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A system dynamics based perspective to help to understand the managerial big picture in respect of urban event dynamics

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Abstract

In the PED-community, a lot of conducted work focuses on a detailed aspect of the big picture in respect of pedestrian dynamics and disaster avoidance. Surprisingly, the field of research does not offer a lot of models including a managerial macro perspective to explain – for example – why there are mass gatherings that result in high density pedestrian conditions. To improve the mental models of researchers, managers and policy makers, this paper tries to tackle this research gap, by using the methodology of System Dynamics to explain with causal loop diagrams occurring dynamics of urban events to avoid critical situations beforehand.

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1. Introduction

The successful management of urban events is a wicked problem (introduced by Churchman (1967)), because of the occurring complex interdependencies. In the context of wicked problems, uncertainties occur because (1) processes take place on different temporal and spatial scales, (2) not all relevant processes are observable for the involved managers and (3) the dynamics occurring at urban events emerge from complex system dynamics and because feedback responses are highly sensitive to altered system conditions. The bottom line is that there are no repeatable solutions for wicked problems such as the successful management of an urban event (see Rittel and Webber (1973)), so that every urban event is a one-shot-operation. The consequence is that there is no possibility to learn from trial and error, because every problem solution attempt counts significantly and, moreover, attempts aiming to solve a problem in one domain will probably lead to new unexpected phenomena in other domains. This is why the founder of the System Dynamics methodology, Forrester (1971), refers to the counter-intuitive nature of social systems.

The described characteristics lead to the fact that it is impossible to predict the precise course of an urban event. It is especially not possible to predict the behaviour of large crowds at urban events, because of the multitude of occurring interactions among the very large amount of individuals. One should be aware that a human brain consists of 10^{12} neurons and 10^{15} synapses (Helbing (2010)) and the amount of more than a thousand individuals at an event

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increases this number by at least three exponents, so that the emerging system behaviour of this interacting system is complex and bottom-up simulation is not even roughly accurate. Nonetheless, bottom-up simulations of pedestrian flows can provide very important benchmarks. The consequence is that it is not possible to control and steer an urban event where thousands of people are gathered, which is why it is so important to understand the dynamics that determine mass gathering situations. In other words, it is of fundamental importance to be able to explain why events such as the Love Parade take place. With this knowledge, it is possible to design specific real world policies to tackle unwanted situations before they take place.

2. The need for external intervention

Evidence shows that the amount of people is fundamentally important for the risk potential of an urban event. In Fig. 1, the instantaneous causality between the number of visitors and the occurring risk potential of an event is disaggregated. Firstly, the amount of visitors increases the average person density, which – as the key message of the different fundamental diagrams (Hankin and Wright (1958); Weidmann (1993)) – leads to a decrease of average velocity. A low average velocity increases the evacuation time and therefore increases the risk potential. Secondly, with an increasing amount of visitors, the value of the personal injury maximum increases, resulting in a further increase in risk potential. And thirdly, with the size of an event, the complexity of the event rises and the risk of mismanagement gets bigger – intensifying the risk potential once again.

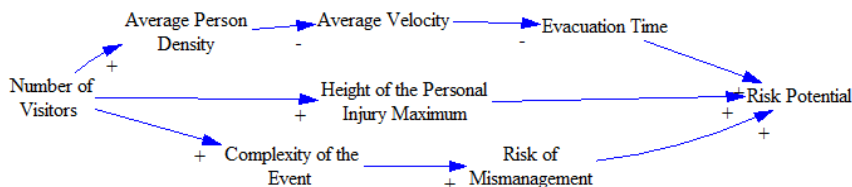


Fig. 1. Disaggregation of the instantaneous causality between the number of visitors and the risk potential.

Before going into detail about the causes of the Love Parade disaster, a generic System Dynamics causal loop diagram is presented in Fig. 2. As discussed above, the complexity of an event increases with the amount of visitors, calling for higher abilities concerning the successful management of an event. The assumption is, however, that the learning curve describing the ability to manage increasingly complex events may not rise simultaneously with an increasing event complexity, due to the reinforced growth in number of visitors. Later reinforcing growth processes are brought about by effects like word of mouth, means to increase the amount of visitors, pressure to succeed and/or by an increasing effort to reach new visitor records. In addition, debriefings that are crucial for the learning performance in the course of the whole planning process usually take place after the actually important initial event planning, which confers additional validity to the delay in this causal relationship.

