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Conceptual Modelling for Smart Cities: A Teaching Case

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Abstract. The continuous urbanization forces city planners to be more creative and supported by approaches that enable an abstract perspective on the complex reality. Metropolitan cities have concrete plans to transform districts or the whole city towards a ‘Smart City’. Emerging technologies and the need to process data of millions of sensors raise challenges for city planners. This paper reports on experiences gained from a Smart City conceptual modelling teaching case we presented at the Next-Generation Enterprise Modelling Summer School. The case is subdivided into three scenarios, each focusing on different ways conceptual modelling can contribute in designing a Smart City or leveraging additional services for its citizens. The scenarios complement a theoretical perspective on conceptual modelling foundations by a practical perspective on their tool-based realization. The aim of the paper is to report on opportunities and challenges of teaching conceptual modelling in a Smart City.

Keywords: smart cities, conceptual modelling, meta modelling, teaching case, NEMO Summer School.

1 Introduction

In the 1800’s around 2% of the world population lived in cities. Nowadays this number has risen to 50% and is expected to become 70% in the near future [1]. The increasing demand for living space, infrastructure, citizen security, and public services are major challenges in city planning, especially when cities must reduce waste and be resource-efficient at the same time. Thereby, the transition towards user-driven digital ecosystems in the form of Smart Cities becomes apparent on three levels: a) innovation economy, b) city infrastructure and utilities, and c) governance [2]. Cyber-Physical Systems (CPS) and technologies related to the Internet of Things (IoT) [3], with its ubiquitous sensors, mobile devices, and permanent online interaction stimulate Smart City developments. However, at the same time they also increase the complexity in planning, design, and operation of such cities. New sensors need to be integrated in the infrastructure, the generated data needs to be processed, and smart devices of the citizens need to be considered an integral part of the Smart City infrastructure.

Currently, Smart City planning concentrates on resource efficiency, e.g., considering energy, waste, or ‘time’ as a scarce resource. The resource ‘time’ is one central concern, as it represents a competitive factor of cities, e.g., related to the question how efficient is the public transportation system and the infrastructure in general. What is still an open issue is how to use the possibilities enabled by emerging technologies in the context of a Smart City.

The paper at hand presents conceptual modelling as a possible approach towards managing complexity by applying abstraction in the context of Smart City planning, with a focus on socio-technical aspects. Thus a teaching case has been developed applying conceptual modelling in Smart City planning. It is composed of three scenarios, developed in the context of the ‘Next-Generation Enterprise Modelling in the Age of Internet of Things 2015’ summer school¹. The scenarios focus on:

- 1) Designing concepts and properties of Smart Cities
- 2) Emergency management in Smart Cities
- 3) Waste management in Smart Cities

Each scenario describes concrete challenges faced in cities on a daily basis. In addition to the conceptual specification of the scenarios and the solutions developed by the students, the paper presents our experience in presenting the case at the 2015 edition of the NEMO summer school. The NEMO summer school series establishes a testbed for the Open Models Initiative Laboratory (OMiLAB) [4]. Accordingly to [5], the OMiLAB can be considered as an open collaborative virtual environment for conceptual modelling methods and modelling tools². The teaching case is expected to be used by more than 1.000 students during presence and interactive online phases.

The contribution of this paper fits to the Smart City framework proposed by [6] in the fields of *technology*, *governance*, *people and communities* and *natural environment*. Considering the research challenges stressed by [7], this paper proposes a case study and prototype evaluation of ideas towards the societal impact of IoT, more precisely on “*how governmental agencies may use the IoT to serve citizens in the smart city of tomorrow*” [7, p. 1538].

1.1 Teaching Objectives and Pedagogical Means

After working through the teaching case a student should be able to understand and apply conceptual modelling to design or extend a modelling method for a specific domain. More precisely students are able to conceptualize solutions using abstraction, creativity and co-creation techniques. They are able to transform the designed solution into a prototypical implementation on meta modelling platforms. They have the skills to define and implement a conceptual modelling language and to create

¹ NEMO Summer School 2015: www.omilab.org/web/guest/camp2015, [Online], accessed: 28.10.2015

² See the OMiLAB image video for an introduction to OMiLAB at www.omilab.org/video, [Online], accessed: 19.02.2016

domain-specific models thereof. Moreover, they are able to query and simulate the generated models.

