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8 SIMULATION-AIDED PLANNING FOR EVENTS

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Abstract
This study investigates how computer simulations of crowds of pedestrians can support the planning of events. It looks into documented experiences collected in past projects and enters into a dialogue with opposing, supportive and critical views, on simulations, and advances a realistic argument on how simulations as a tool fit into the toolbox of event planning. The paper starts with an incident which occurred at a stadium's entrance gates to motivate more fundamental considerations and concludes with details of a project done for the festival "Das Fest" in Karlsruhe.

Introduction

Computers have made their way to many aspects of life and to most professions, and are used for various planning tasks.

Soon after the first models of vehicular dynamics had been introduced (Reuschel, 1950; ; Newell, 1961; ; Wiedemann, 1974; Gipps,1981; Nagel & Schreckenberg, 1992; Chowdhury, Santen, & Schadschneider, 2000; Helbing, 2001), models of pedestrian dynamics were also formulated (e.g. Gipps, 1986; Helbing & Molnar, 1995; Blue & Adler, 1998). The first application of crowd simulations was to enhance safety during emergency egress from buildings. Apart from evacuation and escape crowd simulations have been used to simulate passengers transferring within a station, pedestrians as participants of traffic, and people walking to, from or at an event.

This paper discusses perspectives on the usage of simulations for the planning of events; as such it deals with both exaggerated expectations and also benefits that can be achieved with simulation tools but which are frequently missed, when the usage of simulations is discussed. At this point we note that simulations are elements of the planning process and therefore cannot prevent a bad implementation of best practice planning, for example if less staff was available on the day of the event than planned.

At the Gates

> *"Weeping and screaming children at the hands of their desperate parents, elderly people, who were gasping for air and feared to be crushed – because other spectators, who demanded admittance,*

> *pushed and pressed from behind. This was the shocking scenario in front of the south gate of the arena.*
> *The guests of the club Hertha BSC [Berlin] were there penned up behind barriers and were only dealt with one by one at snake pace by far too few staff. Fans, who stood in front of the stadium at 2 pm, could take their seats only a few minutes before the kick off [planned for 3:30 pm]."*
>
> (Translated from Wolf, 2005)

This excerpt from a newspaper article together with the reactions it spawned in online forums is a documentation of an incident that presumably did not cause any permanent damage nor much attention outside Berlin. However, the incident and the then forthcoming soccer world championship triggered activity to address the problem. Already for the next league match more favorable feedback on the issue is documented on the web indicating that procedures were changed and for that reason ingress to the match went more relaxed.

The incident made it to the newspapers as in Europe soccer, in general, receives much attention, and also the number of people involved was remarkable. However, on events of a smaller scale, similar incidents occur every day, which suggest that the problem is not one of a spectacularly large event, extreme conditions, which cause tragic casualties; rather it may be one of infrastructure and of procedures not meeting the demand, nor being able to cope with injuries, annoyed customers, and bad press.

An incident like the one in Berlin, we suggest, could be triggered by different causes: bad planning or bad execution of the planning; it could also be that the number of fans who attended was unforeseeable. In the Berlin's event, the latter was not the case as the match was sold out.

Without actually making a claim about what caused the incident, we assume in this paper that the day in Berlin went *as planned*, where no major organizational element that was planned for was missing or modified. In this way the incident can be used as concrete example of what would have been accessible with simulations.

Exaggerations

When simulations of pedestrians or traffic systems are discussed in the public, one sometimes gets the impression that a simulation is mistaken for a crystal bowl telling the future. This high expectation might be rooted in the nearly unlimited confidence in and expectation of technology in general and computer technology in particular.

Simulation no more than a tool made to serve particular purposes. For this it only uses aspects of reality as input and is only able to reproduce aspects of reality. As the justification for any tool is to be *useful* and *helpful*, the results from using a simulation of crowds or vehicle traffic needs to be *policy sensitive*, as Bell (1997) described it.

A good example for a non-perfect image of reality that is helpful and which offers a policy sensitive usage is that of a street map of a city. A street map is only a very imperfect image of a city; it does not contain information on the culture, language, smells, climate, kitchen, club life, and the millions of individual daily lives the city houses. Street maps of New York, Florence, Cairo, and Tokyo may look very similar. If the differences between the real cities were actually as small as their map differences, no one would travel around the world for a visit. Satellite photos offer a better idea of possible differences, although they too are still 2D images. Yet a street map (maybe in combination with a compass) is helpful and policy sensitive for the purpose of choosing the right direction when navigating through the city; hence the lasting success of the concept of a map.

In planning a public event cited in the introduction, a helpful purpose of the simulation might have been to learn about the number of fans in the queue in front of the gates, maybe, to learn about the average individual queuing time. This might have sufficiently improved the basis for decisions in the planning to trigger additional measures. With the exaggerated expectations from simulations there are two linked dangers: the first is that meeting the expectations is correctly estimated to be very difficult if not impossible. Doing simulations is then rejected as being unhelpful and simulations are removed from the planner's toolbox. As a consequence the existing realistic benefits of simulations are are ignored. The second danger is a consequence of the opposite extreme position, namely to take the results of a simulation as fulfilling the expectations ignoring the purpose of the project and the abilities of the model. From this it is only a small step to assume that simulations can be used to replace other efforts to ensure safety, even to be able to relinquish local and scene-specific organizational experience. Yet it is this experience that allows, for example, to estimate how a certain social group will react under certain circumstances, something which cannot come as a result of the simulation.

Calibration and Intended Results

To take into account the effect of various external influences a model of pedestrian dynamics has a number of parameters, which can be calibrated to produce quantitatively reliable output. This section deals with latest efforts to collect data that can be used for calibration and with limits to the precision of a pedestrian simulation model.

There are numbers of factors that influence the desired as well as the maximum speed. Some of these are age, sex, environmental temperature, time of day (Weidmann, 1993; Buchmüller & Weidmann, 2006), motivation (closely linked with the walking purpose), and individual fitness. The precise impact of each factor is not easy to measure; whenever one is measuring walking speed at some spot in a city, it inevitably is at a certain temperature and a certain time of day. Each time of day implies a bias in the sample of persons being measured, i.e. in age and walking purpose. Collecting data at some spot and time therefore allows calibrating a simulation model to simulate pedestrians at that spot and time. The calibration may also be a good one for simulations at another spot and time, but not necessarily the best one.