If an organization seems unable to manage a complex event with an anticipated high number of visitors, the appropriate reaction is to take action to reduce the amount of visitors. Possible measures could be to try and decrease the demand by raising the price or to restrict the supply by a limited amount of available tickets. However, many years of organizational and management research have shown that the abilities of the own organisation are overrated if a task belongs to a usual task (Moore and Small (2007)). Kahneman and Tversky (1977) introduced the planning fallacy bias to delineate the tendency of individuals and organisations to underestimate risks, costs and/or time that are needed to solve a task. Here, there is a cognitive distortion in the form of hubris (overestimating the own abilities), so that the dashed causal link (the initial discernment to limit the amount of visitors if the own abilities are not advanced enough) is quite unlikely to be found in reality. Therefore, it becomes necessary to close this missing causal link by means of an external regulator. This dynamic corresponds to the generic system archetype of *Shifting the Burden to the Intervenor* (Senge (2006)). The result is that the cost to determine an appropriate size of the event is shifted to the intervenor.

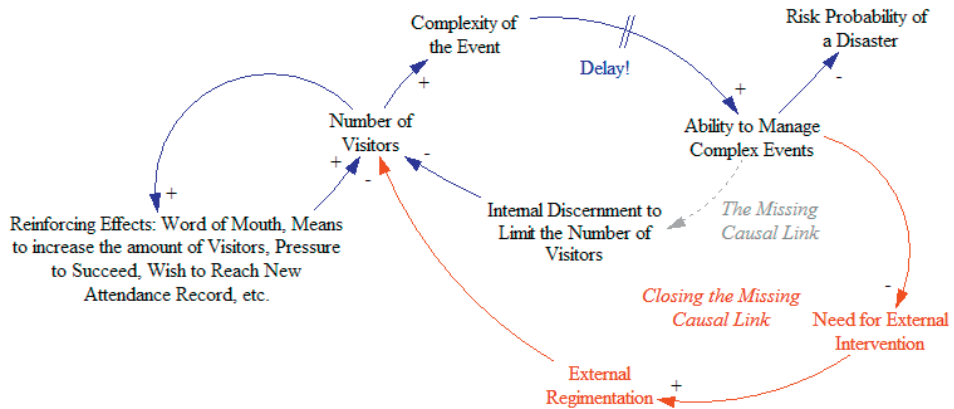


Fig. 2. Delay in the learning curve of event organizers and the planing fallacy bias are responsible for shifting the burden to the intervenor.