Using the constructivist approach [8] coupled with the classical engineering approach, the aim of the Smart City conceptual modelling teaching scenarios is to enable students to think on an abstract level while fostering creativity. This was necessary in order to a) comprehend the presented Smart City scenarios, and b) to identify further scenarios in a green field setting. Therefore, open questions were asked in order to keep the discussions among student groups as well as between students and lecturers alive.

Constructivist learning enables *“individuals to create their own new understandings, based upon the interaction of what they already know and believe, and the phenomena or ideas with which they come into contact”* [9]. The engineering approach contributes design and application perspectives to the task at hand. Hence, students were asked to define domain-specific requirements, formalize them by means of a conceptual modelling method, and finally apply the method in the concrete Smart City scenario. Using exercises as a supplement to the theoretical lectures of the Summer School enabled a hands-on experience of the practical aspects of conceptual modelling. Following the guidelines by [10], the NEMO students first got a introduction to the upcoming exercise session, comprising an introduction to the exercise scenario, a list of concrete challenges faced, and a set of objectives and competences the students shall acquire. Afterwards, small groups of students worked in parallel sessions on solutions for the various challenges.

1.2 Conceptual Modelling for Design Requirements

The following teaching case will primarily focus on the aspects of the city infrastructure and utilities. This will be a key element in realizing services such as smart parking, smart mobility provision, real-time monitoring, or citizen safety/security management. In particular, the increasing usage of IoT technologies in smart vehicles, smart infrastructure and smart phones allows the development of new business models and services. Based on the tremendous amount of data generated every second by sensors in a smart infrastructure, innovative applications for environmental and energy monitoring, services for the prediction of mobility requirements, smart meters for measuring resource consumption, or medical surveillance and assistance for elderly people can be realized [11].

“A smart city scenario is based in the centrality of the person considered in all her/his complexity, interconnected with others and with the context of his/her daily life through the mediation of technology” [12]. Hence, a Smart City can be defined by means of *“connecting the physical infrastructure, the IT infrastructure the social infrastructure, and the business infrastructure to leverage the collective intelligence of the city”* [13]. Similarly, the definition by [14] states, that a Smart City combines *“ICT and Web 2.0 technology with organizational, design and planning efforts to dematerialize and speed up bureaucratic processes and help to identify new, innovative solutions to city management complexity, in order to improve sustainability and livability”*. There are several other definitions of smart cities. The

question to be answered is what are the invariants in such an environment? For leverage all the benefits mentioned above, we assume infrastructure as an invariant.

The complex setting of a Smart City infrastructure raises the need for city planners to identify novel design requirements for the development of new business models and services. Conceptual modelling is one candidate for breaking down this complexity by providing a more adequate abstraction level in order to answer selected Smart City requirements. The aim of conceptual modelling is to apply abstraction mechanisms in order to enable human beings to understand the complex reality [15]. These abstraction mechanisms can be classified into two categories:

▪ **Technological Abstraction**

A technological abstraction provides the ability to describe e.g., software architectures by abstracting from the concrete technological realization thereof. For example, entity relationship (ER) diagrams that enable a technology-independent specification of a relational database schema. An ER diagram fosters intersubjective understanding of a certain data level of an application independent from its implementation.

▪ **Domain Abstraction**

A domain abstraction provides the ability to abstract specifics of an application domain by utilizing a more generic vocabulary. One example is the Unified Modelling Language (UML). The UML enables domain-independent specification of software systems using a common and generic set of diagrams (e.g., Use Case diagrams for requirements specification) and concepts (e.g., Class, Activity).

The challenge in Smart City planning is combining these two abstraction mechanisms in order to handle the complexity and leverage the benefits, without forgetting to consider vital aspects such as citizen behavior and citizen involvement. Hence, technological abstraction, e.g., the infrastructure and the sensors, and domain abstraction, e.g., how to capture the specifics of Smart Cities in a generic way, need to comprehend a perspective on the citizens. The teaching case at hand raises some questions aligned to the preceding statements and also provides initial ideas based on conceptual modelling and meta modelling techniques.

This paper proposes Smart Cities as a novel learning space for foundations of information science education. Typically, conceptual modelling is taught using data modelling or enterprise modelling targeting at information systems specification. However, we propose to use it for capturing the specifics of Smart Cities towards design requirements for Smart City planners.

2 A Three Pillar Approach

Before discussing the application of conceptual modelling in Smart Cities, an introduction to i) the foundations of conceptual modelling, ii) the OMiLAB as an experimental collaborative environment for conceptual modelling, and iii) the NEMO summer school series, as an organizational framework for educating Master and PhD

students are introduced. These three pillars comprise a holistic approach towards conceptual modelling in research and education.

