Development of a Methodological Approach to Strategic Fire Service Planning Combining Concepts of Risk, Hazard and Scenario-based Design

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Abstract: Strategic Fire Service Planning is a quite new field of research because of which there is a need for fundamental research and methodological work. Existing approaches like risk management, the hazard-concept and scenario-based design have been found to not be fully applicable on its respective own to the research question of "how much fire service is necessary in a city". Based on analytical work and the analysis of incident data it is shown that a combined approach of risk and scenario-based methods is a good starting point for further research.

Keywords: risk, hazard, scenario, fire service, data analysis

1. INTRODUCTION

Several scientific disciplines – from economics [1], performance [2] and risk management [3], [4] to operations research [5], systems analysis [6] and probabilistic studies [7], [8] - have already developed methodological approaches to answer parts of the question "how much fire service" is needed to provide for adequate safety against fires and other life-threatening hazards. However, not one single approach of those is able to serve as a holistic blue-print for a comprehensive method for fire service planning on a national scale.

A current work-in-progress research project in Germany called "TIBRO" (German acronym for tactical-strategic innovative fire service and risk-based optimizations) was started in February 2012 and is scheduled for its final report in the first quarter of 2015. The aim of the project is to outline the fundamentals of a comprehensive methodology to derive necessary fire service resources in accordance with the legal tasks to be fulfilled by the fire service.

2. METHODS

2.1 Analytical review of hazard-based, risk-based and scenario approach

In simple terms, the risk-based approach can be described as the composition of a hazard with the probability of its incidence. The hazard-based approach therefore cannot be used to quantify necessary fire service resources for a municipality, because this would result in an overly conservative estimation as only the possible extent of an incident would be considered without paying attention to the probability of it. This can be strikingly depicted with the example of a nuclear power plant: If one would exist in the boundaries of a municipality, a huge hazard of nuclear and radiological incidents exists. However, considering the probability of different accident-scenarios somewhat relativizes the necessary fire service resources needed for the protection of that city. Therefore it would be unsustainable to have all the firefighters, trucks and special equipment on duty every day that would be necessary in a severe accident within the plant.

However, on the other hand fire service planners cannot simply bring small probabilities into play in order to use the small number of large accidents to postulate that very small resources would be adequate as the remaining number of incidents excessing the small scenario could be considered a residual risk. Turn-out data over six years of eight German municipalities ranging in population from ca. 4.000 to 170.000 shows that under a pure probability perspective a fire department in a town with

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less than 18.750 population would not have to be prepared for a residential fire with persons endangered in an upper floor (a popular design scenario in Germany) as the frequency of those incidents was zero [9]. Therefore it would be enough to purchase equipment and crew the department in a fashion that it could respond to false alarms, incidents resulting from torrential rains and storm winds as well as removing small oil spills (stains) from streets, which together make up more than half of the total number of incidents. For those operations, obviously only very limited equipment, training and personnel would be needed, compared to more complex and life-threatening incidents like house fires or car accidents. However, common sense suggests that it would be irresponsible to regard the more complex incidents as residual risk, disregarding their actual frequency and probability. But it is very difficult to draw a line between types of incidents that have to be regarded and ones that can be disregarded. Using the frequency of incidents in the past alone obviously is not the suitable method to decide that question.

Contributing to those problems with a risk-based approach to fire service planning is the problem of large uncertainties, both aleatory and epistemic, in terms of what type and extent of incidents a fire service will have to deal with one day and what that will require of the fire service. The different interpretations of black swan concepts [10] all apply here. It is important that existing uncertainties are quantified and transparently communicated to the deciders and stakeholders [11], i.e. the locally responsible political body and the citizens.

What is more, the traditional approach of multiplying the probability of an incident with its severity has been found to be not fully applicable to the problem at hand as there exists not one scale on which to measure damage and benefits and also the conversion into monetary dimensions is viewed as controversial. Especially the public often does not understand or accept that kind of engineering calculation when there is a large hazard in place [12]. It can be argued that the prospect of a fire service not being able to confidently deal with a house fire or car accidents seems to be a large hazard to the citizens of the community served by the fire service. At the same time, those citizens and their politicians are the public to which the fire service has to answer and has to go to in order to receive funding, which adds to the complexity of the problem. It is important to bear in mind that though the risk perception of laymen and so-called experts has been found to closely correspond, they are not identical as laymen also include qualitative aspects into the risk assessment, especially dread and put more emphasis on worst-case outcomes [13].

From a scientific point of view, a “safe” risk level cannot be determined as such matters involve not only scientific facts, but also societal and especially ethical questions. Therefore and because the decisions made in that area come with a high demand for political accountability, the decisions rest with the political authorities having jurisdiction, and not with the local fire service, which is only the executer of political will, and not with the scientists, as it is not upon them to decide what should be deemed safe [14].

However, risk science has an important role to play in that process, in that it can offer the deciders valid background information on the decisions at hand, therefore enabling informed decisions. It is especially important that the consequences and outcomes of the different decision options must be made transparent and understandable to the deciders, who are more often than not laymen in this specific area. This so-called analytic-deliberative approach to complex safety and risk questions [11] should be understood by all parties involved, therefore clarifying what to expect from the different parties and where boundaries of competencies lie. Especially the remaining uncertainties of scientific analysis must be made clear to the decision-makers.

