Technical innovation in fire fighting; an ICT approach

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Abstract

Recent developments in infrastructure, urban and land use planning have focused the attention of fire fighting, rescue and emergency and researchers towards innovation. On one hand a tendency is discernable towards increasingly intense, compact and embedded objects in a tightly coupled interaction with their environment. On the other hand, isolated objects in remote areas with low population densities and decaying service levels indicate a decreased match with timely response and accessibility requirements. Simultaneously, a reduction in supply among volunteers is noticed, while the requirements from a professional view are increasing regarding skills, training and proficiency. The fire fighting community has expanded its tasks to other tasks requiring co-operation with medical services and police forces. OSHE and traffic law requirements put increasingly restraints on the flexibility of responses for emergency.
The issues raised have questioned the conventional approaches to fire fighting, rescue and emergency handling, leading to an innovative approach, focusing on technical equipment and the opportunities for ICT decision making support in all phases of operational practice. The results of a pilot study by the Eindhoven Fire brigade are presented.

Introduction

In the Netherlands, several relatively independent developments are going on in transportation, regional economical development, land use, urban and spatial planning. These developments are dealing with:

- an absolute growth in road infrastructure and means of transportation for passengers as well as goods within and between cities and regions, including hazardous material transportation on road, rail and inland waterways
- the development of a small number of major infrastructural projects with international perspectives such as dedicated cargo railway lines, high speed railway passenger

lines, maglev technology and the extension of the two mainports in the Netherlands, the Port of Rotterdam and Schiphol airport.
- stimulation of economical regional developments, modeled after Silicon valley like industrial areas, combined with knowledge infrastructures and newly build major dwelling areas
- the development of compact cities, with an increased density and occupancy rate, diversity of activities and multifunctional use of limited space. Especially in the centers of major cities developments focus on revitalization of railway station areas.
- transformation of rural areas into areas with low density dwelling and economical activities, replacing agricultural activities by environmental friendly and extensive land use and nature preservation functions.

These developments are dominated by economic constraints such as a 24-hour economy, underground infrastructure and multifunctional use of scarce spatial opportunities.
Until the last decade, fire-fighting organizations have been dealing with conventional situations, focusing on fire fighting and have based their approaches on practical experiences in the past. Two new types of response seem to be appearing, necessary to comply with the mentioned developments. On one hand a response is required in a very compact and interactive urban and transportation environment, on the other hand a response in a very isolated and desolated rural area may be necessary.
The question will be raised whether present fire fighting concepts are still adequate to comply with these new situations, which will be encountered in the next decade.

A changing world

The traditional world of fire fighting is changing. Initially, a fire-fighting brigade consisted of a large team of volunteers, managed by a small professional staff or single commander. The fire fighting activities and responsibilities were allocated to the local governmental levels without much coordination beyond this level. Only in major cities and high-risk private enterprises, a full-time professional fire fighting service existed to cope with the scale and frequency of the events. This concept has been under pressure due to a lack of national and local political and managerial priorities, financial cutbacks and cost-efficiency considerations. As an example, the overall number of fire fighting services in private enterprises reduced within a decade from 550 to 362 (B&B 2001.1). The military fire fighting response at the Hercules aircrash at Eindhoven was heavily criticized for its inadequacy, but proved to be seriously understaffed due to budget reductions. On a social and policy level, a shared responsibility concept is embraced, leaving unsettled agreements between stakeholders on the allocation of responsibilities in public-private partnerships. OSHE and traffic law requirements put increasingly restraints on the flexibility of responses for emergency situations, also putting high demands on professional judgement during decision making in crisis and emergency situations (B & B 2001.2). A controversy emerges between the responsibilities of organizations and the responsibility of their emancipated employees, questioning the capabilities for decision making for on-scene commanders. In accordance with more generic social developments, litigation and liability enter the area of fire fighting responsibilities and accountabilities, fueled by true or false allegations of misconduct, inadequacy or poor performance. This trend seriously discourages people to join the volunteer fire fighting ranks, which are already facing a reduction in new entrants due to economical and occupational pressure of modern society.

As a result of ending the cold war and the millennium issue, a re-engineering of crisis management has been taken place. The new concept has abandoned the ‘worst case scenario’ and has defined ‘crisis’ as a major incident . Although some incidents may be rather small, they may contain valuable lessons to be learned as well and as such, may contribute to a more pro-active and preventive approach. Simultaneously, the focus has been shifted from the vital role of a ministry towards the field organizations where coordination and context are dominant factors. Principle requirements in the new concept are networking, disaster planning and quality assurance, including training and exercises. The concept of a ‘pilot flame’ organization, which could be activated in case of warfare, is abandoned in favor of integrating crisis management in regular policy making and emergency planning activities. Topics focus on environmental pollution, transportation, flooding hazards, hazardous material incidents, underground infrastructure and information network breakdown. This list of new topics has expanded the required scope of the fire fighting community tremendously. In addition, the fulfillment of the Post-Seveso Directive of the European Union to deal with disaster and major accidents has put pressure on the community to scale up in resources and striking capabilities. It has lead to the concept of a ‘Critical Size Event’ and the introduction in the Netherlands (Stoop 2001) of a Guideline for such events.

