Visualizing and Simulating Inner City Construction Work to Support Multi-Stakeholder Meetings

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Abstract

To align the majority of the stakeholders during urban planning activities, planning experts organize multi-stakeholder meetings. A main problem during these meetings is that participants do not always have the necessary knowledge to decide or evaluate planning alternatives. Visualization and Simulation (V&S) tools can help to generate this knowledge that is necessary to make informed decisions during meetings. Experts can communicate their knowledge to laypersons easily and, in this way, improve the stakeholder's knowledge. However, V&S tools only help stakeholders to evaluate several planning alternatives if the simulation and visualization outcomes are meaningful for stakeholders. Theory lacks a process that describes how V&S system designers can find indicators that developers of simulation programs can use to make the mathematical simulation results understandable for laypersons. This paper presents a process model that allows V&S system designers to identify stakeholder-relevant indicators for V&S tools to support urban construction projects. We validated the process model on a case study in which we developed a V&S tool to support traffic planning activities during the reconstruction of the city centre of Enschede. We used a V&S tool for indicators that we identified using the process model in two meetings where it helped to generate and streamline meaningful discussions among stakeholders. In particular, it enabled stakeholders to learn about relative differences of planning alternatives. This helped to generate and communicate new knowledge by supporting the evaluation of different planning alternatives.

Keywords: process model, visualization, simulation, stakeholder meetings, indicators

1. Introduction

Decision makers of urban planning projects need to involve stakeholders in collaborative consensus making activities (Graaf, 2005: 59, Healey 2006: 30). During such activities, stakeholders meet to discuss and align opinions about planning alternatives. A main problem with these meetings, however, is that not every participating stakeholder has the necessary knowledge to create or judge plans. Communicating knowledge through sophisticated expert reports takes a lot of time, is inefficient and delays the decision making process. Decision makers can use visualization and simulation (V&S) tools to improve the creation and communication of knowledge, which leads to more effective decision making. V&S tools can model geospatial data in the planning environment and simulate design alternatives. Although they are powerful tools to improve knowledge communication and to generate discussions (Smeds & Alvesalo, 2003), “they only contribute to strengthening management processes when they are adapted to the specific needs of a project (James, 2002)”. In the past, V&S tools did not work effectively due to insufficient integration in meetings. Participants did not accept the program as a knowledge generator in their design process. To get user acceptance, V&S tools need to represent simulation outcomes using relevant indicators that show how well planning alternatives score according to stakeholder objectives. V&S system designers should consider the amount and quality of indicators very well. Too much indicators will overload the stakeholder and too little or irrelevant indicators won’t contribute the necessary knowledge to the decision making process. This paper describes a process model to identify and quantify stakeholder-relevant indicators that adapt V&S tools better to its users.

We tested the process model in a case study to support traffic planning in the city of Enschede. This case study represents a complex urban planning problem because four massive construction projects will influence the traffic in the next four years. We developed a V&S tool using the process model and validated the tool in two multi-stakeholder meetings. The outcomes of the meetings provide first evidence that the process model can effectively help to find stakeholder-relevant indicators for V&S tools. The tool created discussions which helped stakeholder to get insights in the relative differences of different planning alternatives. It also enabled stakeholders to have meaningful discussions in which they developed new insights. In particular, we show that many discussions originated from the indicators in V&S tools, but also from shortcomings in the underlying model of the simulation program. Overall, this research provides first evidence that V&S tools stimulate knowledge creation and communication, and have potential to generate meaningful discussions.

The paper is structured as follows: It first describes the potential to support knowledge sharing and creation in urban planning with V&S tools theoretically and summarizes the challenges to make V&S tools work in practice. The paper then introduces the process model that we used to develop indicators for a V&S tools. The paper continues with explaining and summarizing the validation of the process model on the planning case. It concludes with discussing the key findings and implications of this study.

