Decision making in emergency response - Structural analysis of decision-making processes of fire services at industrial accidents

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The decision making process in general is a multi-layered process that depends on a variety of influencing factors. During the handling of industrial emergencies and disasters decisions made by emergency response workers (e.g. firefighters) may influence the development of a scenario significantly. Especially at major industrial accidents not only industrial but also municipal emergency services are dealing with the incident. Investigations showed, that emergency workers are strongly influenced by their professional background during decision making processes in industrial emergencies. The present investigation deals with the developments and influencing factors of the decision-making process in emergency response. The analysis of several models and theories from different scientific disciplines is intended to provide an accurate insight into the different perspectives of the decision making processes. Based on that background municipal firefighters and fire officers have been tested for their performance in an industrial surrounding, under different stress levels. Results of the testing show that common conventions as well as different heuristics play a major role in the decision making process. Especially in high stress situations well trained procedures are overruling adequate decision making processes.

1. Introduction

Decision making is an aspect of daily life, present in a professional surrounding as well as in private life. The future development of various aspects of life is mainly influenced by our own decisions. So to make decisions is a very common procedure for most people. A more obscure process is the way how decisions are made. It is generally questionable whether every part of the decision making process is always fully understood by everyone that makes decisions. Are all decisions that are made fully conscious decisions or are there decisions and situations that are strongly influenced by factors that are not recognised consciously? During the handling of industrial emergencies and disasters decisions made by emergency response workers may influence the development of a scenario significantly. How hard it is especially for emergency responders to make adequate decisions was shown by the 2016 explosion at BASF SE Ludwigshafen (GER). A pipeline fire led to a massive explosion, where four emergency responders and a civilian were killed. In the 2013 explosion of an ammonium nitrate storage area at a fertilizer plant in West (TX) 12 emergency responders and three civilians were killed. Although the hazards of the materials stored were known, typical procedures and measures known in industrial firefighting were not set in action. Most analyses of similar incidents only focus on the decision itself that led to a certain action, the decision making process itself is often not taken into account. Good or bad decisions have their origin in different factors that are consciously and unconsciously taken into account during the decisions making process itself. Despite a huge load of different decision factors, a lot of decisions are made by simple decision standards and rules. Investigations showed, that emergency workers are strongly influenced by their professional background during decision making processes in industrial emergencies. The structure of the decision making process especially from the view of emergency responders will be discussed in the following.

2. Decision making in emergency response

Especially in the German speaking countries a leadership model is common which is very similar to the control circuit of technical systems. The so called “tactical control circuit” was introduced by Schläfer in the early 80’s of the last century (Schläfer, 1998). German and Austrian fire services included the “tactical control circuit” into their standard leadership model. The Austrian ministry of interior developed a “control circuit of leadership” based on Schläfers tactical control circuit (Fig. 1). The tactical control circuit includes all procedures from size up to the issue of tasks and can be executed several times during an incident.

For the decision making process especially the phases “size up” and “assessment” are relevant. The process of size up focusses on the general situation (time, location, weather, etc.), the own situation (personnel, equipment, etc.) and the hazard situation. The hazard situation is generally only identified partially, especially in the first minutes of an incident. This lack of information in a central aspect of the decision making process contains a certain risk for bad or false decisions because of misjudgement. This lack of information leads to the dilemma, that especially in emergency response decisions have to be made under acceptance of an information deficit in a central area, the problem itself. Especially during training young leaders are taught to elaborate different problem solutions and weigh them carefully against each other. Pros and cons of the different possible decisions are analysed and the decision is made after filtering the best solution. Collect information, evaluate different possible solutions, decide. Even without time pressure this procedure seems complex but at least reasonable. The scientific theory of decision making goes beyond this structured model and includes also additional influencing aspects of the decision process.