2.1 A Content View: Conceptual Modelling

Modelling plays an important role in managing the complexity of Smart City development or reorganization [8]. Models not only facilitate coping with the increasing complexity of Cyber-Physical Systems and IoT-enabled technologies by providing structuring, analysis and further processing qualities for human beings (i.e., conceptual modelling [15]). Moreover, they can be used for the development and management of software systems or CPS. Modelling methods guide the creation of valid models. A modelling method, referring to the definition by Karagiannis and Kühn [16] is composed of three building blocks (see Fig. 1):

- A *modelling language* defines the elements of the modelling method and the rules for combining them (syntax). A comprehensive specification of a modelling language is built up of three parts: *notation*, *syntax*, and *semantics*. For every element of the modelling language's syntax, semantics defining the meaning, and notation defining the visual representation need to be specified.
- The *modelling procedure* then uses the modelling language and defines the steps a modeler performs while applying the modelling language in order to create valid models. The combination of modelling language and modelling procedure is referred to as the *modelling technique* of a modelling method.
- *Mechanisms & algorithms* provide the functionality used by the modelling procedure to process the models, e.g., simulation algorithms, model transformation algorithms, model queries, model validation etc.

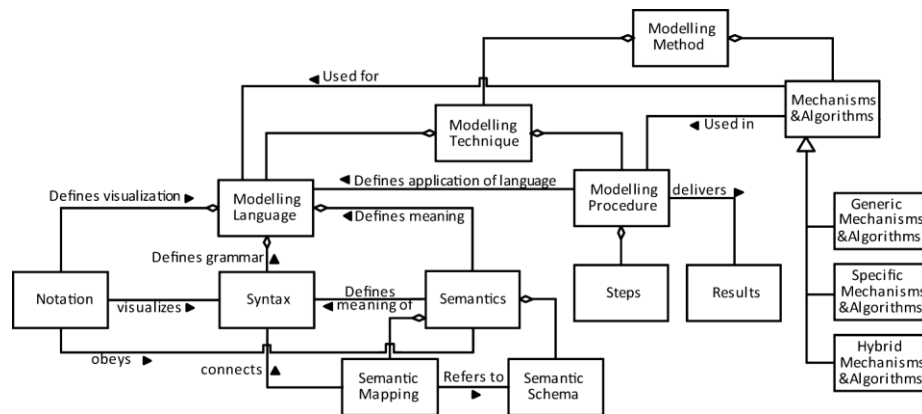


Fig. 1. Components of modelling methods [16]

A comprehensive specification of a modelling method needs to provide information regarding all aspects introduced above. Depending on the origin of the modelling method and its purpose, different degrees of formalization regarding the

modelling method specification can be distinguished (see [17] for a comparison of enterprise modelling methods). Based on the definitions of modelling methods, we now briefly describe our understanding of meta models and meta modelling.

In contrast to modelling, centering the application of a modelling method, i.e., the creation of models as instances according to a given meta model, meta modelling is concerned with the specification of modelling methods using a hierarchy of meta levels. This specification covers all three parts, i.e., modelling language, modelling procedure, and mechanisms & algorithms. In this context, a meta model defines the abstract syntax of a modelling language [18]. Accordingly, meta meta models then define the language that is used to describe this abstract syntax.

2.2 An Experimental View: OMiLAB

The OMiLAB establishes a presence and virtual collaborative learning environment for formal learning. Located at the University of Vienna, the OMiLAB provides an environment for the development and utilization of domain-specific conceptual modelling methods and corresponding modelling tools. The laboratory is meant to establish a meeting point for international modelling methods enthusiasts interested in developing their own modelling methods using an open meta modelling platform³.

The foundation of the OMiLAB is an open infrastructure that everyone in academia can use in order to contribute with his/her modelling method and modelling tool. The development of these OMiLAB tools, is based on the open use meta modelling platform ADOxx⁴. ADOxx is an industry-proven meta modelling platform developed by the BOC AG that is also frequently used in research projects, e.g., the Next-Tell project (<http://next-tell.eu>) or the Learn PAd project (www.learnpad.eu), both related to collaborative learning and e-learning.

With ADOxx, the technology barrier of developing modelling tools is broken down to very little programming experience and the abstraction competence of the user. Specifically designed platform functionality and an application programming interface that is aligned to modelling method development foster efficiently realization of modelling methods with ADOxx (cf. [19]).