3. The Love Parade disaster

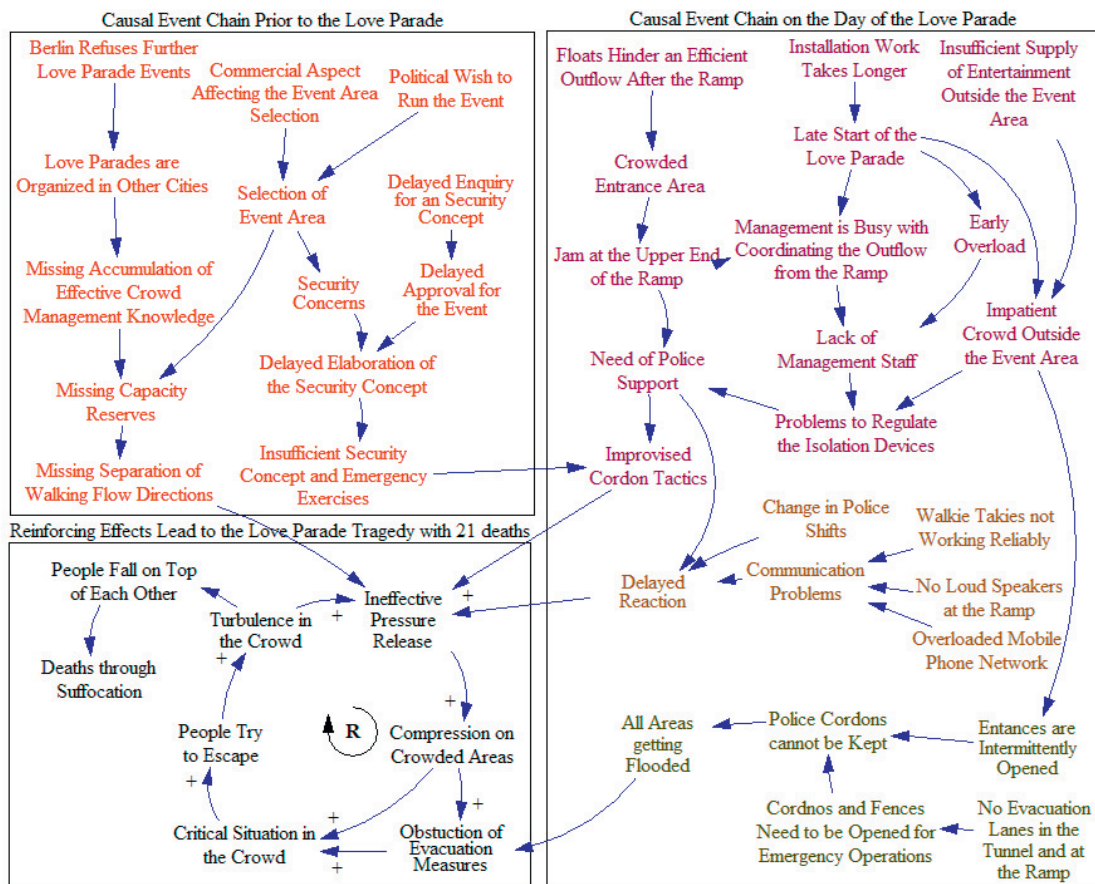


Fig. 3. The Love Parade Disaster from a combined event- and process-oriented perspective (Adapted from Helbing and Mukerji (2012)).

In the following, the focus is on discussing the Love Parade disaster in order to get to a more empiric level. A very deep investigation of the causes that led to the disaster can be found in Helbing and Mukerji (2012). Their paper includes a summarizing illustration that shows the main causal interdependencies. This original figure has several drawbacks as it mixes up an event-based and process-based world-view (see Sterman (2000)). Included here are several other events – prior to and on the day of the Love Parade – leading to the disaster, including a reinforcing feedback loop to represent the continuous processes that caused the turbulences in the crowd and resulted in the deaths of 21 people who suffocated because people fell on top of each other. In Fig. 3, the original illustration from Helbing and Mukerji (2012) is tidied up and partly restructured in its causal logic. Furthermore, the process oriented feedback loop is separated from the causal event chain prior to and the causal chain on the day of the Love Parade.

In the upper left box, the main unfavourable event chain prior to the Love Parade is shown. The two key messages, illustrated by the variables at the bottom of the box, are that (1) awkward events caused a missing separation of the walking flow directions in the tunnel and at the ramp on the one hand and that (2) there was no sufficient security concept and no emergency exercises had been carried out, resulting in improvised cordon tactics of the police on the day of the Love Parade. In the box on the right, further events leading to improvised cordon tactics are illustrated, including the occurring communication problems that entailed delayed reactions and the causes for the flooding of all areas, resulting in the obstruction of the evacuation measures. The missing flow separation, together with the improvised cordon tactics and the delayed reaction times, were responsible for an insufficient pressure release at the ramp, resulting in a compression of the crowd in this area. The high density evoked for fear, perceived danger and a critical situation within the crowd, leading to a situation in which people tried to escape. These escape manoeuvres caused turbulences in the crowd and reinforced the insufficient pressure release by the occurring non-unidirectional impulses in the crowd. And as stated before, the turbulences were finally responsible for the deaths and the many people injured.

An additional causal loop diagram (Fig. 4), explains how the existing escape points (stairs, container, scaffolding) resulted in a heterogeneous density distribution in the area. Around these attraction points, high local densities occurred. These were the areas in which the most people were harmed (Mamrot (2010)). On the left side of the diagram, the variable inflow and outflow is responsible for the overall density. These flows are the exogenous drivers in the structure. The overall density infected the mood of the people causing frustration and impatience in view of the tense situation. The higher the level of frustration, the stronger the desire to reach one of the visible escape points. Therefore, a movement to these points took place and the local density around these points increased. Two feedback effects are responsible for making the situation even worse. Firstly, an increase of local density leads to a higher noise level, making staff announcements less understandable – while the lack of information increases the level of perceived danger and thus the desire to reach a visible local point of attraction, reinforcing the respective movements. Secondly, as shown in the other loop, the level of perceived danger is also due to the the number of affected persons – which, in turn, rises with an increase of local density.