2. Theory on V&S tools in urban planning

In collaborative consensus making activities agreement is only possible if stakeholders generate and communicate relevant knowledge. They often do this during multi-stakeholder meetings. Discussions in such meetings oftentimes lead to design questions. To answer the questions, decision makers must generate knowledge and communicate this to relevant stakeholders. This gives stakeholders a better understanding of the design alternative and enables them to judge the alternatives better. It leads to higher quality discussions and is more likely lead to a broadly accepted design; a collaborative consensus. Effective tools to support knowledge generation and communication are V&S tools. V&S tools can help stakeholders to share, create, edit and evaluate new design alternatives (Repetti, Soutter, & Musy, 2005) and to trigger meaningful new ideas and discussions (Smeds and Alvesalo, 2003).

To support urban planning activities effectively, V&S tools should at least offer the following basic functionality:

- Simulation algorithms. Algorithms are the underlying expert knowledge of the V&S tool. They calculate for example traffic flows or noise pollution.

- Logical indicators transfer simulation algorithm results into understandable and relevant criteria, such as, CO2 pollution levels or traffic density.

- Geospatial data. These are data of the planning environment, such as, street capacity and dimensions of buildings. It is important that users can easily change this data to model alternatives and predicted changes over time that serve as basis for the simulation of future anticipated situations.

Although research shows great potential for V&S tools, they are seldom used in urban planning practice (Nunamaker et al., 1991 and Repetti, Soutter, & Musy, 2005). To stimulate their use, V&S tools need to provide the following features (Repetti, Soutter and Musy, 2005):

1. Adapted interface. Everyone should be able to understand and use the tool.

2. Relevant set of data and indicators. Too much data leads to information overload and reduces the legibility of the system. Too little or irrelevant data leads to poor decision-making. Thus, geospatial data and indicators must be well balanced, accounting for specific stakeholder needs.

3. Data management functionality. Data are not static; they change over time. V&S tools must have functionality to update data regularly.

4. Institutionalization in meetings. Meeting participants must accept the tool and the power it has to create knowledge and support discussions. Therefore, the tools should fit stakeholder needs.

In the past, visualization system designers succeeded to create V&S tools with interfaces that stakeholders understand. The tools also have functionalities to update data regularly. However, most V&S tools still do not contain stakeholder relevant indicators. Hence, they are not yet suitable to support meetings. To enable V&S system designers to identify stakeholder-relevant indicators we developed a process model. The process consists of seven different steps, each visualized in figure 1.

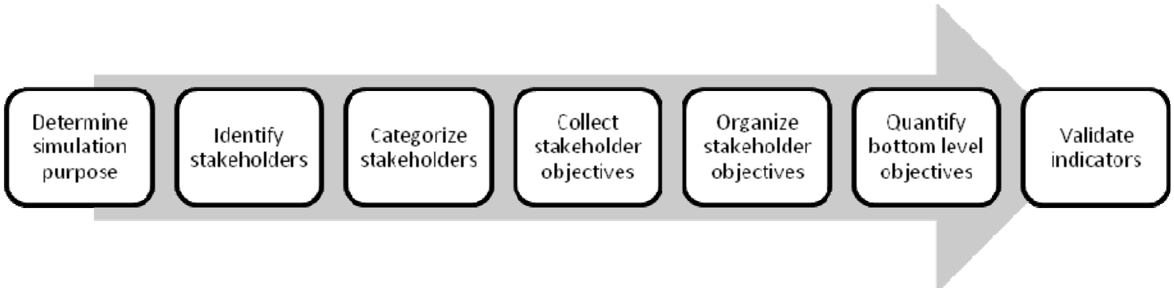

Figure 1: The seven steps of the process to find stakeholder-relevant indicators for simulation tools

2.1 Step 1: Determine primary purpose of simulation tool

In the first step, V&S system designers need to determine the primary purpose of the simulation tool (Evers, 2008). They need to meet up with all relevant stakeholders to align their expectations and set up requirements. To define the primary purpose, they answer the following questions:

- Which geographical area do we want to simulate?
- What time frame do we want to simulate?
- Which building projects or development plans do we take into account?
- What expert knowledge do we need?