Even more discussed than the free, unrestricted walking speed at very low densities is the relation between walking speed and density and the flow volumes (number of people per time) that fit through a door or corridor of a given width. Over the decades in different realms different relations have become acknowledged that differ a lot one from the other (Schadschneider, et al., 2009). There exist, for example, two acknowledged works of which one assumes standstill at a density which is below the density of maximal flow claimed in the other work. Part of the reason of such discrepancies may be that flow and densities have been measured with different methods (Zhang, Klingsch, Schadschneider, & Seyfried, 2011). Also, the location of measurement can lead to significantly different results; for example, in a simple and specific situation students in Germany and India are found to walk at a different pace in identical density (Chattaraj, Seyfried, & Chakroborty, 2009).

Some experiments were carried out, as part of the ongoing HERMES research project (Holl & Seyfried, 2009, 2010; Klüpfel, et al., 2010), to measure bi-directional flows, flows around corners and merging flows (Klüpfel, et al., 2010). |These experiments were thought as equally important for simulation projects but which have not yet received as much attention as the one-directional flow through a door or the one-directional flow through a corridor. Only parts of the results have been published so far (Zhang, Klingsch, Schadschneider, & Seyfried, 2011).

In this study, a simulation was carried out looking at the number of people queuing normally; it did not consider situations where they might panic, start shoving each other and the resulting consequences. This is because the empirical knowledge of the combined effect of crowd psychology and spatial properties on the dynamics of the crowd is not strong enough to built reliable algorithms. However, if one combines the number of people queuing as calculated by a simulation with the experience of a local crowd manager, one can often get a good idea of what would happen. The lesson of this is that simulations should supplement existing planning and not replace elements of it.

Categorization of Projects

With the thoughts of the last section, is there any hope that simulation projects can yield absolute “correct” results (numbers)? The answer is ‘yes’ depending on what is meant with “correct” and which output parameters need to be “correct”.

- … if there is a possibility to measure in a very similar situation and environment and use that data for calibration. Probably the most important input data is at what time how many people arrive at the boundaries of the simulation (i.e. the “demand“),
- … if “correct“ is not expected to be closer to reality than the inherent variability of reality is. For example for the simulation of the egress from a soccer stadium this means that the simulated duration times need to be allowed to lie within that range of observed real durations. An allowed stricter expectation is that the simulated distribution matches the observed distribution, and
- … if the parameter that needs to be “correct“ is not a manifestly non-statistical one, as for example individual trajectories.

A station that is to be modified offers the possibility to fulfill the first condition: the passengers can be video-taped, relevant parameters (number of persons, density, walking speed, and dwell times) can be evaluated, used for the calibration of an “as is” simulation and with the calibrated parameters a “what if” simulation can be done (see Figure 1). There are many reasons why such a simulation still has uncertainty, these include: the demand forecast has an uncertainty and the population characteristics may change[24]. But apart from that – if the calibration process can be done successfully – the uncertainty added by the pedestrian dynamics model for a good model should be small or at least not larger than the uncertainty from other sources of which two have been mentioned above.

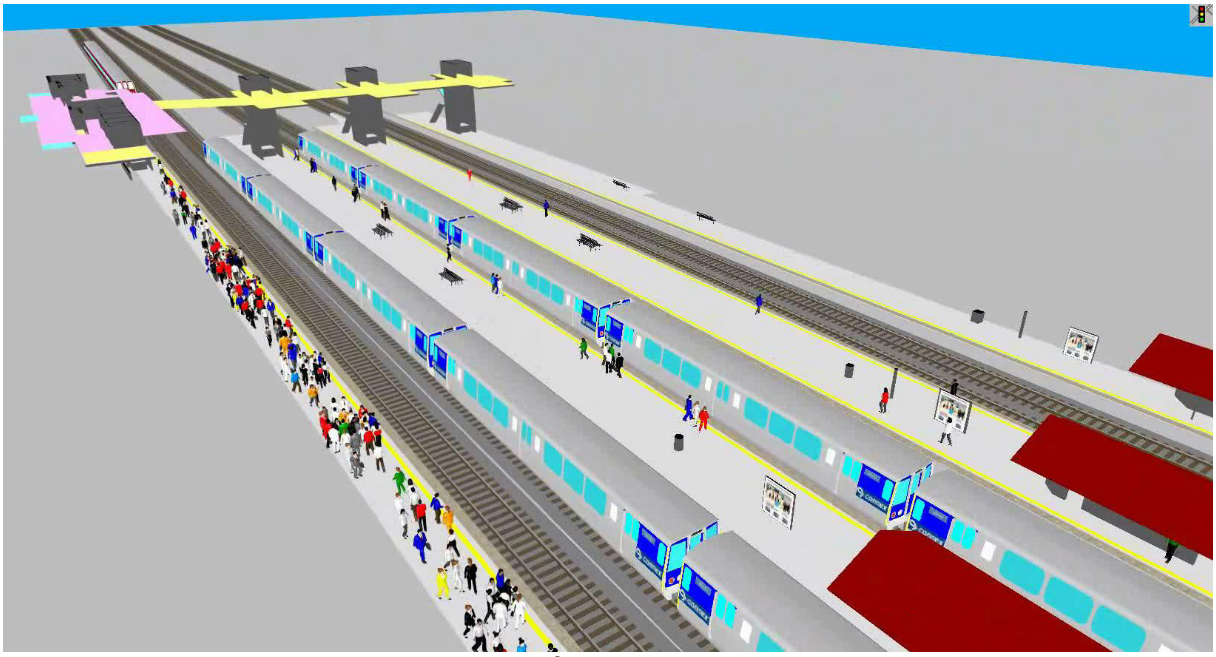

Figure 1: For the simulation of North Melbourne Station considerable effort has been put to collect data for a calibration of the simulation to reproduce the situation as it is today (Laufer, 2008).

Note, however, that in Laufer (2008), the calibration was done relating to speed, density, and walking times; three basic and general parameters. It was not attempted to calibrate for the mood change induced on the passengers by the state on the platform, it was also not calibrated for the average amount of beverages bought by passengers in the station. This is one of the issues with the word "correct". Which parameter has to be correct? A simulation that aims to give an answer to the question of the capacity of the station, the parameters that need to be correct are density, speed, and walking time. In other words, one must make oneself clear about the *purpose* of the model. A purpose, just as geometry and demand (Rahmatabadi, 2010), needs to be part of a simulation model. A clear statement about the purpose also implicitly defines what a simulation model ought not to answer. This is necessary as it limits the degree of precision and details which are necessary as input to the simulation and thus limits the necessary amount of *work* and therefore also *monetary costs*.

The second issue with "correct" is that in real life density, walking speeds and walking times on two different days would not be exactly identical; even if on these two days the same number of people would alight from a train and board it. In real life, measurements always result in distributions; thus "correct" can only be correct with the background of these distributions.