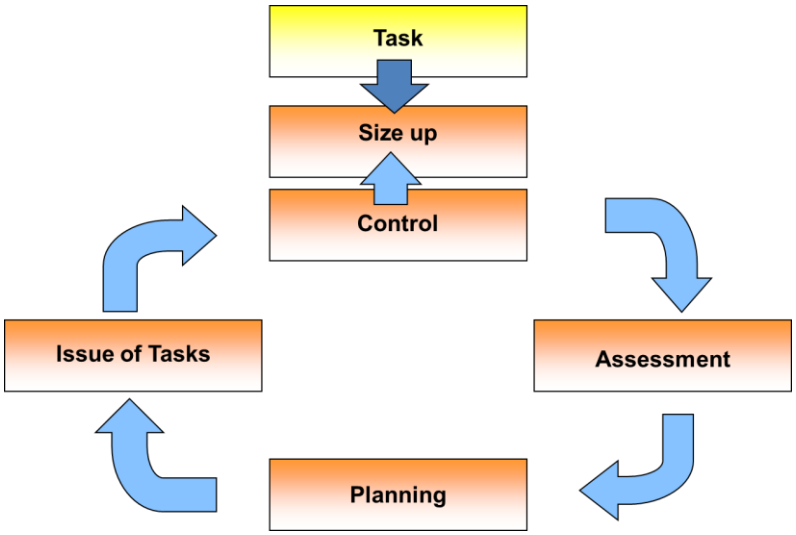

Figure 1: Control circuit of leadership

3. Decision theory

Economics but also military have been dealing with decision making in leadership ever since. It is a central part of their profession in general. Because of their affinity to mathematics and because of a good data basis economic sciences have developed different models for supporting decision processes as well as for decision making itself. Known models are the cost-benefit analysis (Dreze & Stern, 1987), the cost-utility analysis (Zangemeister, 1976) or the analytical hierarchy process (Saaty, 1990). Problems with such decision making processes always occur when uncertainty has to be taken into account. When situations that have to be evaluated are connected to an uncertainty with defined probability, decisions are called "decisions under risk". The risk as a defined value is therefore known. Such decisions can be compared to a game of roulette, where the probability for a certain number to occur can be expressed mathematically. If a defined amount of money is set on a selected number, the risk for a total loss can be calculated. A fundamental precondition for decisions like this is a good data pool and the certainty that data collected in the past will be valid for the process in the future. If that's not the case even a huge load of data will not allow a prognosis regarding the future.

Decisions where all surrounding and influencing factors are known but no probability data is available are called "decisions under uncertainty". For "decisions under risk" the actual risk value is the basic parameter for the decisions process, for "decisions under uncertainty" a prognosis on basis of probability values it not possible. The actual risk is therefore unknown and can only be estimated by experience. Other methods for decision making are intuition or simple decision rules, so called heuristics. Intuition works for several cases but can often not be explained by the decision maker himself. Heuristics are the mechanisms of intuitive decision making processes, they follow strict schematics but are not recognised consciously.

Heuristics are the capability of intuitively finding solutions within a short period of time, having limited information. (Gigerenzer & Todd, 1999) A simple heuristic approach can be observed looking at an athlete trying to catch a ball. The trajectory of a ball is affected by various physical and mathematical factors (launch angle, speed, etc.). Many of these factors are unknown to the person trying to catch the ball. Because of these unknown factors solving mathematical equations will not lead to success. Studies have shown that athletes are using a simple heuristic to solve the problem. The perspective heuristic is one of these mechanisms. By fixing the angle of view towards the object and adopting the running speed so the angle of view can be held fixed, the athlete is able to catch the ball. Based on a simple mechanism an equation with various unknown factors can be solved. Similar behaviour can be found in wildlife. (Shaffer & McBeath, 2002)

Besides that, it is also important that decisions are made in the right situational frame and that the preconditions for a decision are not fundamentally misinterpreted. An example for such a false interpretation of the surrounding conditions is the so called turkey illusion (Gigerenzer, 2014). For a turkey the probability of being fed is at the highest level right before the day it's killed. The same person that fed it several days before thanksgiving will kill the turkey although it expected that it will be fed again. The turkey never knew about thanksgiving. The basis for its decisions where fundamentally wrong, although it had the feeling of being able to evaluate the own risk situation properly.