2.2 Step 2: Stakeholder identification

In the next step, V&S system designers need to identify the relevant stakeholders. There are several ways to do this, such as, for example:

1. **Brainstorming**. This semi-structured group activity generates ideas about possible stakeholders (Cross, 2008: 48-51).

2. **Observing information meetings**. Another possibility to find stakeholders is by observing attendants of information meetings. Traditionally, decision makers arrange these meetings to inform stakeholders about their plans.

3. **Snowball sampling** (Verschuren & Doorewaard, 2007:186-189). Already identified stakeholders can help V&S system designers to identify and contact other stakeholders.

2.3 Step 3: Stakeholder categorization

On most projects, it is not easily possible to simulate all stakeholder objectives. There are too much stakeholders and their objectives oftentimes vary widely. Therefore V&S designers have to shorten the lists of stakeholders and model only the objectives of the most important ones.

Mitchell et al. (1997) proposes a method to identify the most important stakeholders. The method categorizes stakeholder objectives according to the attributes power, legitimacy, and urgency. Power describes the ability of the stakeholder to influence the project outcome. Legitimacy describes whether the V&S system designers perceive them as appropriate with reference to the simulation outcomes. Objectives are urgent if they call for immediate attention. Stakeholders can have multiple attributes (for example: he can have power and his objectives are legitimate, or his objectives are legitimate and urgent). The important stakeholders cover two or more attributes and must be taken into account for further research.

2.4 Step 4: Collect stakeholder objectives

In the fourth step V&S system designers can collect data from these most important stakeholders. They can use different means to do this, such as, for example:

1. **Brainstorming.** (Cross, 2008: 48-51) Visualization system designers use this method to get a general idea of the possible stakeholder objectives. However, this method doesn't give certainty about the relevance of the identified objectives.

2. **Observing** (Verschuren Doorewaard, 2007:134-137; Hommes, 2009; and Edelenbos 2008). V&S designers can also retrieve stakeholder objectives if they observe meetings or workshops.

3. **Dialogue** (Breteler, 2009). A dialogue with the stakeholder is another way to get stakeholder information. Dialogues can be either formal or informal.

4. **Ethnographic interview** (Spradley, 1979). The fourth way to find stakeholder objectives is to conduct ethnographic interviews. Here, the interviewer puts aside his own cultural boundaries and tries to retrieve information from the viewpoint of the respondent.

2.5 Step 5: Organize stakeholder objectives

Once visualization system designers collected the stakeholder objectives, they can explore concepts that have a relation with the stakeholder objectives. One way to do this is using the objectives tree method (Cross, 2008: 78-91). Objectives trees are diagrams that decompose and organize stakeholder objectives hierarchically. This results in an overview of stakeholder objectives at different levels of management. The most abstract stakeholder objectives stand on top; and the operational objectives at the bottom of the objectives tree.

2.6 Step 6: Quantify bottom level objectives

From the objectives tree, the bottom line objectives have a more operational character. They are the most measurable. To translate these objectives into indicators, V&S system designers should derive measurement methods for each. They can do this by looking for variables in which each objective can be expressed. For example, an objective such a maximize traffic flow can be expressed in the variable speed or traffic intensity. Finally, by combining the different variables, V&S designers can then derive meaningful indicators that aggregate the simulation outcomes to higher level objectives in the tree and that are helpful to support the stakeholder during their decision making tasks.

2.7 Step 7: Validate indicators

In this last step V&S system designers should validate the indicators. They should contact the relevant stakeholders and ask them whether the developed indicators cover all stakeholder objectives. This step is very important, since it ensures that indicators have been adapted to stakeholder wishes. According to the outcomes of the validation step, V&S system designers then need to readjust the indicators to ensure that they fit the stakeholder objectives. To further improve the indicators, V&S developers can iterate through the process model a number of times.