To counter the methodological drawbacks of the risk approach outlined above, a scenario approach seems suitable. Scenarios in this case represent independent, representative sets of events and parameters that define the hazards of and the persons exposed to an incident [15] requesting fire service attendance. Using scenarios, the virtually infinite number of tasks and incidents that a fire service possibly has to address are reduced to a manageable number which can directly be linked to operational experience of firefighters. Questions that need to be addressed with this approach are the number of scenarios necessary to achieve a truly representative set of scenarios; currently, methods mainly used in Germany utilize only one scenario of a residential fire with persons trapped in an upper floor. Even a small increase in the number of scenarios from such a limited number obviously offer large advantages in covering the different incidents addressed to the fire service in real life. In addition, also the level of complexity of the covered scenarios must be addressed, as it could range from worst-case scenarios with low-probability and high-impact events (as described above) to simplest-case scenarios [16], both of which are on their own not representative. It is suggested to develop a set of scenarios based on the main tasks the fire service usually has to address (fires, technical rescues, hazmat incidents, water rescue) with each category involving three to four scenarios with increasing levels of scope and complexity. Those 12 to 16 scenarios would cover quite a large spectrum of fire service activities and offer the opportunity to directly link them to different operational readiness levels that could be assigned to different fire stations, as usually not every station has the capability to deal with all possible incidents.

2.2 Analysis of data from fire service turn-outs

As outlined above, further fundamental research is necessary to implement a real risk-based approach. In existing German literature, a number of hypotheses have been found elaborating on risks of different types and heights of buildings, their occupation and the number of units in a building ("risk factors"). The hypotheses in general state that with increasing height, age and size of buildings the fire risk and the demand on the fire service would increase. Similarly, fire risk and demand would be higher in industrial, commerce and special buildings (schools, hospitals, malls etc.) than in private dwellings.
To validate the assumptions of those hypotheses, two studies were conducted with the objective of verifying (or falsifying) them based on turnout data of two German metropolitan fire services (city 1: pop. ca. 350.000, 5 years of data, 1.022 data sets (structure fires only); city 2: pop. ca. 690.000, 4 years of data, 17.093 data sets).
As the work was of a more methodological type, two different methodologies have been specifically developed custom-made to the two available data sets. Knowing that the results of both studies cannot be directly compared, it was considered worthwhile developing two independent ways of data analysis as a fundament for further sophistication, which is still ongoing.
One methodology created absolute risk numbers for the different risk factors, based on a number of items representing the risks (monetary loss and damage compromising the further habitability of the premises, frequency of incidents) and the demand on the fire service operations, covering items like duration of operations on site, number of trucks, personnel and breathing apparatus used, number of rescued civilians and used amounts of extinguishing agents [17].
The second study used a qualitative comparison of the statistical distributions of basically the same items as listed above plus injuries and fatalities of civilians (for which no data was available in the other study), permitting for relative statements like one category of buildings possesses a greater fire risk than others, without giving absolute numbers [18]. Cumulative curves, Q-Q-plots and Box-plots were used in that process.

3. RESULTS

Considering the analytical investigation of the applicability of different methodologies based on hazards, risks and scenarios, it became apparent that a combined approach is necessary, containing both aspects of the risk-based and of the scenario approach. Various problems still remain to be solved, including how to deal with black swans and large uncertainties in general.

To reduce some of the epistemic uncertainty, the two studies of fire service turn-out data tried to substitute assumptions with facts. It has to be admitted, that this objective could not wholly be reached as the results of both studies are inconclusive: Some hypotheses could be proved, some falsified, but not one hypothesis showed the same results in both studies. Some hypotheses could not be conclusively be categorized as the statistical population seems to have been too small to make general statements. Also varying procedures in creating the statistics by the fire services and incomplete data

sets (e.g. the building age was not available for all buildings which had an incident in it) contributed to the inconclusive outcome.
However, the outcome of the methodological research attempted here for the first time seems encouraging enough to continue the data analysis with additional cities and counties and with cross-checking the developed methodologies on respectively other municipalities, with which it is hoped to gain some further understanding of the underlying factors. Both studies delivered the proof of principle that it is possible to aggregate and analyse fire service data to a level of detail sufficient for answering questions on risk as posed here and probably also other risk-related problems.

4. CONCLUSION

A risk-based approach seems appropriate to reach individually good fitting fire service protection levels for municipalities of different sizes, populations and risks. The goal should be to determine a level of risk that is adequate, without over-spending because the assumptions are too conservative but at the same time guaranteeing an adequate level of safety.

However, more fundamental research is necessary to create more reliable quantified data on correlations of risk with characteristics of cities, dependencies on socio-demographic factors and the capabilities of the individual fire services. This is hindered by the lack of a national fire service statistic in Germany, for which reason it is necessary to approach single cities and put substantial effort in making their statistics accessible for further analysis. The studies conducted based on existing data are proofs of principle that this approach is worthwhile.

Historic demand on the fire service, based on calls per area and per stations adequately categorized, should be included in further research. Therefore, both a priori (generalized categorization of areas based on risk characteristics drawn from past incidents) and a posteriori (actual historic demand in the area under scrutiny) perspectives could be included in the analysis.

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