[24] If the „what if" scenario is 20 years to the future, for example effects of the dynamics of the average BMI may take place.

The above example can be categorized in two ways: first it is a “high precision / high effort” project, and second it is a station project. The first categorization is based on a) what is the purpose, and following from that, b) how the project was done. The second categorization is the type of application; for this project it it is typically to test if capacities and transfer times to connecting trains are sufficient.

If no empirical data in comparable situations is available a reliable calibration cannot be carried out. However, this does not necessarily mean that simulation cannot turn out to be a *helpful* tool. Even without confidence in the absolute values of the results, there still can be confidence in the *policy sensitivity* of the simulation project (Bell, 1997).

One way – and this is the next purpose/method-related category – to carry out such a simulation project is a comparative study. For example, different variants of an infrastructure configuration or an egress organization plan or variants in any other degree of freedom of a system can be compared by making multiple simulation runs using different sets of parameters of the dynamics model. Sections 5.1 and 5.2 of Kretz (2007) give an example of a project undertaken with this method for an emergency egress procedure at a sports event. The intention was to find the best planner-proposed variant according to some specific but arbitrary criteria (e.g. best LOS or smallest egress times). Success is only possible, if a vast majority of parameter sets of the dynamics model yield the same variant as the best one. This implies that there is a chance that such a simulation project fails in the sense that it might not yield a result.

Another category of projects, currently unavailable, but which could generate benefit from pedestrian simulations without entailing calibration work to a simulation project, is planning for a ‘building fire’. Here, it is by no means clear, how large the fire will be, which materials will be set on fire and how the combustion smoke will be composed. Obviously there is no way of calibrating the effect of a building fire. To allow fire safety engineers to develop an intuition for the interplay of fire and building, a small set of ‘*design fires’* are defined and integrated into regulations. These provide a common ground on which the statement “in case of the design fire the height of the smoke free volume falls below 2 meter” immediately has a meaning to fire safety engineers. The simulation of pedestrians, for example, the RiMEA initiative (Brunner, et al., 2009) (see figure Figure 3), aims to achieve a comparable state. By defining a set of standard examples which need to be simulated with model parameters such that certain ‘result corridors’ are met, implicitly for different models of pedestrian dynamics parameter sets are defined that have a meaning for anyone familiar with RiMEA's guidelines. The difference to fire safety engineering is that the design fire is defined explicitly, while the parameters of the simulation models are defined implicitly with the definition of the ‘*design scenarios’*. This includes the uncertainty if parameters obtained in this way for different simulation models yield similar results when they are used to simulate other situations. Note that although a realistic definition of the expected result corridors gives rise to the expectation that the obtained parameters lead to realistic simulation results in other situations, it is not necessary that the results come very close to the real particular situation. The benefit of this method of doing a project lies in the common ground provided by the *design scenarios*.

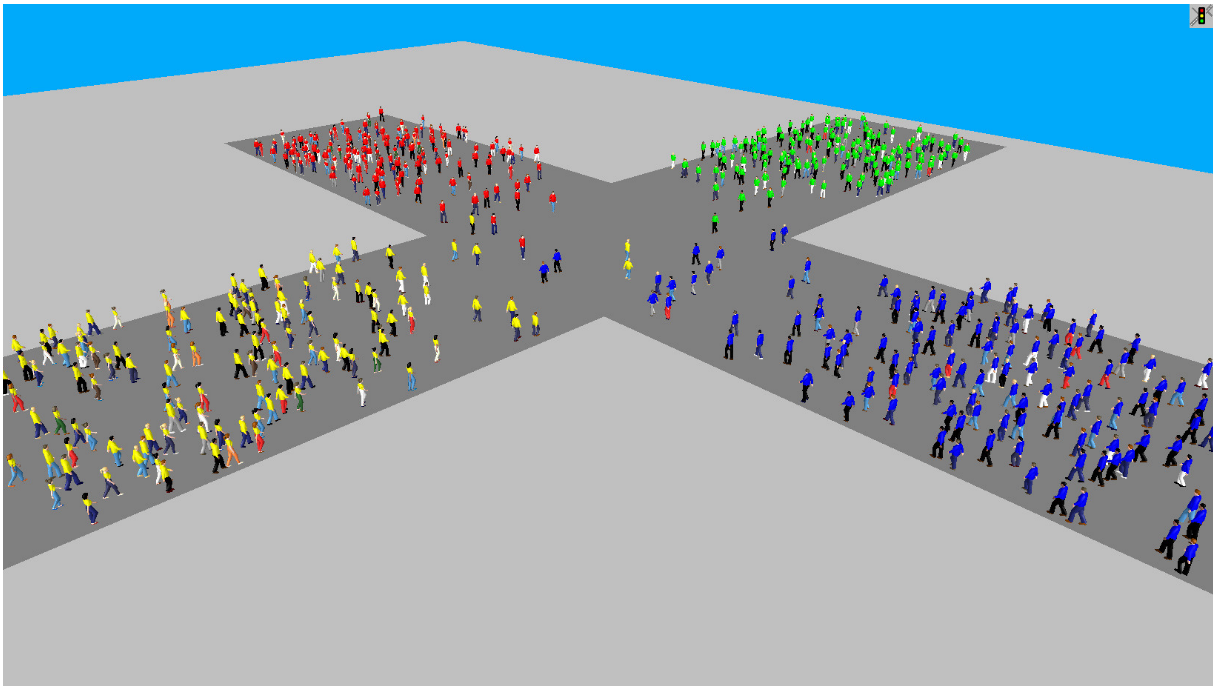

Figure 2: Snapshot of a simulation animation. From each side 25,000 pedestrians per hour walk towards the crossing. The snapshot is made *before* any relevant interaction between the four directions occurs, which shows that details of the underlying pedestrian dynamics model in this case are irrelevant. Already now it can be seen (even better in the animation than in the still image) that the capacity might be insufficient. A rough calculation will confirm this. However, the point is that this issue might be overseen as long as it only occurs in form of some tables in the planning process, maybe even distributed over several pages. In the form as it is shown here, the problem cannot be missed.

The three approaches to a simulation project as mentioned above implicitly assume that a simulation project is carried out because one is aware of critical elements in the planning and that simulations are used to answer the question "Does it work?" or "Can it work?". However, if the simulated process has some degree of complexity it may happen that a simulation initially *generates awareness* for possible problems. In our experience this happens frequently during the process of building up the simulation model before starting the simulation for the first time. This suggests that often a simulation project will succeed in generating awareness for possible problems correctly even if the dynamic model is calibrated for some average situation and not for the specific local conditions.