3. Research method

To test the process model, we conducted a case study applying the above described process during traffic planning activities for the mid-sized city Enschede. This city plans to execute four big construction projects in the city center between 2010 and 2015: (1) the renovation of a hospital (Medisch Spectrum Twente) including the construction of a new square in front, (2) the construction of a new hotel/apartment tower (Dish-Hotel) next to the hospital, (3) the construction of a new entrance to an underground parking garage (Van Heekgarage), and (4) the realization of an underground pedestrian tunnel that links the existing parking garage to the new hospital. These projects will occur almost simultaneously. This means that the city must plan the traffic situation during construction time very well to reduce nuisance for a large number of stakeholders. Therefore, this case represented a great opportunity to test whether our process model enables us to identify V&S

tool indicators that can meaningful support the stakeholders during collaborative consensus making activities.

We used the process model to identify indicators that we implemented in the existing browser based V&S tool DigiMap. DigiMap enabled us to reduce our V&S tool development efforts because it consists of an easily editable user interface and features that allow for regular data updates. Further, DigiMap already provides simple algorithms to calculate traffic flows. However, the tool does not have a relevant set of indicators and is not adapted to stakeholder needs very well. According to the developers of DigiMap this was also the reason why the tool was only used on three projects. We used the process model to identify and quantify stakeholder-relevant indicators and modeled these into DigiMap. We then validated the developed indicators by using the tool to support two multi-stakeholder meetings. In the end, we used the observations of these meetings to validate the process model.

4. Application of the process model

In this section, we describe how we applied the theoretical process model in practice. Following the theoretical process model, we first identified the primary simulation purpose together with two stakeholders that also represented the sponsors of this study: the hospital's project manager (HPM) and the municipality's traffic engineer (MTE). Together, we decided to simulate traffic planning alternatives during the construction period in the area around the hospital.

Subsequently, we started identifying relevant stakeholders with respect to this primary simulation purpose. We identified an initial list of stakeholders with a brainstorming effort with the HPM and the MTW: patients, visitors of the hospital, the hospital's board of directors, visitors of the inner city, hospital employees, the municipality, the hospital's architect and the contractor. We then applied snowball sampling by interviewing several of the stakeholders we identified through this initial brainstorming session. A detailed interview with the MTE allowed us to differentiate between different interest groups within the municipality: the municipality's project manager, the traffic engineer, and the town planner. An interview with the HPM allowed us to differentiate between stakeholder groups of the hospital's organization: the hospital departments logistics, trauma, radiology and security. A further interview with the municipality's traffic engineer allowed us to identify emergency services, the landscape architect, town planner, and the water engineer as additional stakeholders. During an interview with municipality's town planner, he suggested adding the aesthetical committee of Enschede. A conversation with the municipality's project manager finally led to the last stakeholders: a parking expert and the province.

Table 1- Case study overview of stakeholder categorization according to Mitchell et al. (1997)

Stakeholder Category	***Short description***	***Stakeholders in this category***
0. Non	*Stakeholder has none of three attributes*	*Hospital architect, landscape architect, water engineer, aesthetical committee Enschede*
1. Dormant	*Stakeholder has power but its objective is not legitimate and urgent*	*Province*
2. Discretionary	*Stakeholder has a legitimate need*	*Hospital's Board of directors, Hospital's department Radiology*
3. Demanding	*Stakeholder has an urgent need.*	-
4. Dominant	*Stakeholder has a legitimate need and has power to influence decision making*	*Police and Fire dept.*
5. Dangerous	*Stakeholder is powerful and has an urgent but non-legitimate need*	-
6. Dependent	*Stakeholder with urgent and legitimate need does not have power to influence decision making.*	*Local residents, entrepreneurs, contractor and construction workers, visitors and patients of the hospital, visitors of inner city, hospital employees*
7. Definitive	*Stakeholder comprises all three attributes*	*Hospital's project manager, hospital departments trauma, security and logistics* *Municipality's project manager, traffic engineer, town planner, and parking expert*

To identify the most important stakeholders from this list we categorized the stakeholders using the method of Mitchell et al. (1997). The result is depicted in table 1. The most important stakeholders for our research comprised at least two out of the attributes power, urgency and legitimacy. We also visualized the categorization in figure 2, where important stakeholders are marked in grey.

