station*.

In order to derive answers to such questions, an ADOxx workload analysis simulation needs to be configured and executed. To do this, the same configuration as for the capacity planning simulation needs to be performed. Consequently, the same three models as visualized in Figure 1 need to be modeled and linked.

After the students executed the workload analysis simulation, the platform shows the simulation results in a special simulation results window. The students were asked to investigate the results, understand them and navigate through them using the different perspectives and operators provided by ADOxx, i.e., *Process related*, *Person related*, and *Working environment*.

Figure 3 illustrates sample workload analysis simulation results after selecting the *process related* perspective for the whole marathon. The results are hierarchically structured, starting from a specific role of the resource model to drinking stations, down to the volunteers that are delivering the drinks to the runners.

Looking at the results more closely, it can be identified, that at the first drinking station only one volunteer is responsible for serving Red Bull, Almdudler, and Vöslauer. Hence, it is no surprise that the workload of this volunteer is approximately 100%. This confirms the results of the capacity analysis simulation (cf. Section 4.3.2). Creating more volunteers in the resource model and linking them to the drinking station will decrease the workload level and therefore solve the problem. Moreover, the simulation shows how many drinks are required at each drinking station and which volunteer is responsible of handing it to the runner.



Simulation results - Workload analysis (Working environment/Evaluation period) - Application model: 52

	Role	Simulation Process	Road	Volunteer	Number	Execution time (sum)
1.	Drink Station 1 (Volunteers)					00:000:07:59:56
1.1.		Marathon				00:000:07:59:56
1.1.1.			Almdudler DS 1 (4. DS-1 0.1)		2399,000000	00:000:02:39:56
1.1.1.1.				Volunteer 1 at DS 1 (Volunteers)	2399,000000	00:000:02:39:56
1.1.2.			Red Bull DS 1 (4. DS-1 0.1)		2359,000000	00:000:02:37:16
1.1.2.1.				Volunteer 1 at DS 1 (Volunteers)	2359,000000	00:000:02:37:16
1.1.3.			Voeslauer Ds 1 (4. DS-1 0.1)		2441,000000	00:000:02:42:44
1.1.3.1.				Volunteer 1 at DS 1 (Volunteers)	2441,000000	00:000:02:42:44
1.1.4.			Nothing DS 1 (4. DS-1 0.1)		786,000000	00:000:00:00:00
1.1.4.1.				Volunteer 1 at DS 1 (Volunteers)	786,000000	00:000:00:00:00

Figure 3. Excerpt of the results of the Marathon workload planning simulation.

TABLE 1. SURVEY QUESTIONS

	Closed questions
Q1	*The Smart City is a good application domain for teaching conceptual modeling?*
Q2	*The Smart City is a good motivator for teaching conceptual modeling?*
Q3	*Do you have the impression, that the Smart City scenario contributed to understanding the foundations and applications of conceptual modeling?*
Q4	*Do you think it was beneficial to use the OMiLAB and ADOxx tools for practical hands-on experience instead of only theoretical content?*
Q5	*Would you recommend the Smart City exercises for people interested in learning conceptual modeling?*
	Open questions
Q6	*Which Smart City scenario did you find most interesting?*
Q7	*What did you like about the Smart City exercises?*
Q8	*How would you improve the Smart City exercises for the next Summer School?*

5. Evaluation

In this Section we present our evaluation which has been performed in two ways: Using the survey data received from the NEMO 2016 students, conclusions following a *quantitative evaluation* can be drawn. Additionally, a *qualitative evaluation* is performed by means of a SWOT analysis.

5.1. Survey Results

One week after NEMO 2016, we invited the participants via E-Mail to take part in a survey on the Smart City exercises. The survey comprised 8 questions out of which 5 were closed and 3 were open. Closed questions were asked to be answered using a Likert [30] scale from 5 (full agree) to 0 (don't agree at all) (see Table 1). Out of 67 participants, we received 34 complete surveys as a response (50,75%).

Table 2 summarizes the survey results. It shows the questions asked as well as the average value and the statistical variance based on the closed questions. In total, the evaluation results are very positive, the average value is throughout above 4. The lowest value has the question whether students felt that the Smart City contributed "to understanding the foundations and applications of conceptual modeling". Albeit being still a very positive feedback, this is not surprising. Smart Cities is an emerging area and it is currently not covered in conventional university curricula. Hence, most students had their first contact with Smart Cities. Even more, applying conceptual modeling in Smart Cities is still an open research area. Besides this, students strongly recommend the Smart City exercises (average value: 4.5588). The highest value throughout our survey was on the question whether the tool-supported practical hands-on experience was favourable compared to solely theoretical lectures (value: 4.7941). This statement is underpinned by the lowest variance in our survey (value: 0.2223).