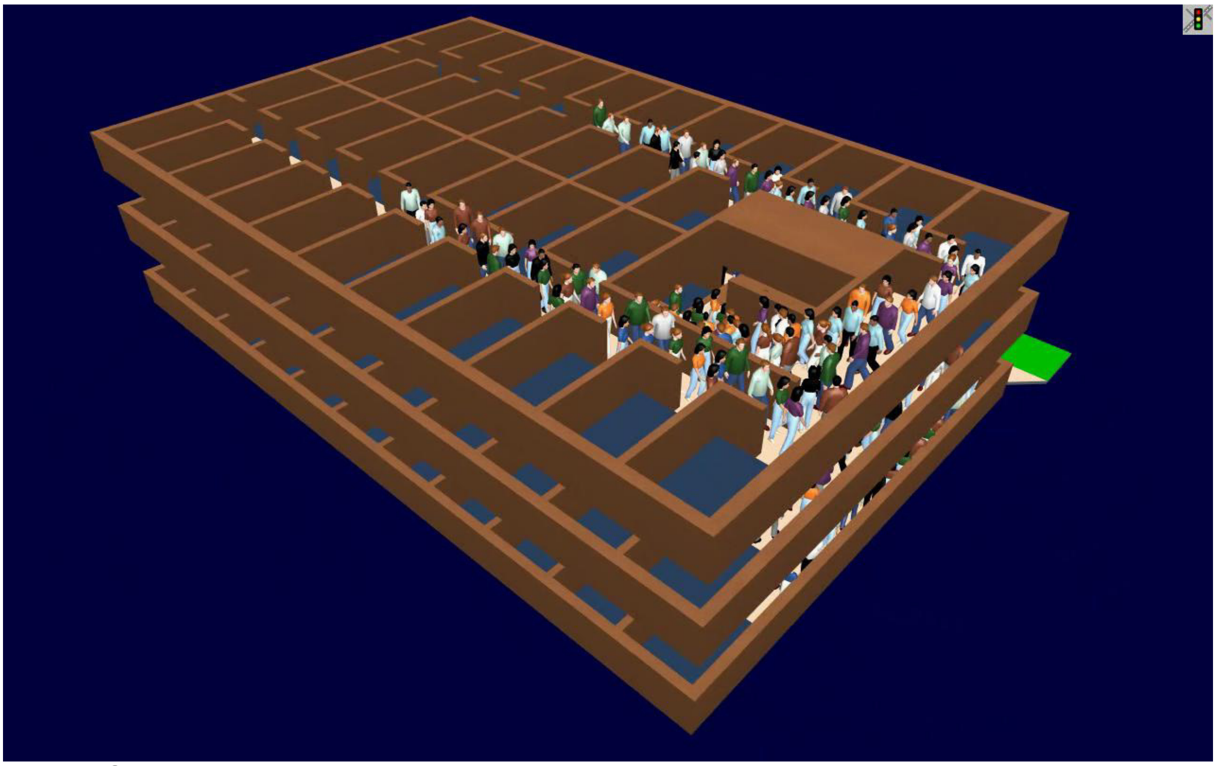

Figure 3: Snapshot from a simulation of a RiMEA test case (Brunner, et al., 2009).

A typical project, where a simulation is used with the intention of a *'check list'* to '*generate awareness',* is a large scale event in a newly built event infrastructure, where no experience exists and no preceding event could have created awareness of problems. The way how a simulation can be made use of then is to first do a classical planning, for example, with Excel sheets making use of the Predtechenskii & Milinskii's (1978) theory, and then use the simulation as described optionally in conjunction with the intention of a refined planning. Once awareness has been created for possible problems, a solution is often at hand following from the planners experience without further usage of elaborate methods.

Planning for very large projects, e.g. first Formula 1 Race in Abu Dhabi (Figure 4) a check list mode project is suggested. First the geometry would have to be modeled precisely, including every single litter can. Precision constraints in the model are implied, if undertaking precise check list is excluded by budget or time constraints. Second it is often the case that one cannot be sure of having a precise estimate of the demand and how it varies over time.

The fact that a project with this purpose and carried out in this manner often produces benefits during the creation stage of the model (geometry, population, etc) is usually overlooked and after a project is completed it is often forgotten that this actually has happened. At the same time this fact also shows that – while it is of course also desirable to have the parameters calibrated as much as possible for the local conditions – normally the purpose can be fulfilled by using average parameters for the simulation[25] which are known to

[25] Using average parameters for the whole simulated population regardless of social or cultural peculiarities may give the impression of doing only a "rough check" of the planning.

produce plausible results. In such a kind of project a visualization of the simulation can be sufficient and measurements and analysis of these might not be necessary.