2.3 An Organizational View: The NEMO Summer School Series

The NEMO Summer School series was initiated 2014 by the University of Vienna and is currently partially funded through the Erasmus+ Strategic Partnership Project OMI (grant number: 2014-1-AT01-KA203-000942). Its aim is to provide an educational forum for international Master and PhD students interested in applications of conceptual modelling. Each year more than 50 participants participated in lectures about foundations, applications and technologies of conceptual modelling. NEMO

³ Open Models Initiative Laboratory, www.omilab.org, [Online] accessed: 16.11.2015

⁴ ADOxx meta modelling platform, www.adoxx.org, [Online] accessed: 09.11.2015

2015 focused on “Next-Generation Enterprise Modelling in the Age of Internet of Things”. The theoretical lectures were comprised by exercises, enabling the students to transform their theoretical knowledge towards practical application. Table 1 summarizes the NEMO 2015 lecturers by grouping them based on their institutions country. In total, 43 lecturers from 20 countries, distributed over five continents participated.

Table 1. NEMO 2015 lecturers grouped by their institutions country

Australia	1		Japan	3
Austria	12		Latvia	1
Belgium	1		Norway	1
Brazil	1		Poland	1
Canada	1		Romania	1
Finland	1		South Korea	1
France	1		Spain	1
Germany	6		Sweden	2
Greece	4		Switzerland	2
Italy	1		United Kingdom	1

Table 2 summarizes the NEMO 2015 students by grouping them based on their university’s country. In total, 51 students from 15 countries, distributed over three continents participated at the Summer School.

Table 2. NEMO 2015 students grouped by their university’s country

Austria	13		Poland	1
Belgium	2		Romania	4
France	1		Serbia	1
Germany	8		South Korea	3
Greece	2		Switzerland	5
India	1		Turkey	1
Italy	5		United Kingdom	1
Japan	3			

The Smart City as an emerging field in research and development comes not only with new possibilities for its citizens. It also 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. Therefore, we consider Smart Cities as a perfect fit to our Next-Generation Enterprise Modelling Summer School (www.nemo.omilab.org).

3 Smart City as a Learning Space

The following sections describe the Smart City conceptual modelling teaching case syllabus of the NEMO 2015 Summer School. Based on an experimental approach, we identified three different scenarios that are capable of illustrating opportunities and strengths of applying conceptual modelling in a Smart City.

3.1 Learning Scenarios

The structure of the scenarios refers to the modelling method components as introduced in Sec 2.1. Hence, the first scenario was meant to cover the modelling language part. The goal was to put student's focus on answering the question "How to model concepts in a Smart City". The second scenario then provided the students a well-defined Smart City modelling language, enabling the utilization of model querying functionality. It was focusing on the question "How to analyze Smart City models using query techniques". Finally, a further model processing functionality was introduced – model simulation. The third scenario consequently aimed at answering the question "How to process Smart City models using simulation". A brief overview of the case's structure is given in Table 3. The following Sections discuss conception, goals, and methods of each scenario in more detail.

Table 3. Structure of the NEMO teaching case scenarios

I: Model Design	How to model concepts of a Smart City? Basic meta modelling concepts required to realize a modelling language for a Smart City are presented. Tools of the OMiLAB will be introduced, e.g., the GraphRep Generator will be utilized to create graphical visualizations for the Smart City concepts.
II: Model Queries	How to analyze Smart City models using query techniques? Basic model analysis techniques will be discussed, enabling the modeler to use the information captured in the models in order to e.g., answer non-trivial questions, or support decision makers.
III: Model Simulation	How to process Smart City models using simulation? Introduction to simulation algorithms and how such algorithms can be applied to process the information captured in conceptual models. Hands-on experience will be achieved by adopting and executing several simulation algorithms on sample Smart City models.

3.2 Scenario I: Model Design

In this scenario, students were meant to apply the abstraction mechanisms as introduced in Section 1.2. More precisely, they needed to elaborate on new Smart City infrastructural concepts that need to be reflected in an extension of a given fictitious graphical modelling language, the Smart City modelling language (SmartML). SmartML is aimed at supporting urban city planners in their Smart City planning activities, e.g., planning streets, smart traffic signs, smart street and traffic lights, smart infrastructure, LAN's, ad-hoc networks etc.

At the beginning of the first exercise, students got a brief introduction on the foundations of modelling methods, meta modelling and conceptual modelling. Consequently, the task was to extend an initially provided modelling language with abstract concepts that play an important role in a Smart City. Fig. 2 illustrates the very simplified initial Smart City modelling language, constituting of streets, crossings, Stop signs, traffic lights, buildings, and cars, by means of a sample model.