Consequently, during the last decade, within the fire fighting community a scaling up to regional levels is taken place, raising questions with respect to reinforcing organizations, budgets, resources, professionalism and co-operation with other professional in the rescue and emergency sector.

So far, many measures have been developed at a detailing level to reinforce the capability of the fire fighting community to comply with these expanded tasks and requirements. The development can be compared with mitigation of occupational and road traffic safety issues, where major efforts have been dedicated to engineering, enforcement and education at a detailing level in operational practice. Such efforts may be very cost-effective and may have a huge impact on the eventual safety improvement, but have their limitations if system characteristics change and new developments occur. Such changes may indicate system deficiencies and require innovative approaches to fire-engineering concepts.

Two new system types emerge with specific characteristics such as:

- a high compactness or extreme openness
- present in a densely populated and developed area or isolated and remote environment with equivalent high and low service levels
- with a very closed and confined nature or extreme spatial openness
- dealing with unidentified and large amounts of people or individuals at unknown positions.

Such systems require timely synchronization of primary and emergency processes to cope with emergency shutdown, rapid crash site accessibility, high degree of situation awareness, information processing, communication resources, high diagnostic skills for resource allocation, rapid familiarization with the situation, sustained risk assessment and high degree of self-relianceness of the population at risk. They may put constraints on the required rescue and emergency resources in terms of size and costs of preparation, repression and after-care.

Fire as a hazard

Apart form other hazards which the fire fighting community are confronted with nowadays, fire itself is still a very important hazard. A number of changes in the system have caused changes in fire characteristics as well (Van de Leur 2001).

The nature of fires are changing due to changes in building materials, construction principles, sizes and complexity of buildings. Conventional fire curves and fire load calculations may be no longer applicable, ventilation and smoke propagation may be different from a conventional building and situation-awareness of the exposed population in case of emergency evacuation may be low due to the complexity of the situation and lack of oversight. The overall population at risk may be very significant with respect to the numbers and triage of potentially injured. Fire curves have changed by the application of new materials with different ignition characteristics, combustion and toxic smoke properties.

Especially the trend to apply underground structures may aggravate the fire load and smoke propagation situation, if combined with large open spaces inside buildings and a luxurious furnishing. Tight coupling of production processes and multifunctional use may cause interference of activities and developments as demonstrated frequently with small fires at airport or railway terminals, causing major system and network breakdowns.

Exploring a railway station fire load may be illustrative. Causes of fire are multiple such as in railway stations, where furnishing, technology, equipment and merchandize in shops and other facilities may provide ample fuel for a considerable fire load. This despite the fact that most stations give a fire resistant impression at first sight due to their concrete, glass and steel materials and fashionable styling. Rolling stock may contribute to fire load and evacuation issues at stations as well by stopping in tunnels and at underground tracks. Major evacuations may become necessary because the concept of safe havens has replaced the concept of compartmentation, with a consequent evacuation need for passengers rather than restriction the fire expansion. Such massive evacuations may be hampered by lack of oxygen in confined areas, which may cause backdrafts and flashovers. Large evacuation distances may become standard due to the size of the buildings. Limited surveillance and security may hamper a proper and timely diagnosis and rescue initiation.

Finally, scientific support in fire engineering knowledge is still limited in the Netherlands. Smoke propagation and ventilation concepts are not developed for such major constructions and their extrapolations may give unreliable outcomes in calculations and simulations.

Intervention strategies

Proactive

Measures taken to reduce the risk discriminate between the probability of an occurrence and the mitigation of the consequences. At present risk reducing strategies for the fire

brigade focus on the detailing level in design and regulations by applying standards and certification. This approach is a generalization from operational practice, allowing gradual deviations from established concepts and principles.
Regulations are not available for new building concepts such as mainports and transferia. The present system in the Netherlands allows the fire brigade of a local community to issue Construction and Operational Licenses in the detailing phase of a major project. This does not comply with the need to participate in the conceptual and functional phases of the design and construction processes and the responsibility to prevent or mitigate disaster. Such a licensing procedure will generally lead to 'negotiated knowledge' and consensus among stakeholders about acceptability of risks as 'social constructs'. If a substantive analysis of the hazards involved and a quantitative assessment of risks and accident scenarios is not incorporated this approach, the final result may lead to 'negotiated nonsense'.. During the operational phase a multitude of risk reducing measures of a managerial, organizational or legislative nature are available, such as safety management system, audits, inspections, standards and regulations. They will however require permanent attention and dedication and should be maintained during the operational life span of a system. Safety Impact Assessment procedures are in their first phase of development and are presently elaborated in design and construct pilot studies for underground parking lots and warehouses (COB 2000). Integrated safety management systems, which incorporate rescue and emergency aspects, do not yet exist.