Transferred to decision making processes within emergency services some decisions during emergency work must be seen differently. Heuristics have been known in emergency services for a while but are often not recognised as such. The common opinion is that simple rules can only be applied to simple problems. The following examples show some complex decision making processes where heuristics have been applied.

4. Heuristics

As mentioned above, heuristics are commonly known and used throughout emergency services. From "never pass a fire" during interior fire attacks or "VES – Vent Enter Search", such rules of operation are based on simple everyday life rules. Those rules are used if a high grade of insecurity exists on an emergency scene or if no further information on hazards or tactical restrictions is available. Such heuristics have proven well within rescue operations throughout the past. Numerous heuristics are commonly unknown to users and their origin is not only related to emergency services. The origins of heuristic approaches within decision making are bound to development processes within human evolution.

After the 2013 explosion in West (TX) an official accident investigation commission was formed to investigate the death of 12 fire-fighters (Bass et al, 2013) killed on April 13th 2013. The accident took place during an industrial fire that can be categorised as a high-risk-fire because of the stored chemicals especially because of large amounts of ammonium nitrate. West Voluntary Fire Department (VFD) had average experience in dealing with structural fires (2011 - 3 structural fires, 2012 - 18, 2013 - 1) but no significant experience in industrial firefighting. Following remarks are mentioned in the inspection report (Bass et al, 2013):

„Residential fire attack approaches are highly effective in controlling a large percentage of most structure fires and were likely effective in controlling a large percentage of the fires the West VFD had encountered over the years. However, for a large and complicated commercial occupancy, alternative firefighting strategies must be considered early and reassessed continuously throughout the incident" Besides different other options like abandon the building and evacuating the area, VFD choose the commonly used method and approached the fire by a standard attack procedure."

By rethinking the decisions made during the accident in West analysing benefits and disadvantages between an offensive approach and abandoning the building, only limited rational reasons can be found for the decision to approach the fire. Emergency services had to deal with various problems like bad water supply. The extent of the fire already involved large areas of the building and also a minor number of fire fighters were available. One question still remains. Knowing of all the problems and the potential threat of an explosion because of the stored ammonium nitrate, why did they choose to fight instead of an evacuation?

A possible explanation can be given by the Fluency Heuristic (Jacoby & Dallas, 1981). If a person is dealing with two or more options, the option that comes into mind the quickest will be chosen. Decisions are not made based on different factors but only because of the time needed to remember.

Especially in the US, offensive and defensive operation methods are trained, especially mentioned and well known. But if one method shows great success during a period of time, other possible options seem to be put in the background, which means it takes longer to remember them. So the possibility of choosing the second option is decreasing. VFD mainly dealt with structural fires, where an offensive attack is a common strategy.

In extreme cases, for example if only one option is known and other alternatives are unknown, decisions may be made because of the "recognition heuristic". The recognition heuristic is based on the fact, that when it comes to choose between two options, the common option will be chosen (Goldstein & Gigerenzer, 2002). Assuming the option of abandoning the building in the mentioned case was fully unknown but the better solution, people would still have chosen the common option, even if this is objectively seen, a bad idea. In case of the West incident a Captain from the Dallas Fire Department which incidentally came along the scene during emergency operations offered his help and proposed to abandon the building. His suggestion got refused.

Decisions based on recognition heuristics are the main topic in "Falsche Taktik - große Schäden" (False Tactics – Big Damage) by Markus Pulm (Pulm, 2002). The publication deals with the process of choosing tactics and strategies for fighting fires in buildings. It seems to be very likely for firefighters to choose common access ways into a building, even if alternative ways would be more suitable related to the overall result (damage control). Also these decisions are based on heuristics and not because of weighing consideration and possibilities. Accessing via a stairway is a common way of entering a building. Alternative options are unknown during the early phase of an incident and have to be evaluated. The main entrance will be recognised immediately as an entry way into a building, windows or a garage door won't. Similar decisions can be seen during technical rescue operations after a car accident. A trapped person is often recovered via the front door although recovery via the boot lid can be a very fast and effective method.