The Summer School students discussed in groups and came up with several new concepts that need to be realized in a Smart City (e.g., smart meter, smart parking spots). Following the constructivist approach, each group of students was asked to extend SmartML with a formal representation of their new concepts. Therefore, the relevant functionality of the ADOxx platform was showcased by lecturers. Consequently, modelling classes and relation classes have been customized with ADOxx by the students themselves. During these tasks, students have been given as much freedom as possible. They could decide on the concepts to realize, the attributes these concepts should have, the visual representation of these concepts, and the way of connecting the new concepts with the existing concepts of SmartML.



Fig. 2. A simplified Smart City modelling language and a sample model

In a final task, students were asked to utilize their extended modelling language in order to create valid models of ‘Vienna Seestadt’, a new district in the suburbs of Vienna that is currently under development⁵.

3.3 Scenario II: Model Queries

The second scenario was focusing on how to further use the knowledge, captured in the SmartML models by means of model queries. Consequently, the NEMO students have been introduced to model query foundations and their ADOxx realization. The theoretical part captured *standard model queries*, *pre-defined ADOxx model queries*, and finally *complex queries*. The latter can be realized with the specifically designed ADOxx Query Language (AQL) whereas the former two query types can be configured in an user-friendly dialog-driven manner in ADOxx.

After the foundations have been presented, students were again asked to utilize their gained knowledge in the Smart City environment. The lecturers provided a set of concrete questions students should provide answers to. Hence, students were required to transform the theoretic model query foundations towards their application with provided SmartML models. The students tried to find the best query strategy. Finally, they realized their strategy with ADOxx and reflected on the query results. Comparing the results with the expected (visual) answer, students immediately got the feedback whether or not their query strategy was correct. In case of differences, students would reflect on a) the strategy of the query, and b) the development of the query with ADOxx (cf. [20]). The students were asked to answer the following questions:

1. Which smart parking spots can be booked at ‘Währingerstrasse’?
2. What is the location of a doctor in proximity to a car accident (see Fig. 3)?
3. What is the healthiest running track in a certain Smart City area (cf. [21])?
4. Which smart traffic signs need to be adjusted by a Smart City planner in case of an accident at a certain street?

Fig. 3 illustrates the query strategy to answer question 2. It shows a car accident that occurred at the crossing ‘Währingerstrasse’ and ‘Sensengasse’. An emergency officer may use the conceptual model, enriched with real time sensor data of the Smart City and apply model query functionality to find citizens that are geographically close to the accident. Assuming doctors would act as volunteers and provide their location data, the emergency officer may identify doctors in proximity and notify them within seconds. This would decrease the time passing by without expert medical support of injured people and help to bridge the time from emergency call until the arrival of the ambulance. First empirical studies evaluate that such systems might have a significant impact (cf. [22]).

⁵ Vienna Seestadt, www.aspern-seestadt.at/en, [Online] accessed: 30.10.2015

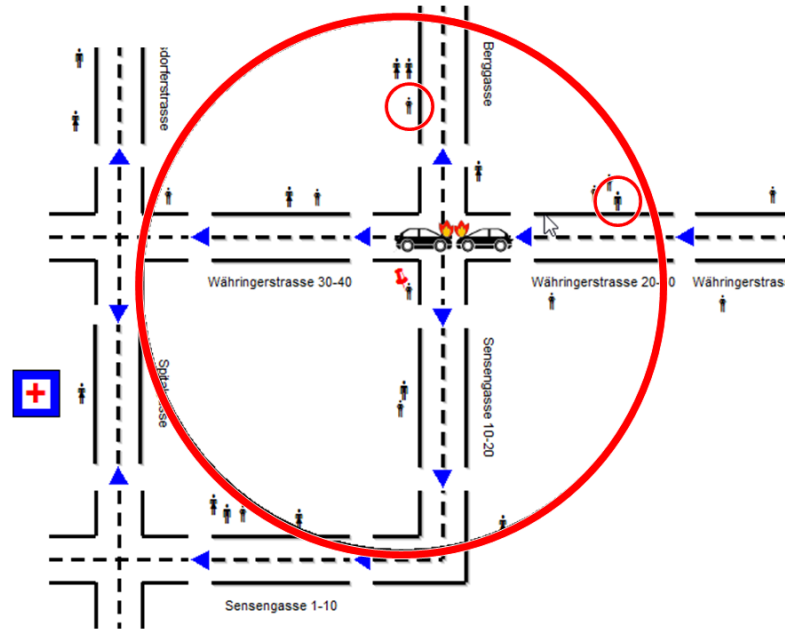


Fig. 3. Using conceptual models and model queries to find a doctor in proximity to a car accident