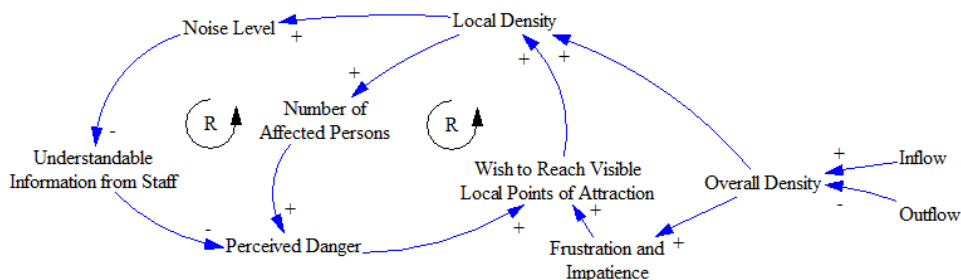


Fig. 4. Points of Attraction led to high local densities (Adapted from Mamrot, 2010).

Fig. 4 clearly shows that the best way to calm the situation would have been to regulate the in- and outflow. But, as many empirical studies have documented (references can be found in Sterman (2010)), even highly educated people tend to misunderstand the dynamics of stocks and flows: "People fail to grasp that any stock rises (falls) when the inflow exceeds (in less than) the outflow. Rather, people often use the correlation heuristic, concluding that a system's output is positively correlated with its input." (Sterman (2010, p. 1)). It is very likely that the correlation heuristic

somewhat contributed to the disaster. In other words, the non-comprehension of stock and flow dynamics was very likely responsible to delay the awareness that a stop of the inflow is necessary and additionally, the already mentioned delayed communication did the rest. Sterman (2010) concludes to train people’s mental models, to overcome the difficulty in understanding accumulation, in form of stock and flow dynamics. One way to do this and to improve the mental models of involved managers is to use Group Model Building (Vennix (1996)).

4. Thoughts about risk reducing policy options

Above, the instantaneous causality in regard to how more visitors lead to an increased risk potential, were discussed (Fig. 1). From this point of view, it seems to be an adequate solution to lower the risk on a macro scale by preventing high density conditions by minimizing the size of urban events globally and to distribute people locally. The causal loop diagram (Fig. 5) is based on the simplifying assumptions that (1) two event organizers are competing for potential visitors and that (2) perfect competition takes place. The diagram shows that each organizer can take action to increase the amount of visitors, based on previous revenues and employable funds (loop on the left and the right). Visitors attracted by one of the event organizers are not available for the other event organizer any more, so the potential visitor population of the latter decreases (loop in the middle). If one of the event organizers gains the upper hand, he will continue to be more successful, because the other organizer loses visitors and therefore revenues and means to poach visitors from his competitor. The unstable equilibrium point at which both event organizers have the same amount of visitors is called a repeller.

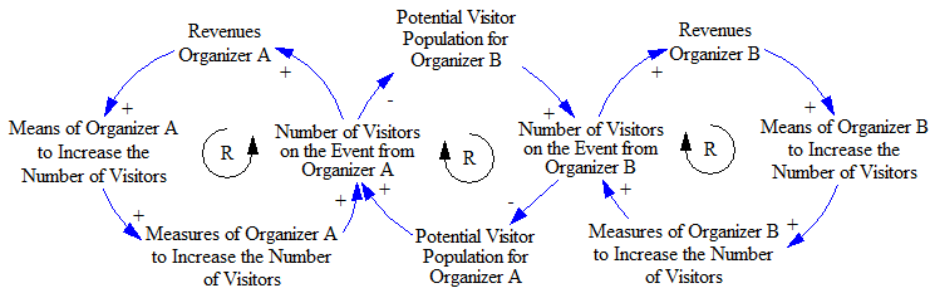


Fig. 5. Repeller effects cause hypes like the Love Parade event.

The shown diagram conforms the system archetype *Success to the Successful* (Senge (2006)). The competing resource is the potential visitor population. In regard to the initially discussed instantaneous causality that a higher number of visitors will lead to a higher risk potential, it seems obvious to design a policy to curb the power of the reinforcing effects or to bring the shift to a standstill at some point in time. In regard to this model of reality, there are basically two policy options. On the one hand, a balancing mechanism can be implemented on macro level, to fairly distribute the limiting factor (means to increase the number of visitors). On the other hand, the underdog could be supported by an easier mobilization of his resources.