In a next step we identified the objectives of the stakeholder in classes 4, 6, and 7 that are summarized in table 1. We, for example, identified the objectives of the HPM with a number of informal dialogues. These dialogues enabled us to understand that the HPM's responsibility was to coordinate the renovation activities for the new hospital, while ensuring that other processes within and around the construction site could continue with minimal nuisance. His detailed objective with respect to the inner city traffic planning activities was to maintain quick access to all entrances of the hospital during construction activities.

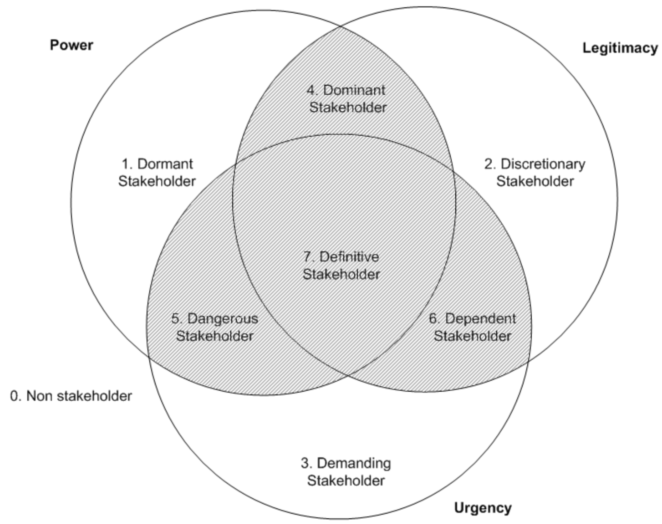

Figure 2: Visualization of stakeholder categorization method Mitchell et al. (1997)

Another example of how we identified objectives is an ethnographic interview that we conducted with the MTE. We visited the MTE at his workplace and simply asked him to tell us about his role during the planned construction activities. During this interview the MTE described that his task on this project is to find adequate answers to three questions: “How do patients or visitors enter the hospital or city centre? Where do they park?, and How can they travel from their parking to the hospital?” Further, objectives that the MTE mentioned during the interview were to “ensure access to the city centre – mainly parking garages and hospital - for different travel modes” and “ensure living quality for city centre residents”. We subsequently used the objectives tree method (Cross, 2008:78-91) to understand the hierarchical relationships between the different stakeholder objectives. First, we decomposed every single stakeholder objective apart. Subsequently we put all objectives together by expressing mutual relations between higher and lower level objectives. Figure 3 exemplarily shows how we combine the objectives of the MTE and HPM that we described above in one branch of the objectives tree.