Analyzing the correlations between the different questions, it can be stated, that there is a strong correlation (0.9956) between indicating that the Smart City domain was not only a good motivator but also contributed to understanding the foundations and applications of conceptual modeling. Moreover, a correlation of 0.7083 between the Smart City as a good motivator and recommending the exercises could be measured. We see this correlation also underpinned by our experience of teaching conceptual modeling without the Smart City at regular university courses, and the increasing number of both, students asking for admission to the summer schools and lecturers inquiring to participate in forthcoming editions, respectively.

Additionally to the closed questions, we added three open questions in order to receive some general feedback on the Smart City exercises. Analyzing the gained feedback, three aspects can be identified that have been mentioned multiple times:

Tooling. We received excellent feedback concerning the tool support for the exercises. Students heavily appreciated the hands-on experience and strongly recommended saving more time for practical experience in future editions.

Time. A lot of students mentioned that they would have liked to have more exercise time. Most students state, that they would have wanted to have more time to successfully solve all scenarios by themselves.

Scenarios. There is no clear favorite scenario for the students. Some liked the emergency scenario best, whereas others liked the marathon planning scenario best - mostly due to its simulation aspects. Several scenario suggestions have been made, e.g., smart houses, smart campus, or safety and infrastructure accessibility.

To sum up, the evaluation shows, that Smart Cities are a very good application domain for theoretical and practical

TABLE 2. EVALUATION RESULTS

Question	Average	Variance
Q1: Application Domain	4.7059	.3253
Q2: Motivation	4.5882	.4775
Q3: Understanding	4.3824	.4715
Q4: Tool Support	4.7941	.2223
Q5: Recommendation Exercises	4.5588	.4230

aspects that are not yet directly related to this domain. The Smart City acts as a facilitator, improving interest and motivation on both sides, students and teachers. In the end, a better learning experience is achieved, motivating students to further investigate upcoming and emerging domains.

5.2. SWOT Analysis

In addition to the quantitative evaluation presented in the previous section, a qualitative discussion of the strengths, weaknesses, opportunities, and threats (SWOT) of using conceptual modeling for addressing Smart Cities challenges is presented.

The *strengths* of the approach clearly lie in the possibilities of using the Smart Cities domain as a motivator for teaching solid theoretical foundations. Moreover, the availability of open modeling tools within the OMiLAB, in particular the ADOxx platform, enable immediate application of the theoretical knowledge and hands-on experience. The survey showed, that the students emphasized on the positive aspect of having the possibility to practically apply their knowledge. One student from Italy stated *"I liked to see some basic principles of conceptual modeling in action. It is also very interesting to understand how to actually use models, by means of analysis and simulations"*. Moreover, the socio-technical nature of the Smart City requires different abstraction mechanisms, hence, contributing to the need to educate information science and computer science students in abstraction [31].

The open survey questions revealed two major *weaknesses*: Students need more time to understand: a) the complexity of the Smart City, b) the foundations of domain-specific conceptual modeling, and c) how to combine these two worlds in order to solve complex and wicked problems. Moreover, students want to solve any presented challenge themselves. Providing material for further studies left few students with the feeling they did not manage to solve any exercise in due time.

The scenarios presented in this paper are by no means comprehensive when it comes to the challenges of Smart Cities and the possibilities of applying conceptual modeling. Hence, we see a lot of *opportunities* for addressing further Smart City challenges with mature techniques from the conceptual modeling domain. We are also planning to incorporate the teaching case into the new OMiLAB homepage, e.g., in an area dedicated for educational purposes. The teaching case is expected to be used then by several hundred students during presence and interactive online courses in the future. Future research will also concentrate on applying model serialization techniques (e.g., as proposed in [14]) to bridge the design-time and run-time challenges by making running systems aware of model designs.

One *threat* to the validity of the approach is that the evaluation was not anonymous. Hence, students might not be as honest or critical as they would be in an anonymous setting. However, as the survey has been performed after the students received their certificate and had been back home, there was no dependency to the organizers. We also received serious criticism, albeit mostly considering the time management.

6. Conclusion

The paper at hand introduced domain-specific conceptual modeling as a means of addressing innovation challenges of Smart Cities. Using multiple scenarios of teaching domain-specific conceptual modeling at the 2016 Next-generation Enterprise Modeling Summer School, the paper illustrated the possibilities of applying conceptual modeling techniques in order to tackle innovation challenges in Smart Cities. The scenarios focus on the planning, management. and operation of Smart Cities.

Evaluation results show, that the Smart City scenarios considerably promote the usage of domain-specific modeling techniques. Conceptual modeling plays a vital role in managing the complexity of Smart Cities in the future. However, a lot of research is left to be done to define mature and intuitive modeling languages for the emerging and changing requirements of Smart Cities.