In SmartML, students were enabled to use the red circle to define the relevant area centering an emergency. The query will only consider elements inside this area. The query strategy was quite easy. Within the area delimited by the red circle, search for all pedestrians. Then filter for any pedestrian that has the profession 'Doctor'. Using the coordinates of the model, the query results can be ordered in increasing distance to the accident. In a Smart City, the identified doctors (surrounded by a small red circle in Fig. 3) could be notified by push messages on their mobile devices.

A quite similar approach has been recently discussed by [23]. The authors propose a Volunteer Notification System (VNS). Whenever an emergency situation, e.g., a cardiac arrest, is reported to the VNS, the system matches the location of the emergency with the GPS-based location information it gets from the infrastructure. Consequently, the VNS contacts closely located citizens in order to navigate them to an emergency, thereby providing first-aid support until the emergency medical services arrive.

Fig. 4 illustrates the query strategy for question 4. It visualizes two different routes an ambulance could follow while transporting an injured person into the hospital located at 'Spitalgasse'. Using the SmartML model and model query functionality, the city planner can delimit all possible routes. Consequently, using real-time data on traffic jams and the number of cars on certain streets, the perfect route can be identified and the traffic lights be adjusted accordingly. This would enable a more efficient transportation of injured people to the hospital.

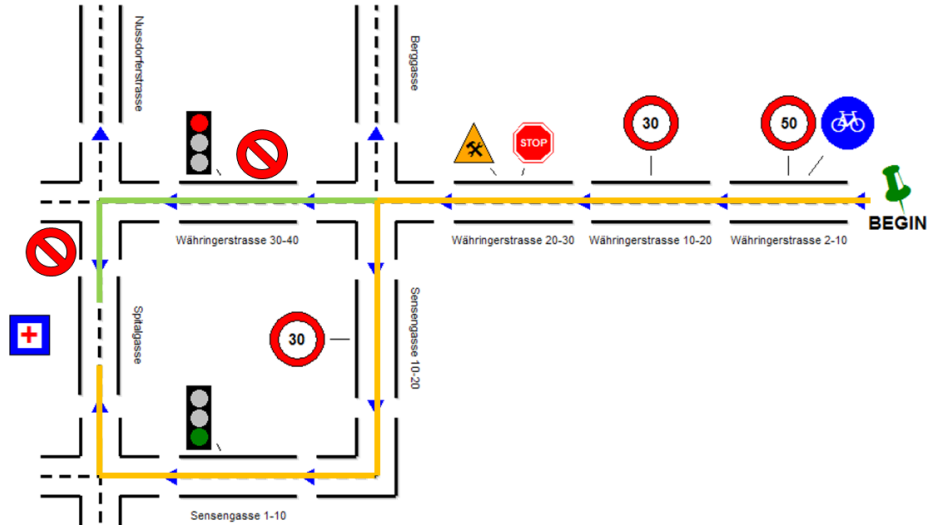


Fig. 4. Identify optional routes through smart signs and smart street lights in case of an accident in a Smart City

One query strategy identified by NEMO students can be characterized as follows: 1) Find all possible routes from the 'Begin' to the street where a hospital is located; 2) Select the shortest route according to the attributes of the different streets on the route (e.g., throughput in number of cars per hour, number of lanes); 3) Get all traffic lights and traffic signs located on the best route; 4) Set every necessary traffic light to a green signal for the ambulance and change traffic signs where necessary (e.g., one way signs may change the direction temporarily).

Albeit these are very simplified examples, students were enabled to immediately grasp an idea on the possibilities of using a domain-specific modelling language – in this case SmartML – for planning a Smart City. Moreover, students were enabled to be creative in finding further model query applications in Smart Cities. Consequently, they discussed possibilities to extend SmartML to incorporate such applications.

As a side-effect, students became aware of the possibilities of having the Smart City information codified in a formalized manner through the SmartML model. This enables not only an intersubjective understanding of the models but also machine processing by means of the model queries or the model simulation (as discussed in the following).

3.4 Scenario III: Model Simulation

The third scenario was focusing on a different way of realizing an additional value of the SmartML models – model simulation. The ADOxx platform comes with a pre-defined set of simulation algorithms. Utilizing this functionality, one has to map the

concepts of his or her domain to the simulation-specific concepts of the platform. This is again a good example of domain abstraction and technology abstraction.