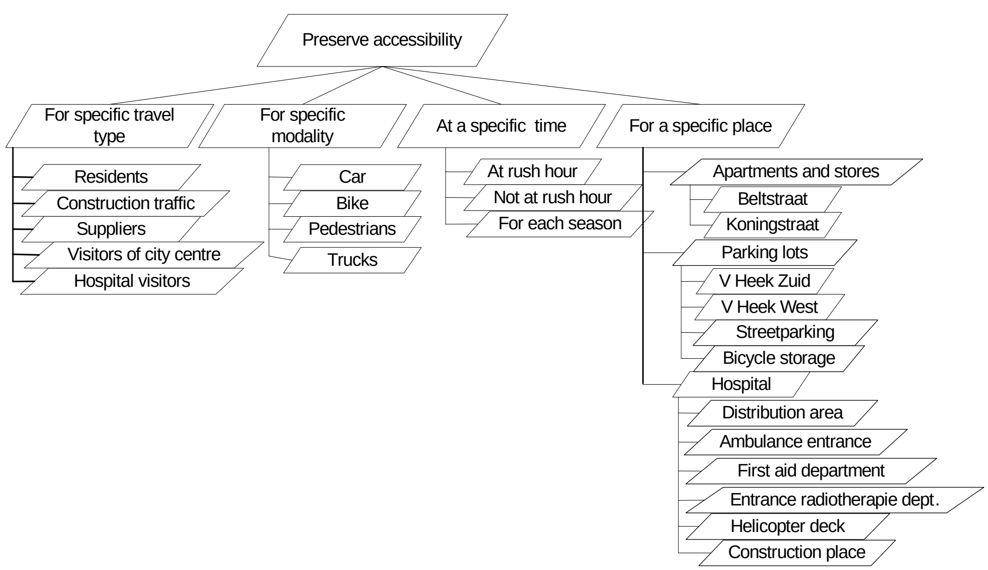

Figure 3-Hierarchical decomposed objectives tree of maintain accessibility to city centre

In the end, this led to a comprehensive objectives tree with many of these branches that contained all stakeholder objectives. Overall, the objective tree method allowed us to identify five overall high level objectives that presented a good aggregation of all the lower level stakeholder objectives we identified in the previous phase: preserve accessibility to city centre, reduce nuisance, stimulate new construction project dynamics, minimize construction time, and preserve spatial quality.

In the sixth step, we established variables which express a way to measure characteristics of the bottom level objectives to quantify the objectives to allow for simulation. Again, we will exemplarily describe this quantification effort using the branch that aggregates the objectives of the MTE's and HPM's: preserve accessibility to city centre. We asked the MTE to think of ways to measure his objectives. He suggested the traffic intensity/capacity ratio or saturation of roads to measure accessibility for cars and trucks. He told us that each specific travel type, like residents and visitors of the city centre, perceive the same traffic situation very differently, therefore he suggested to express this travel effort in travel time. In that way everybody can compare the travel time for a design alternative with his own reference of quick or slow traffic. He suggested measuring this during and outside rush hour. To measure accessibility at a specific place, the MTE also advised us to measure the traffic flow in terms of travel speed, length of traffic jam, and number of road blocks. Further, we looked at professional traffic literature and found measures that allowed us to simulate extra travel distance due to road blocks, and parking occupancy. We also asked an independent traffic expert to verify these variables. In a final step, we adjusted DigiMap's simulation algorithm to calculate indicators for the variables we identified in this way: saturation of street network, average travel time, number of road obstructions, average travel speed, occupancy of parking garages and extra travel distance due to construction work road blocks.

Table 2- Time line with design alternatives evaluated during multi-stakeholder meetings

	2010	*2011*	*2012*	*2013*	*2014*	*201 5*
Demolish part of hospital						
New hospital						
Dish-hotel						
New Entrance Heekgarage						
Pedestrian tunnel						
New square						

Alternative1 Alternative2 Alternative3 Alternative4

We tested the indicators during two real live multi-stakeholder meetings. We prepared four urban planning alternatives in advance. Tables 2 and 3 describe these alternatives. We derived these alternatives from a master schedule that comprised all urban planning construction activities in the next five years. We chose different cross sections in this time line to create four totally different alternatives. The differences of each alternative are summarized in table 3.

Table 3- Characteristics of planning the simulated urban planning alternatives

	Current situation	***Alternative 1***	***Alternative 2***	***Alternative 3***	***Alternative 4***
Parking lots hospital	*235*	*0*	*0*	*0*	*0*
Additional cars on road network	*0*	*100*	*290*	*375*	*275*
Increased parking demand in underground parking garage	*0*	*280*	*525*	*610*	*485*
Road blocks	-	*Beltstraat, Koningstr.*	*Beltstraat, Koningstraa t*	*Beltstraat Koningstraat Mooienhof*	*Beltstraat Koningstraat Boulevard 1945*