Another widely used heuristic is named "Take the best" (Gigerenzer & Goldstein, 2003). If both alternatives are well known, so called "cues" are collected and used for decision making. All collected cues are ranked based on their validity. By comparing cues a decision will be made as soon as a difference appears. The decision is based on only one factor.

Compared to complex statistic models, the "Take the best" method is coequal when dealing with problems on a low level of information. In contrast to "Take the best", the cues for the so called "Tallying" are not weighted but added up (Dawes, 1979). The chosen method is the one with the most positive hints. Again the decision is made by only one factor, the highest number of positive cues.

A heuristic that does not require any additional information is the so called "Default Heuristic", also known as the "Default-effect" (Johnson & Goldstein, 2003; Pichert & Katsikopoulos, 2008). The Default effect can be explained as behaviour of not changing anything if there's a default. Decisions are made under expectation that a given status quo will lead to a better outcome than any change. People also tend to the default even if the default is set randomly. A study on cardiopulmonary resuscitation (CPR) on new born babies, carried out by Haward (Haward et al, 2012), revealed that 80 % of the tested physicians would suggest CPR measures if these measures are set as default or standard. If "no CPR" is set as standard procedure 39 % of the participants would refuse to give CPR to a neonate. This shows the enormous influence of standard procedures during the decision making process.

In order to investigate the influence of standard operating procedures (SOP) on the quality of decisions within fire services an experiment has been conducted with several fire officers during a short study. Eight fire officers from the fire departments of Graz, Linz, Salzburg and Innsbruck have been confronted with six comparable standard scenarios allowing decisions towards the standard procedure but also an alternative way of solving the problem was possible. All participants had a comparable level of experience. For three of the six scenarios decisions had to be made within three seconds after a series of 4 pictures of the incident. The other three scenarios had to be solved without any time pressure. 90 % of the participating fire officers chose the standard procedure for the situation with and without time pressure. All eight officers have also been confronted with scenarios from an industrial surrounding where no SOP was available. For the three tested industrial incidents no common approach was found within the group of participants. Time pressure led to more deviating decisions compared to situations without time pressure.

The following example explains some of the effects of the so called "imitate the successful heuristic" (Boyd & Richerson, 2005). Within live fire training in Germany and Austria standard shipping containers fired by wood pallets or chipboards are used to model compartment fire behaviour (cfbt) and to train firefighting tactics. During the establishment of this training method also different emergency procedures for firefighters encountering extreme fire behaviour have been discussed and developed. One of the procedures was the so called "flashover-reflex" (Ridder et al, 2013). The flashover reflex originates from a very innovative German group of cfbt trainers which have been recognised for their work during the establishment of this type of training in the early 2000s. The fact that they dealt with live fires drew some attention on this "successful" group of trainers. The flashover reflex, that later proved ineffective and hazardous, was adopted by a lot of firefighters prior to training or tests in real emergency situations. The developers of the flashover reflex later refrained from using this procedure.

Closely analysing the incident happening in 2016 at BASF SE in Ludwigshafen it can be concluded that heuristics fail in situations where the preconditions do not meet experience or knowledge about a certain hazard. The explosion of a high pressure ethylene pipeline killed three firefighters and a civilian in the northern harbour area of the BASF SE Ludwigshafen plant. One firefighter died a year after the incident in the hospital. At 11:21 a.m. on October 17th 2016 a fire occurred at a pipeline route in the northern harbour area. Emergency services arrived at 11:24 a.m., the fatal explosion took place three minutes later (Haselhorst & Friedrich, 2016). When the explosion hit the emergency response workers they have been busy setting up water monitors cooling the neighbouring pipelines to prevent an explosion. Whatever decision was made by the incident commander it was based on the assumption that there is room for decisions to be made. By experience and because of the short response times there should have been a short time frame for emergency measures. A total loss of the pipeline within the first minutes was not expected or seen before. Several experts later stated that the decision of the incident commander to offensively cool the affected area was not a false decision but made under assumptions that had been successful so far. The common heuristics for comparable situations were not applicable for this specific incident.