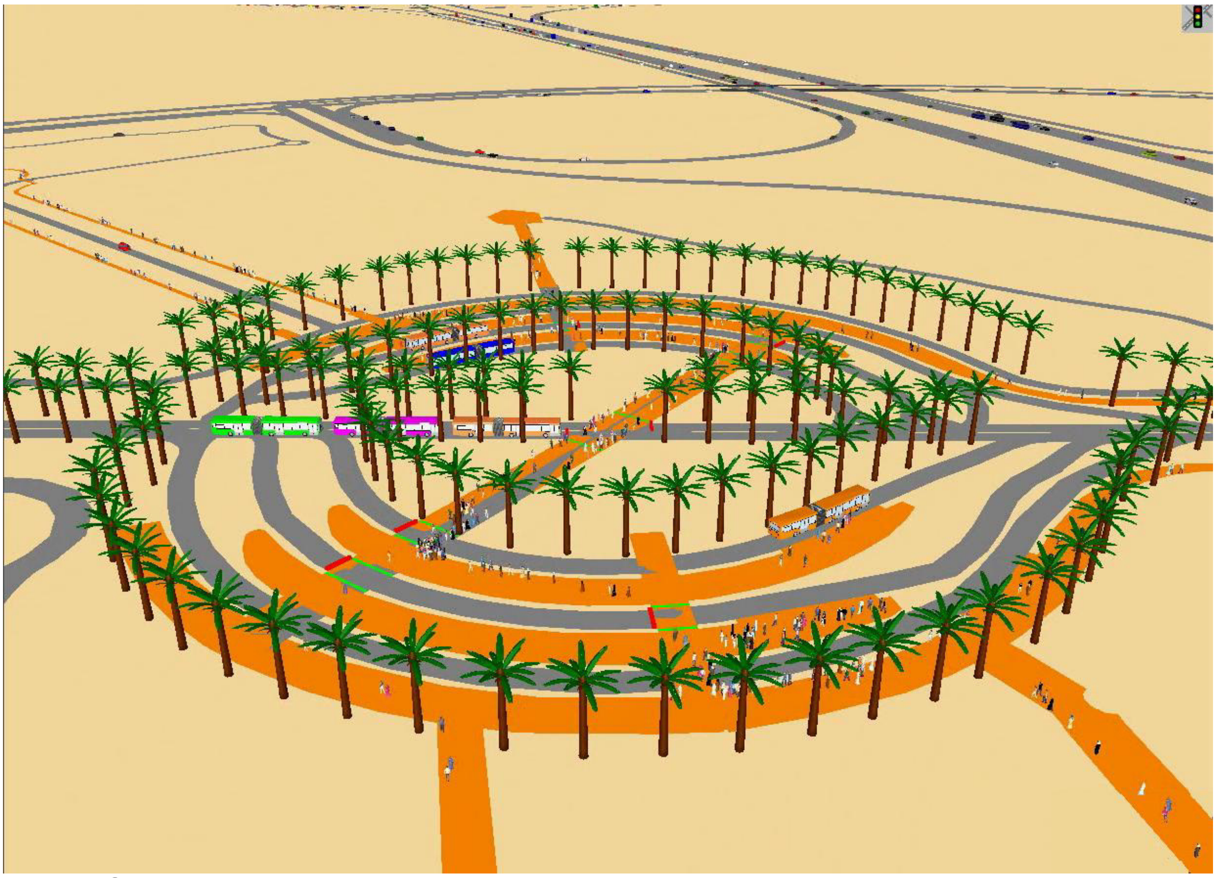

Figure 4: Still image from a simulation made to assist planning for the first Formula 1 Race in Abu Dhabi. This simulation was multi-modal: the visitors arrived by car, walked to the bus hubs (as one is shown in the image here), boarded the buses there, were taken by the bus to their grandstand, alighted there and passed the security check. When the simulated pedestrians reached the grandstands, they were taken out of the simulation. The results of the simulation among other effects lead to the construction of an additional tunnel for pedestrians and increased crew presence at predicted hotspots. In retrospective the simulation was acknowledged to have given the right hints and had not missed an important issue.

Simulation visualization can help to develop an intuitive understanding of large demand numbers. 3D visualizations can intuitively and immediately show where ends do not meet. The alternative method of realizing this from sequences of linked tables is arduous, takes a lot of time, and does not lead to the same degree of conviction that one has not missed a problem as a simulation with its visualization does.

To accept that a project carried out in this way with this limited precision has its justification, one has to compare it to standard planning procedures and their precision which reach limits

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Nevertheless as is demonstrated in (Mayer-Zawar, Schomborg, & Schroeders, 2009) such a simulation is a much more detailed level of planning than a classical planning approach based only on densities, speeds and flows as suggested by (Transportation Research Board, 2000) (Kommission Bemessung von Straßenverkehrsanlagen, 2001)).

in the size and complexity of today's buildings and events. One must *not* compare it to a high-precision measurement or simulation in physics as judged on this ground no simulation of a system that involves human actions can stand ground (Bell, 1997). The standards of the classical natural sciences nevertheless can serve as a guiding light for the *direction* in which models and simulations of social systems should develop.

An Example: Simulation for "Das Fest"

Introduction and Motivation

"Das Fest" (Das Fest GmbH, 2012) is an annual event taking place in Karlsruhe, Germany, at a weekend mid to end July. It has a history of more than 25 years and in the course of these years has grown from an audience of a few dozens to about 200,000 during the course of the weekend. The area is one of the city's parks and has not been specifically constructed to host events. It has an elongated form (Google, 2012). One end of the area is used for the music festival part of Das Fest while at the other end Das Fest has more the character of a fair addressing and attracting families with young children and giving clubs and organizations space to present themselves. For a number of years it has become usual that at the music festival at each of the three evenings one or two of the most prominent national bands or even well-known international acts are presented to the audience (examples include Seeed and the Beatsteaks). The fair part Das Fest, on the other hand, houses activities of which some are rather common (for example activity spots for the very young, presentations of non-profit organizations, parties and clubs) others are more uncommon (e.g. finger skate boarding and volley club), but in any case activities with very limited commercial potential.

In this way Das Fest attracts people from all of society; the audience is socially very heterogeneous, comprises local as well as more remotely located even people from outside Germany, and it changes constantly from Friday afternoon to Sunday night. This alone sets Das Fest apart from most other events. However, for a festival of that size and with such rather highly-ranked artists, its most special feature might be that it has been admittance-free and even without tickets until 2009. As a consequence there was never a limit on the number of visitors one could expect to show up at the area. One of the main reasons – aside tradition – why Das Fest was kept free so long, although it had grown large and attractive to the masses, is that the non-commercial fair part has no chance to survive as part of a festival with usual ticket prices.

After in 2009 the audience for the top act had grown very large, it was decided that the number of visitors had to be controlled with a ticket system. The area of the festival was divided into a music area and a free area. Tickets had only to be bought to access the music area and the security checks were in place to control access for the whole area. Therefore, two spatially separated queuing systems had to be installed: one for security checks for all visitors, and one forticket checks for the music area.

As this was a comparatively large re-configuration of the entrance procedure of preceding years, the desire arose to verify the capacity of the whole system and check in advance as much as possible for potential problems. The project was carried out as part of a Master's thesis in 2010. It was preceded in former years by the creation of animations which were displayed at the festival's video walls to inform the visiting crowd about the position of the emergency routes and exits (Beller & Kretz, 2010).

Project Work

While it was a rather straight forward task to model the geometry of the festival area as well as the infrastructure of the public transport service, fixing the demand (the temporal distribution of fan arrival) was more difficult. As there has been no ticket system in use in preceding years, there was no data available, and even if it had been available, the relative attractiveness of the artists for the various types of fans has a major impact on when, and how pronounced the peak arrival time is to be expected. To estimate this variable is not easy and as it is an input to the simulation, the estimated uncertainty with it is a lower bound to the expected precision of the simulation result.

The estimation then was done as follows: the local tram service organization (VBK) had compiled data from experience of when it is necessary to double the train services to the festival area. This information was interpreted such that at that point in time the trains at the lower frequency were fully occupied. Furthermore it was assumed that about the same number of people arrived by car, foot or bike as by tram. This information for a fixed point in time was combined with estimations about the attractiveness of the artists to the crowd and how much the audiences of the last three presenting artists overlap[26]. In repeated discussions (see Figure 5) which included the presentation of the current state of the simulation, the festival organizers were given the possibility to modify this theoretical estimation based on their experience.