5. Validation of indicators developed with the process model

To test whether the indicators we indentified with the process model helped stakeholder during their traffic planning activities we tested them during two meetings with a number of stakeholders. In the first meeting, we supported a discussion between the MTE and HPM. In the second meeting, we supported a discussion between the MTE, the HPM, two project team members of the hospital, a parking expert representing the municipality, one first aid expert, one trauma staff member, and one logistical and security expert from the hospital. We created a number of urban planning alternatives that represent future situations in the city centre before the meetings as a starting point for discussions. In particular, we established four alternatives by choosing different points in time during which two or more project activities were planned at the same time (Table 2) by changing a number of initial input variables for the simulation (Table 3). The next section summarizes and analyses our observations from these meetings.

Overall the two meetings provided evidence that the V&S tool generated and streamlined meaningful discussions. For example, during the first meeting, the visualizations of the road saturation created a discussion about two critical road sections in the simulation area. The V&S application allowed us to dynamically simulate a road block on one of these critical roads. All meeting participants were able to understand at once that this option decreased indicators like travel time, average speed, and extra travel distance. At the same time, everybody easily understood that the same measure increased the saturation of other roads on the network significantly. This dynamic simulation and visualization of a possible traffic planning alternative enabled the project manager of the hospital and the traffic expert from the municipality to meaningfully discuss the length and number of roads that they should block.

In the same meeting, the indicator “occupation of the parking garages” led to a discussion about the actual distribution of construction workers’ cars among parking spaces in the city centre for a number of different traffic routing alternatives. This triggered the idea to oblige construction workers to carpool or travel in large groups to the city center to reduce the amount of automobiles in the city center. Surprisingly, in both meetings, shortcomings of the V&S tool also created discussions. For example, a discussion related to the car traffic simulations occurred. Meeting participants discussed about the possibility to simulate indicators for traffic flows like construction truck, buses, cyclists, and pedestrians as well. This, in turn, created ideas about the possible routing for buses and construction vehicles during construction time.

In the end, the simulations from the two meetings support several advices for a traffic consulting report from the hospital to the municipality. This report contained for example an advice related to the indicators saturation degree of the roads and extra travel distance. These support the recommendation to set up a network of road signs that reroute the traffic around residential area during construction. Simulations showed that, traffic otherwise would choose its shortest path trough this area, which leads to undesired nuisance for local residents.

6. Conclusion

This paper describes develops a process model to identify and quantify stakeholder-relevant indicators. It also describes our effort to validate the process model using the activities of the city of Enschede to plan its inner city traffic for the next 4 years. We supported traffic planning activities by using a V&S tool that we specifically develop to show indicators we identified with the process model. Overall, the evaluation shows that the process model effectively created stakeholder relevant indicators for simulation tools. This provides first evidence that the model is effective to design V&S tools to support multi-stakeholder meetings in urban planning.

Additionally, the case study provides first evidence that V&S tools can generate meaningful discussions in meetings about topics stakeholders would not have addressed without the help of the V&S tool. Some of these discussions resulted directly from the indicators. To our surprise, discussions also were triggered as meeting participants realized the shortcomings of the simulation model. As stakeholders realized shortcoming in the underlying simulation model they started discussing about possible what-if-scenarios that they would like to see simulated with the V&S tool. While the V&S tool was not able to simulate these what-if scenarios, meeting participants still continued to evaluate these without the simulation tool. This led to meaningful discussions about different panning alternatives.

One major shortcoming of this study is that we validated the process model in only one case study. We simulated and visualized *traffic* flow *during construction time* of an area in the *city centre of Enschede*. Consecutive research efforts must point out if the process model is applicable in other contexts.

Up till now, literature lacked a process that describes how visualization specialists can develop V&S tools with indicators that custom-fit stakeholder needs. The process model in this paper introduces a structured way to find stakeholder-relevant input for V&S tools. In practice, we showed how the process enabled the development of a meaningful V&S tools. As a consequence, stakeholders become more satisfied with the V&S tools during multi-stakeholder meetings. This better institutionalization of the tool generated and supported important discussions during these meetings.

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