The survey results show, that it is very important for students to also practically apply their theoretical knowledge whenever possible. Hence, lecturers should always try to provide tool support. The Smart City as a learning and application domain has proven to be very suitable as both a motivator and fascinating playground with challenging tasks. Students claimed to have more time practicing and experimenting during the exercises, we consider this as a positive feedback and think about how to consider this in the next edition of the NEMO Summer School series which will take place in Summer 2017 at Vienna.

Future research will focus on balancing the creation of challenging and motivating Smart City modeling scenarios albeit taking care of the available time. As this is a central requirement for planning courses, we are confident that this is not a serious deficit. Moreover, we are planning to identify new scenarios addressing not yet covered challenges faced when transforming a city towards a Smart City, e.g. smart buildings, smart infrastructure, and smart services.

The paper showed how emerging domains with changing requirements can be addressed by conceptual modeling approaches. Through the domain-specific specification of such approaches and the utilization of the created conceptual models as knowledge basis for further model processing, a contribution towards bridging the research gap can be achieved.

Acknowledgments

This research is partially funded through the Erasmus+ Strategic Partnership Project OMI (grant number: 2014-1-AT01-KA203-000942).

References

[1] D. Karagiannis, H. C. Mayr, and J. Mylopoulos, Eds., *Domain-Specific Conceptual Modeling, Concepts, Methods and Tools*. Springer, 2016.

[2] M. Naphade, G. Banavar, C. Harrison, J. Paraszczak, and R. Morris, "Smarter Cities and Their Innovation Challenges," *Computer*, vol. 44, no. 6, pp. 32–39, 2011.

[3] H. Chourabi, T. Nam, S. Walker, J. R. Gil-García, S. Mellouli, K. Nahon, T. A. Pardo, and H. J. Scholl, "Understanding Smart Cities: An Integrative Framework," in *45th Hawaii International International Conference on Systems Science (HICSS-45), Proceedings, Maui, HI, USA*. IEEE Computer Society, 2012, pp. 2289–2297.

[4] S. Alawadhi, A. Aldama-Nalda, H. Chourabi, J. R. Gil-Garcia, S. Leung, S. Mellouli, T. Nam, T. A. Pardo, H. J. Scholl, and S. Walker, "Building understanding of smart city initiatives," in *International Conference on Electronic Government Electronic Government: 11th IFIP WG 8.5 International Conference, EGOV 2012, Kristiansand, Norway, Proceedings*, H. J. Scholl, Ed. Springer Berlin Heidelberg, 2012, pp. 40–53.

[5] D. Topetta, "The Smart City Vision: How Innovation and ICT can build smart, "liveable", sustainable cities," 2010. [Online]. Available: http://www.inta-aivn.org/images/cc/Urbanism/background%20documents/Toppeta_Report_005_2010.pdf

[6] F. J. Riggins and S. F. Wamba, "Research Directions on the Adoption, Usage, and Impact of the Internet of Things through the Use of Big Data Analytics," in *48th Hawaii International Conference on System Sciences, HICSS 2015, Proceedings, Kauai, HI, USA*, T. X. Bui and R. H. S. Jr., Eds. IEEE Computer Society, 2015, pp. 1531–1540.

[7] H. W. Rittel and M. M. Webber, "Dilemmas in a General Theory of Planning," *Policy Sciences*, vol. 4, no. 2, pp. 155–169, 1973.

[8] R. Buchanan, "Wicked Problems in Design Thinking," *Design Issues*, vol. 8, no. 2, pp. 5–21, 1992.

[9] I. Hawryszkiewycz, S. Pradhan, and R. Agarwal, "Design Thinking as a Framework for Fostering Creativity in Management and Information Systems Teaching Programs," in *The 19th Pacific Asia Conference on Information Systems (PACIS 2015), Singapore*, 2015, pp. 5–9.

[10] M. Kehoe, M. Cosgrove, S. Gennaro, C. Harrison, W. Harthoorn, J. Hogan, J. Meegan, P. Nesbitt, and C. Peters, "Smarter Cities Series: A Foundation for Understanding IBM Smarter Cities," *Redguides for Business Leaders, IBM*, 2011.

[11] M. Batty, K. W. Axhausen, F. Giannotti, A. Pozdnoukhov, A. Bazzani, M. Wachowicz, G. Ouzounis, and Y. Portugali, "Smart cities of the future," *The European Physical Journal Special Topics*, vol. 214, no. 1, pp. 481–518, 2012.

[12] B. Guo, C. Chen, D. Zhang, Z. Yu, and A. Chin, "Mobile crowd sensing and computing: when participatory sensing meets participatory social media," *IEEE Communications Magazine*, vol. 54, no. 2, pp. 131–137, 2016.

[13] M. Bartolozzi, P. Bellini, P. Nesi, G. Pantaleo, and L. Santi, "A smart decision support system for smart city," in *2015 IEEE International Conference on Smart City/SocialCom/SustainCom (SmartCity)*. IEEE, 2015, pp. 117–122.