Figure 6 shows how the estimation of arrival flows clearly deviates from later on-site counts. With this deviation it is immediately clear that the simulation cannot “show what is going to happen when” which would be the most preferable information of any planning tool. Nevertheless, as we will show presently, the conclusion that a simulation “cannot help” is not correct as well. Already, Figure 6 can indirectly be seen as a benefit of the simulation. As the simulation relies so strongly on knowing about the demand, the creation of the simulation model revealed very clearly the limited knowledge which exists and has created a desire to clarify this issue with increased efforts for visitor counting in future editions of Das Fest. Such data would be of use for any kind of planning work, apart from its use in simulations.

The simulation – carried out using the software package VISSIM (PTV AG, 2010) – made immediately clear that counter flows would occur at an undesirable spot and in unacceptable numbers, see Figure 7. As a consequence the barrier locations and process configuration was modified. This issue is an example of a problem, which appears to be obvious in retrospect, once the simulation has created awareness for it. To create awareness, no arduous analysis of the simulation results is necessary, as awareness comes directly from the animated 3D visualization of the simulation. Nevertheless, it is not self-evident that such an issue comes to mind without simulations, as it is just one among hundreds of elements that need to be thought over in the planning for such an event. During the project some other issues were similarly brought up; dealing with the simulation model, for example, triggered that one staff person per ticket gate group was added to assist wheelchairs and parents with kid buggies to pass the ticket gates.

[26] As an example the last artist might be by far the most prominent one, but if the two artists before him address the same audience, one can assume many people to arrive earlier and not leave until the end.

After this re-configuration the flows and queues in the simulation were considered to be acceptable. As a next step a "What if...?" scenario was investigated: it was assumed that the ticket gate right behind the security check was broken and out of service, and that all visitors had to walk first to the admittance free area to access the music area from there using one of the other ticket gates, see Figure 8. First it was simulated what would happen if a majority of these visitors would head for the nearest ticket gate (see Figure 9). The result clearly indicated that in the case of a broken ticket gate at the security check, care must be taken for a good distribution of the visitors on the remaining ticket gates – for example by having security staff advising people where to go.

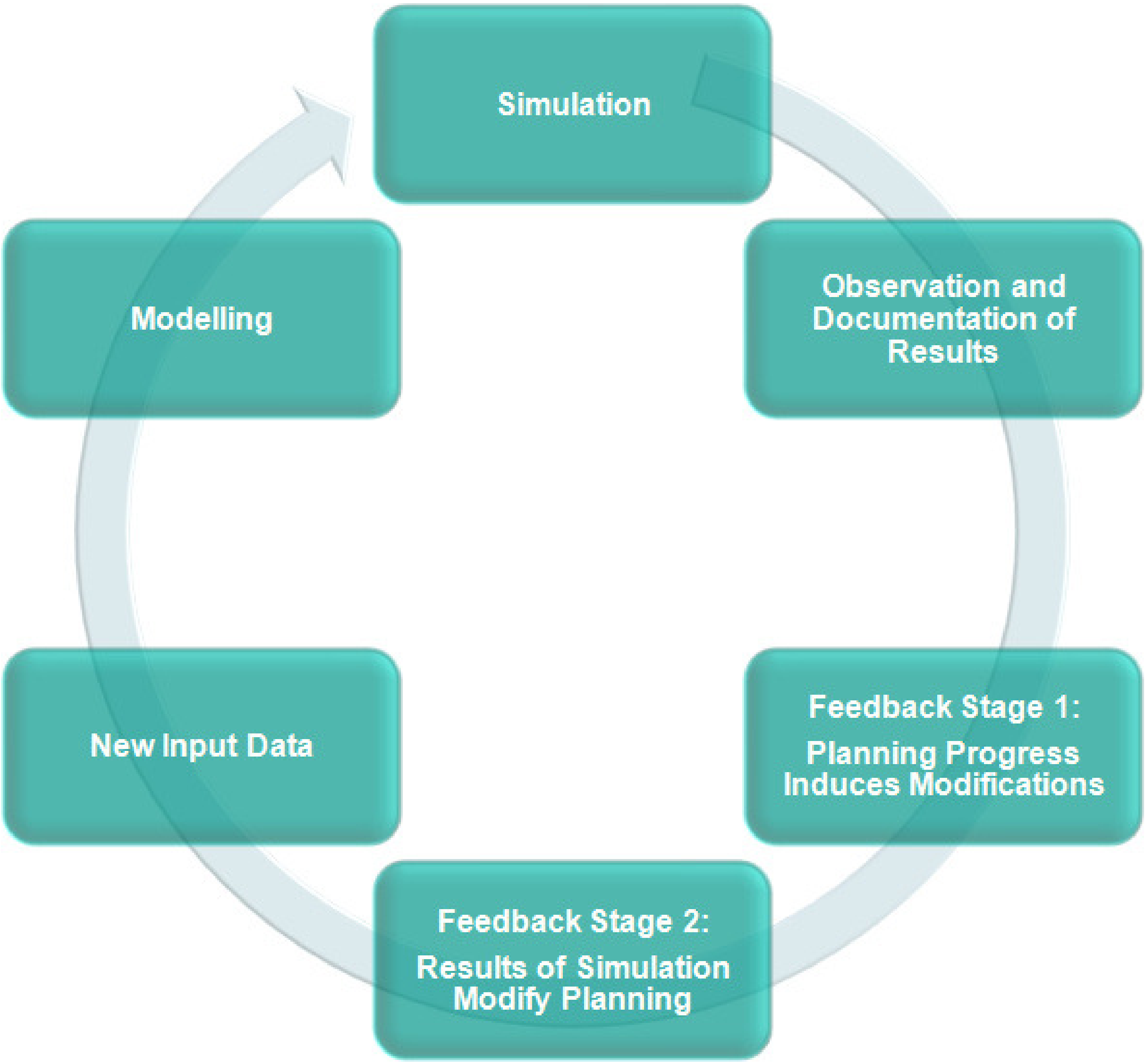

Figure 5: Schematic representation of the workflow including the communication between simulation modeler and festival organizer. This process occurred when the demand was jointly determined and as well in later stages of the project. This means that modeling and result delivery were not separated, sequential stages but were interwoven.