The above examples only provide a short insight in the topic of heuristics within the work of emergency responders. Complex decisions are often reduced to simple approaches especially under high uncertainty and time pressure.

5. Problems with heuristics

According to the examples and considerations above heuristics are simple decision tools which only require limited information on the subject itself. Generally it is assumed that the quality of decisions increases the more information is available. Regarding heuristics that assumption cannot be verified. Decisions based on heuristics tend to suffer from an increase of information. Beilock & Carr (2001) investigated two groups of golf players to study the influence of information on their gaming results. Results from professional golf players were compared to the results of beginners under a specific test setting. During the first experiment all two groups of golf players were given an unlimited amount of time before strike. At the second experiment all players were given exactly three seconds to execute a strike. It was observed that rookie golf players had a benefit of the longer preparation times. They had enough time to adjust to the new task and were able to prepare for the strike. Although overall better, professional golf players achieved worse results with longer time for preparation. The time they used to think about their strike and question their own intuition in advance, influenced the result negatively.

An example for such an information overflow was given by an experienced fire officer of Osnabrück Fire Department after an extended fire in a sauna area of a fitness club including a fire gas explosion (Südmersen, 2017). The mentioned fire officer was well trained and spent a lot of time scientifically investigating phenomena of extreme fire behaviour within compartment fires. He was mainly involved in the development of training standards and various training materials for compartment fire behaviour training. Within this emergency situation he encountered exactly the situation he had the biggest theoretical expertise in. Regardless of these positive preconditions the mentioned fire officer described his decision making process as strongly negative, influenced by the huge amount of possibly relevant parameters he knew about. The situation itself was described by several other fire officers as sophisticated but more or less a standard situation. One testimony later made during debriefing is specifically interesting (Südmersen, 2017):

"...so many facts, opinions and experiences – but no precise plan of operation"

This statement shows the problematic situation of trying to use heuristics under an overflow of information. After 20 minutes of unsuccessful attempts to extinguish the fire the fire officer made the decision he had first in mind when he arrived at the scene. The mentioned problem during decision making slowed down the whole process significantly. In analogy to the example from golf sports the fire officer states (Südmersen, 2017):

"It is a difference between laboratory conditions or test fires and real fire situations. A lot of stressing factors and a lot of useless information is available while there is a lack of crucial information. That leads to the situations where leading personnel is put into a situation where decisions are rather made by a gut feeling than by leadership processes, tactical roles or mnemonic acronyms."

A main demand from this statement is the requirement of experience as a basis for good decision making within emergency situations as well the reduction of "useless" information that may influence the decision making process negatively. Gigerenzer & Selten (2001) postulate that a person owns an "adaptive toolbox" of heuristics that enables each person to choose the right heuristic for a certain problem set. When and furthermore which heuristics are chosen has not been investigated yet.

6. Conclusion

Heuristics play a crucial rule within decision making processes in emergency services. It is still not sufficiently investigated which heuristics are of particular interest for emergency services and how they can be improved and developed. Heuristics influenced by experience bear the hazard of being misleading within non-standard situations. Proper heuristics may not be available for rare situations or single events but decision making processes may be influenced by the available "toolbox of heuristics". For leadership training it is crucial to gain more knowledge about the mechanisms of decision making within emergency services especially regarding the use of heuristics. Especially for decision support tools it may be important to know more about these aspects.

Heuristics that have been developed by long time experience may also lead to wrong decisions when external conditions change. The increase of fire loads within residential buildings or the use of alternative fuels in transportation industry requires also an adaption of heuristics used by emergency responders nowadays. Also a change in constructional preconditions may have a negative influence on acquired and learned heuristics. Shorter standing times of buildings or the use of flammable insulation materials outside of buildings influences the development of incidents and may also challenge the decision making processes. Leadership training is strongly focusing on very structured leadership procedures and decision tools that are often not applied in real situations and replaced by simple but practical rules. It is important to study these simple rules aiming for an improvement of decision making processes especially in emergency services.

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