[14] R. A. Buchmann and D. Karagiannis, "Enterprise modelling for the internet of things: The comvantage method," in *Information Science and Applications (ICISA) 2016*, J. K. Kim and N. Joukov, Eds. Singapore: Springer Singapore, 2016, pp. 1283–1293.

[15] A. R. Hevner, S. T. March, J. Park, and S. Ram, "Design Science in Information Systems Research," *MIS quarterly*, vol. 28, no. 1, pp. 75–105, 2004.

[16] S. Gregor and A. R. Hevner, "Positioning and Presenting Design Science Research for Maximum Impact," *MIS quarterly*, vol. 37, no. 2, pp. 337–355, 2013.

[17] J. Mylopoulos, "Conceptual modelling and telos," *Conceptual modeling, databases, and CASE*, pp. 363–376, 2008.

[18] D. Bork and H.-G. Fill, "Formal Aspects of Enterprise Modeling Methods: A Comparison Framework," in *2014 47th Hawaii International Conference on System Sciences*. IEEE, 2014, pp. 3400–3409.

[19] D. Bork, "Using Conceptual Modeling for Designing Multi-View Modeling Tools," in *21st Americas Conference on Information Systems, AMCIS 2015, Puerto Rico*, 2015.

[20] D. Karagiannis and H. Kühn, "Metamodelling Platforms," in *E-Commerce and Web Technologies, Third International Conference, EC-Web 2002, Aix-en-Provence, France, Proceedings*, ser. Lecture Notes in Computer Science, K. Bauknecht, A. M. Tjoa, and G. Quirchmayr, Eds., vol. 2455. Springer, 2002, p. 182.

[21] U. Frank, "Domain-Specific Modeling Languages: Requirements Analysis and Design Guidelines," in *Domain Engineering*. Springer, 2013, pp. 133–157.

[22] D. Götzinger, E. Miron, and F. Staffel, "OMiLAB: An Open Collaborative Environment for Modeling Method Engineering," in *Domain-Specific Conceptual Modeling, Concepts, Methods and Tools*, 2016, pp. 55–76.

[23] D. Karagiannis, "Agile modeling method engineering," in *Proceedings of the 19th Panhellenic Conference on Informatics, PCI 2015, Athens, Greece, October 1-3, 2015*, N. N. Karanikolas, D. Akoumianakis, M. Nikolaidou, D. D. Vergados, M. Xenos, G. M. Giaglis, S. Gritzalis, L. F. Merakos, P. Tsanakas, and C. Sgouropoulou, Eds. ACM, 2015, pp. 5–10.

[24] R. A. Buchmann and D. Karagiannis, "Agile Modelling Method Engineering: Lessons Learned in the ComVantage Research Project," in *The Practice of Enterprise Modeling - 8th IFIP WG 8.1. Working Conference, PoEM 2015, Valencia, Spain, 2015, Proceedings*, J. Ralyté, S. España, and O. Pastor, Eds., 2015, pp. 356–373.

[25] D. Bork, H. Fill, D. Karagiannis, E. Miron, N. Tantouris, and M. Walch, "Conceptual Modelling for Smart Cities: A Teaching Case," *IxD&A*, vol. 27, pp. 10–27, 2015.

[26] M. Kalz, J. Klerkx, G. A. Parra Chico, J. Elsner, M. Haberstroh, S. Ternier, D. Schilberg, S. Jeschke, E. Duval, and M. Specht, "EMuRgency: Addressing cardiac arrest with socio-technical innovation in a smart learning region," *Interaction Design and Architecture (s)*, vol. 2013, no. 17, pp. 77–91, 2013.

[27] S. Djahel, N. Smith, S. Wang, and J. Murphy, "Reducing Emergency Services Response Time in Smart Cities: An Advanced Adaptive and Fuzzy Approach," in *Smart Cities Conference (ISC2), 2015 IEEE First International*. IEEE, 2015, pp. 1–8.

[28] M. Ringh, D. Fredman, P. Nordberg, T. Stark, and J. Hollenberg, "Mobile phone technology identifies and recruits trained citizens to perform CPR on out-of-hospital cardiac arrest victims prior to ambulance arrival," *Resuscitation*, vol. 82, no. 12, pp. 1514–1518, 2011.

[29] X. Cheng, X. Zhao, Z. Xu, J. Zhou, and N. Yang, "Prediction of the shortest travel time based on intersection delay," in *Smart Cities Conference (ISC2), 2015 IEEE First International*. IEEE, 2015, pp. 1–7.

[30] R. Likert, "A Technique for the Measurement of Attitudes," *Archives of Psychology*, 1932.

[31] J. Kramer, "Is abstraction the key to computing?" *Communications of the ACM*, vol. 50, no. 4, pp. 36–42, 2007.