We conclude this section with an interesting observation from the festival: at the first day with the new entrance procedure in place, the first ticket gate to the area was heavily frequented (see Figure 10). This happened especially in the last 30 minutes before the headlining artist was announced to start. It appeared that at that time not only more visitors arrived at the area, but that they were also in a hurry and for that reason did not take the time to search for another entrance – which actually would have saved them a lot of time. To achieve a balanced usage of all the ticket gates, many more visitors would have had to follow the signs and pass the first visible ticket gate and walk to one of the others (which were not visible at the first ticket gate). In this way the queue in front of the ticket gate resembled much the simulated queue shown in Figure 9 but for another reason than the one assumed in the simulation. This behavior changed already at the second day; the ticket gate usage was much more balanced. The visitors apparently were not willing to be guided by signs, but they were willing to let themselves be guided by their own experience and knowledge. This shows that to set the route choice ratios in a simulation model one has to be very clear about the visitors' knowledge of the area and infrastructure. Signage either in general does not have much impact on the visitors' behavior or it needs to be designed and placed differently than it was at Das Fest 2010.

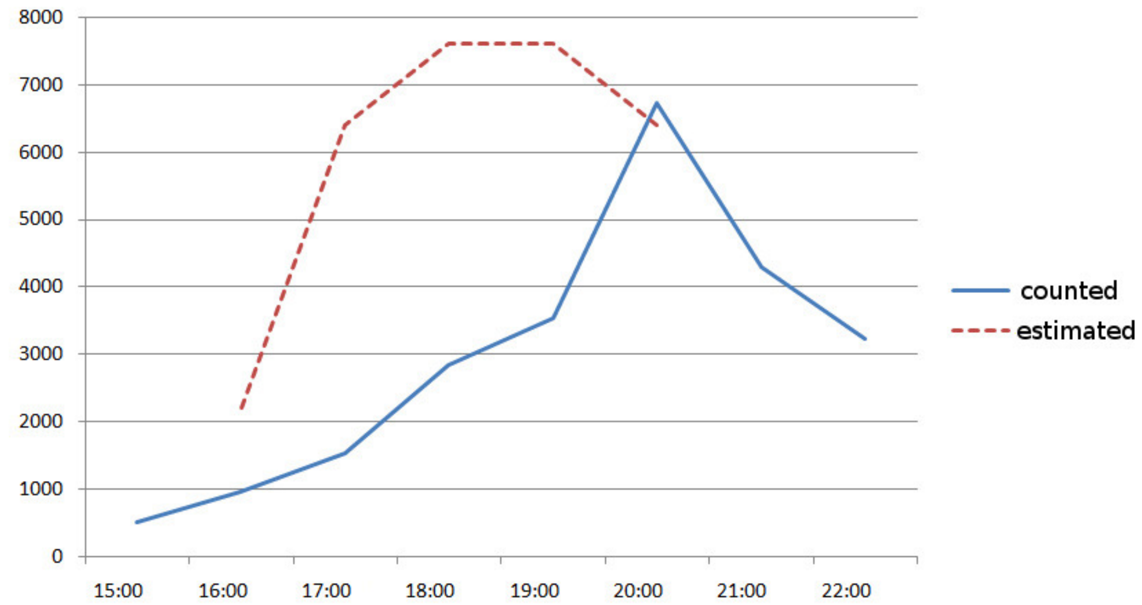

Figure 6 Arrival flow of visitors in persons per hour. The red dotted line gives the estimation before the event, the blue line is based on real counts.

Conclusions

Computer simulations can benefit event organization in two ways. They may investigate issues identified beforehand, but also reveal further problems to the organizers in the course of setting up and running the model. In the former case, data restrictions may often limit the precision and interpretability of results. Commonly, data specific for the event, such as: "When will the visitors choose to go where?", or basic data which is only now being collected (i.e. the dependence of flow on density at junctions) is missing before an event. This sets a limit to the precision of the results which may be lower than desired. However, when using a simulation in the style of a check list to become aware of potential problems, the result is less dependent on such data. Here simulations can be especially helpful to set the mind on issues which – if they would actually lead to problems – tend to be considered a posteriori as “obvious” by outsiders.

The usage of a simulation tool – or any other tool now and in the future – does not guarantee or prove safety in a strict sense such that it allows a head of safety and security to just relax and enjoy the music during their festival. Yet simulations are a way to shift the identification and management of potential incidents from the time of the festival to its planning phase. Thus, simulations contribute to enhancing safety and more likely keeping an event in a manageable state. By improving the planning process they help to reduce the work load of the security staff during the festival.

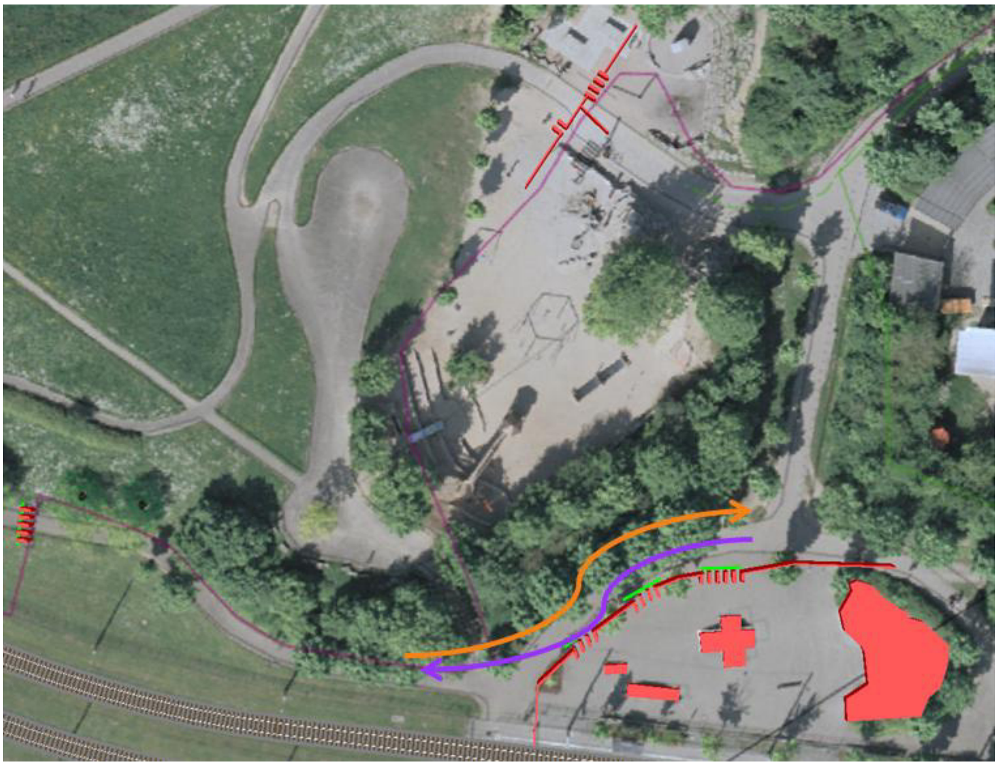

Figure 7: The first simulations showed that with the assumed origins, routes, and destinations counterflows immediately in the back of the ticket gates would occur (upper image, the visitors enter from the lower right and have to pass through the half circle of security checks). This was estimated to be realistic, as it was assumed that the visitors would not automatically and also not with information and invitations align into the right queue according to where they want to go later. Therefore an additional barrier was placed behind the gates (lower image) that prevented counterflows from occurring. This had the consequence that it had to be guaranteed that all visitors aligning at S1 (the left-most security check) were ticket owners, as they only could progress through a ticket gate and access to the free area was not possible.