In the beginning of the third exercise, students have been presented the foundations of model simulation as a concrete realization of graph simulation. Moreover, the lecturers explained how the built-in simulation functionality of ADOxx can be customized for arbitrary modelling methods. Following this theoretical introduction, the students were asked to think about simulation applications in a Smart City. Once again, the students were urged to be creative in a field not familiar to them.

Next, students were asked how they think the concepts of the Smart City domain, e.g., *Crossings*, *Streets*, *Pedestrians*, can be mapped to the simulation-specific concepts provided by ADOxx, e.g., *Activities* as a means of resource-consumption in times/costs, *Decisions* as a means of splitting the graph into several possible sub-graphs based on transition conditions and/or statistical distributions of variables. After the theoretical part, the students were again presented the task to transform their theoretical knowledge towards practical application using the Smart City scenario and SmartML models. Therefore, the students were given concrete questions these models could answer using simulation functionality.

Fig. 5 illustrates such a SmartML model. In this case, the task was as follows: In a Smart City, smart trash cans are used to store the trash of the citizens. Smart trash cans “can reduce the cost of waste collection and improve the quality of recycling” [24, 25]. The smart resource planner is in charge of deciding where to place smart trash cans. The students were asked to identify the best possible distribution of smart trash cans in the first example. Later on, students were given a model in which trash cans had already been placed (as visible in Fig. 5). Now, the task was to identify which trash cans were full (colored in red) and which ones still had some capacity unused (colored in green in Fig. 5) using simulation functionality.

The logic behind the trash can example can be easily transformed in order to answer other interesting questions e.g., what is the amount of construction workers depending on the streets and the number of cars driving on them, or how frequently is a certain street at the capacity borders and at white time of the day occur traffic jams. Moreover, similar model simulations might answer questions related to the distribution of e-car charging stations in a Smart City [26, 27].

4 SWOT Analysis and Discussion

The need for a teaching case applying conceptual modelling in an easily understandable and extendable case with tool use emerged from experience, where complex and multi-layered problems could not be efficiently designed and analyzed in small project teams. The scenario of a Smart City was selected as it is easily intelligible, while at the same time it provides a multitude of further development and application possibilities connected to i.e., technological, socio-economic and demographic developments. To highlight its maturity, potential and possible threats a SWOT analysis has been carried out. The analysis is comprehended with insights gained through a questionnaire that has been sent to the Summer School students and lecturers.