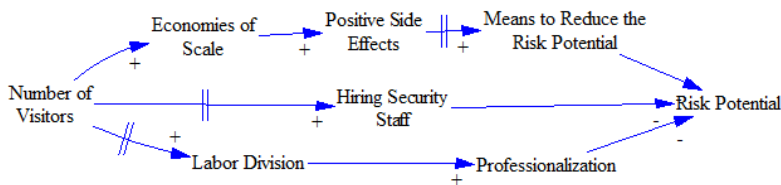


Fig. 6. Disaggregation of the delayed causality between the number of visitors and the risk potential.

Taking into account not only the instantaneous causality, but rather also delayed causality, initially probably counter-intuitive effects for this causal link can be identified that lead to a decrease of the risk potential in case of an increasing number of visitors. In Fig. 6 it is shown that more visitors entail an economy of scale effect, leading to

positive side effects, and with them, providing more means to reduce the risk potential. Moreover, with an increase of visitors, the organizer may hire more security staff and start off with better division of labour, resulting in higher quality and professionalization, thus reducing the risk potential. As marked with the three arrows with delay marks in the diagram, all these effects are delayed and not instantaneous. That means, if a event organizer is taken by surprise with a huge amount of visitors, these risk reducing effects have not yet started to work and are therefore ineffective at a previous point in time. With this lag in mind, the consequence for policy makers should be to make it difficult for an event organizer to increase his number of visitors excursively, so that his ability to manage the situation will not get out of hand (see discussion of the delayed learning curve in chapter 2).

5. Conclusion

In this paper, the methodology of System Dynamics served to outline a managerial macro perspective to explain system behaviour with causality structures in the context of urban events. To begin with, it was discussed how organizational hubris, overestimating the own abilities through - for example - the planning fallacy bias, occurs in the event planing process and thus causes the need for an external intervenor. Special attention was set to the causal relationship, explaining how the size of an urban event affects the risk potential. It could be shown that the risk potential instantaneously increases with an increase of visitors, but that counter-intuitively, in the longer run, the risk potential might be lowered with an increase of visitors. From this point of view, different initial thoughts about policy making to lower the risk potential have been discussed. Furthermore, the Love Parade disaster was evaluated based on previous literature. With a link to the System Dynamics methodology, the assumption was stated that the correlation heuristic was partly responsibility for the occurrence of the Love Parade disaster.

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References

- Churchman, C.W., 1967. Guest Editorial: Wicked Problems. *Management Science* 14, B141–B142.
- Forrester, J., 1971. Counterintuitive behavior of social systems. *Theory and Decision* 2, 109–140. URL: <http://dx.doi.org/10.1007/BF00148991>, doi:10.1007/BF00148991.
- Hankin, B.D., Wright, R.A., 1958. Passenger Flow in Subways. *Operational Research Quarterly* 9, 81–88.
- Helbing, D., 2010. Quantitative Sociodynamics. URL: <http://www.springerlink.com/index/10.1007/978-3-642-11546-2>, doi:10.1007/978-3-642-11546-2.
- Helbing, D., Mukerji, P., 2012. Crowd disasters as systemic failures: analysis of the Love Parade disaster. *EPJ Data Science* 1, 7. URL: <http://www.epjdatascience.com/content/1/1/7>, doi:10.1140/epjds7.
- Kahneman, D., Tversky, A., 1977. Intuitive prediction: Biases and corrective procedures. Technical Report.
- Mamrot, D., 2010. Loveparade Duisburg 2010 - Wi(e)der die normale Katastrophe. *Ingeneurforum* 3, 38–41.
- Moore, D.A., Small, D.A., 2007. Error and bias in comparative judgment: on being both better and worse than we think we are. *Journal of personality and social psychology* 92, 972.
- Rittel, H.W.J., Webber, M.M., 1973. Dilemmas in a general theory of planning. *Policy sciences* 4, 155–169.
- Senge, P.M., 2006. *The fifth discipline: The art and practice of the learning organization*. Random House LLC.
- Sterman, J., 2000. *Business dynamics : systems thinking and modeling for a complex world*. Irwin/McGraw-Hill, Boston.
- Sterman, J.D., 2010. Does formal system dynamics training improve people's understanding of accumulation? *System Dynamics Review* 26, 316–334.
- Vennix, J.A.M., 1996. *Group Model Building: Facilitating Team Learning Using System Dynamics*. John Wiley & Sons, Nijmegen, The Netherlands.
- Weidmann, U., 1993. *Transporttechnik der Fussgänger, Transporttechnische Eigenschaften des Fussgängerverkehrs (Literaturauswertung)*.