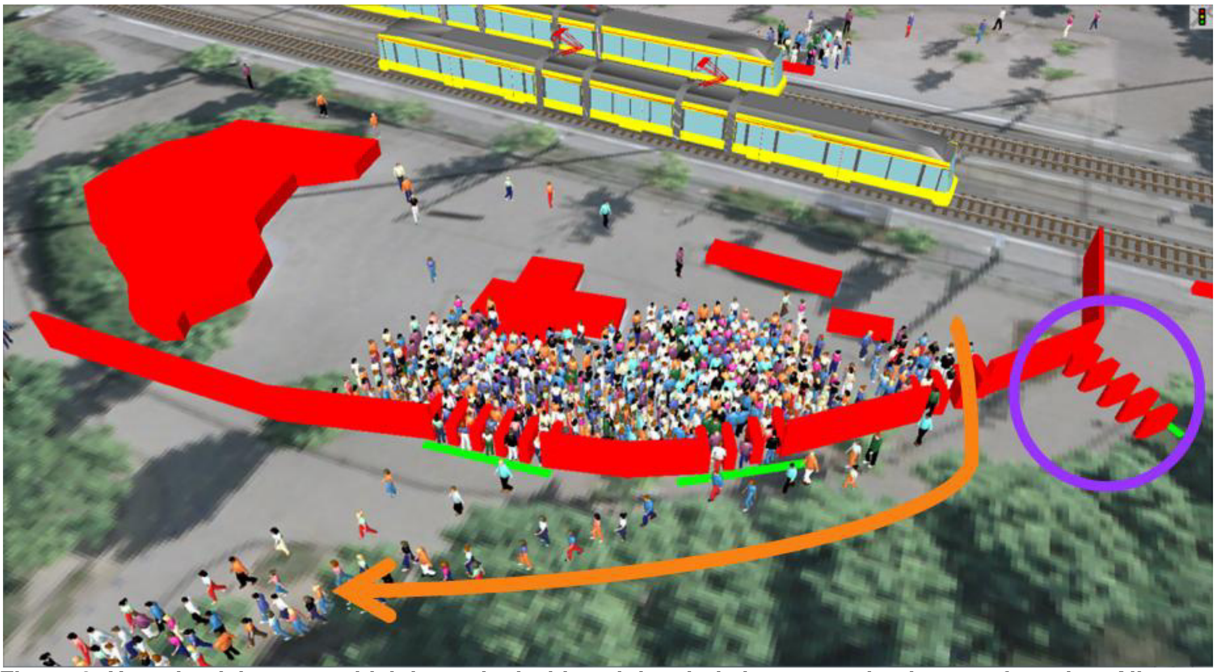

Figure 8: Here the ticket gate which is marked with a violet circle is assumed to be out of service. All visitors now have to follow the orange arrow.

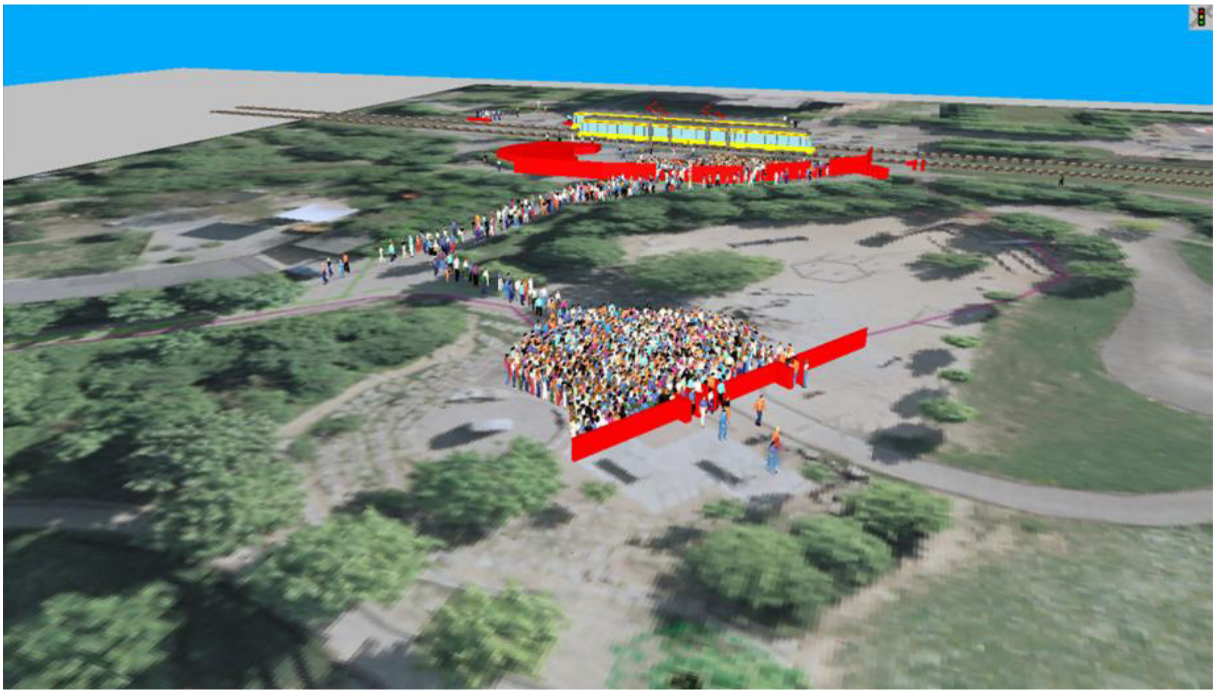

Figure 9: If the ticket gate at the security check is broken, the second nearest ticket gate cannot alone process the crowds and a large queue will form.

Figure 10: Queue in front of the ticket gate (also depicted in Figure 9).

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