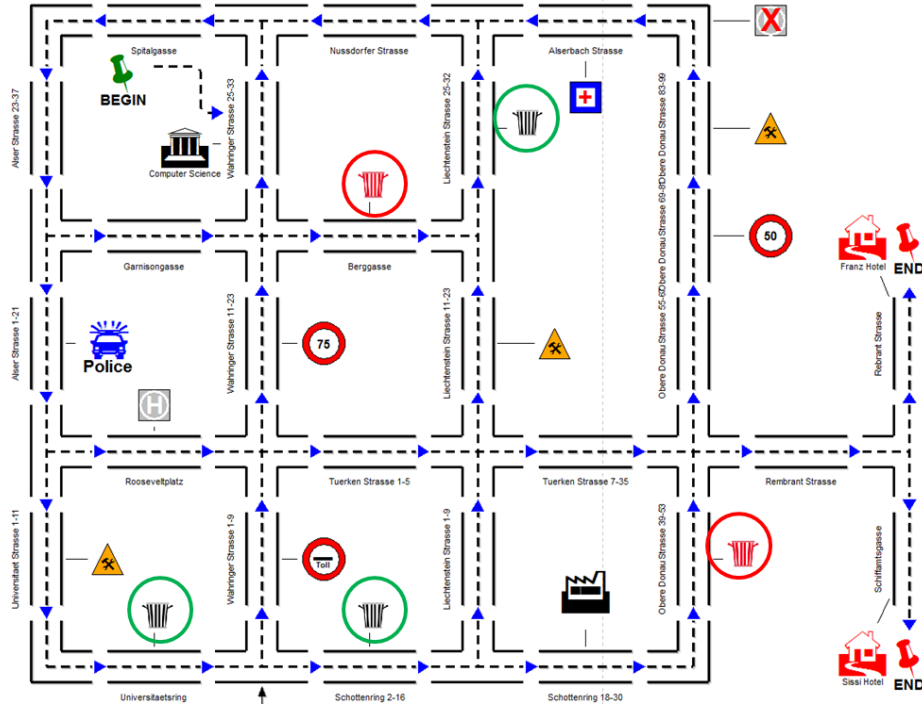


Fig. 5. A smart trash can model with SmartML in ADOxx

The case's strengths lie in the possibility to transform sound theoretical foundations in an openly available platform. The fact that tools, resources and access to knowledge are freely available on OMiLAB enables students and teachers to use, adapt, develop and apply the case in accordance to their needs. One student from Lausanne, France, mentioned the tools *"certainly give an added value toward enriching such practical experiences"*. The generality of the Smart City domain makes the case easily applicable in a large array of domains. The socio-technical nature of the Smart City requires students to apply different abstraction mechanisms, hence, contributing to the need to educate information science and computer science in abstraction [28]. One student stated the Smart City *"can be considered an innovative theme that also invites discussions after the actual exercise sessions"*.

The case has been tested only during the NEMO summer school; hence its weakness is that it has yet to be tested in a large number of courses and different domains. Experience and feedback from communities need to be collected in order to evaluate the case. Yet the case holds the opportunity to attract and connect different domain-specific communities and classes in application cases directed towards the Smart City and subsequently to win these communities over for the use of conceptual modelling and tooling.

The potential inflexibility of users from other domains in accepting conceptual modelling poses a threat as well as knowledge barriers in implementing the scenarios designed. Thus, appropriate support must be offered to students and users in

understanding and adopting the practice of conceptual modelling and tooling. This fact is also reflected in one feedback of a student who stresses, that the exercises can be more efficient if all participants have installed the required tools in advanced and gained a first overview of the software used. Another student from Camerino, Italy, mentioned the idea to build groups and give every group a certain project in the beginning of the Summer School. During the two weeks of the Summer School, students shall be supervised and supported in their project. At the end of the Summer School, all groups shall present and discuss their solutions.

Teaching conceptual modelling without an interesting application domain like Smart Cities at Masters level revealed a lack of interest for some students. Reflecting on the Summer School experience, we learned that using the Smart City as an application domain resulted in a noticeable increase in both interest and learning outcomes. One of the authors who was also in charge of teaching meta modelling at university courses stated *“It was really interesting to see, how theoretical content, surrounded by an interesting application domain like a Smart City fosters motivation and understanding significantly. Albeit previous concerns, I am now convinced to use such domains on a regular basis in my university courses”*. Central criticism received from the NEMO 2015 students focused on the balancing between theory and practice. Multiple times we got the feedback, that more focus should be on practical applications in general and the Smart City exercises in particular.

5 Conclusion

The paper at hand discussed the opportunities and challenges of using Smart Cities as a novel learning space for conceptual modelling education. It presented a case study we developed and used to educate a group of Master and PhD students in conceptual modelling at the 2015 Next-Generation Enterprise Modelling Summer School. In this regard, three Smart City scenarios were described, each of which utilizing different aspects of conceptual modeling: i) model design, ii) model querying, and iii) model simulation. The scenarios are very realistic, cf., the ambulance drone example developed at TU Delft⁶. A number of additional scenarios can be imagined, e.g., using the video surveillance at streets and crossings to automatically detect injured people or accidents as prototyped in the city of London⁷.

We plan to continue the idea of using the Smart City and the Internet of Things as the common and integrative backbone for the next editions of the NEMO summer school series⁸. A concrete scenario we consider to realize for the next year's Summer School is targeting at semantic queries in Smart Cities. Such queries can once more increase the value of the conceptual models e.g., in combination with mobile apps [29, 30] by providing answers to even semantically complex questions. Lastly, we

⁶ TU Delft Ambulance drone video, www.youtube.com/watch?v=y-rEI4bezWc, [Online] accessed: 16.11.15

⁷ Transport for London smart pedestrian press release 07.03.2015, <https://tfl.gov.uk/info-for/media/press-releases/2014/march>, [Online] accessed: 16.11.2015

⁸ NEMO Summer School 2016, <http://nemo.omilab.org/2016/>, [Online] accessed: 11.11.15

consider to expand the exercises to incorporate e.g., field trips [31] or educational games [32] as additional learning techniques in the Smart City environment.

One NEMO 2015 participant from Karlsruhe, Germany, suggested to further increase motivation for the exercises by establishing a contest between different student groups. Comparing and discussing the results among each other in a competitive setting might further improve student commitment and foster reflection.

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