Reactive

If a preventive hazard analysis is not possible, lessons have to be learned from practice. In most cases, these lessons will be drawn from investigating accidents and incidents. Due to a recent series of major incidents in the Netherlands, the concept of independent accident and incident investigations will be applied to rescue and emergency disasters. The concept was developed in the transportation sector, but proves its value in other sectors of industry and social life as well (ETSC 2001). Such independent investigations serve as an instrument for society to guarantee that all possible efforts have been undertaken to prevent similar accidents in the future. It provides all stakeholders and actors with an instantaneous transparency of the systems functioning, identifying possible system deficiencies (Van Vollenhoven 2001). Historically the instrument has been applied to establish the causes of an accident. Today, the instrument is also applied to establish the factors that have been contributing to consequences of an accident. This is a promising application for the fire fighting community since it may benefit from the analysis, findings and recommendations of such investigations. However, the instrument remains reactive in nature and will not prevent accidents to happen.

Conclusion

Consequently, if a pro-active is not yet possible at the level of change in organization, legislation, regulation and a reactive approach does not fulfill requirements of prevention, preparedness towards disaster and accidents offers opportunities. A short time focus on preparation, repression and after care remains. Within the time-span of the next decade technological change offers specific opportunities to improve fire fighting performance.
In general, technology is able to offer concrete results for dedicated tasks, can be adapted to specific needs and environments, has a relative short design and development time and

can be assessed relatively easily with respect to its cost-effectiveness. In addition, it complies with the culture in the fire fighting community towards technology and acceptance of its products in practice.

Technological innovation, a challenge

The fire fighting community in the Netherlands is confronted with changes in the professional scope, which have prominent consequences for the operational practice. Several new tasks of a technical nature have been added to the traditional fire-fighting task in the transition to a new crisis management concept. Major infrastructure, urban and regional planning projects add two new environments with inherent open or closed characteristics to the scope of the fire brigade. Human resources are diminishing because fewer people are available and professional requirements are rapidly increasing.

The fire fighting community is confronted with changes in society as well. Operational practice occurs in the eye of the public with increasingly demands with respect to liability and accountability. Responsibilities are transferred between echelons in administration, while scaling-up of the organization to a regional level takes place.

Under these circumstances, it was felt that present levels of technical innovation were insufficient. Technical innovation was restricted to the detailing level of modification, fire-fighting concepts and repression philosophies were not questioned. Application of ICT for training, simulation, navigation and communication was, if applied at all, not integrated into a systems perspective. Since fire fighter will be confronted with unique situations and will have to rely on naturalistic decision making, a flexible and innovative approach was considered appropriate.

Therefore, the fire brigade of Eindhoven took the initiative for an innovative approach and pro-active perspective entitled ‘Nikita, fire brigade innovation’. The scope of the developments should be defined beyond existing operational practices and techniques for a timeframe of 10 years. Technological innovation was stimulated by questioning existing situations in a series of brainstorm sessions through questions like:

- do we still apply a large vehicle with six occupants to bring the water to the fire or do we apply a two-seater with high tech equipment?
- is the chain of command still operating on-site or is the operations room the center of command?
- do we still apply physical charts and road maps or are we ICT supported by head-up display in the shields of our helmets?
- can we apply virtual reality simulation techniques for training purposes eliminating the need for massive practical exercises?

Applications of technical and organizational nature should highlight a prototyping of repressive tasks for the fire brigade-new style. Starting point was the surrounding environment, the technological opportunities already presently available and the way the fire brigade is able to anticipate on these situations. The essence was the redefinition of the philosophy for repressive action rather than developing new technical equipment.

Technologically, generic design principles were applied, such as flexibility, automation, remote control, miniaturization and transparency. The introduction of ICT applications was selected as a focal point for technological design.

Innovation in repression

To structure the search for technological innovation, a process approach was applied to the repression phase. Eight steps were defined to focus on opportunities for ICT applications; reporting, call out, turn out, arrival, reconnaissance, rescue, extinguishing and after care. A series of brainstorm sessions resulted in a normative and descriptive overview of opportunities (Van Dooren 2000):

Reporting

In 2010 hardly any use will be made of the present telephone network. Everybody will have wireless phones with speech recognition for personal identification. By GPS systems a direct position finding and identification system is operational, facilitating early warnings and eliminating false positive reporting. Calls will be automatically forwarded and confirmed by on-site sensors in the building. By linking calls to objects, on-line information supply is available, supported by video information.

One fully integrated national operating room will be realized, which control all emergency activities. Local familiarity is no longer necessary. Speech pattern recognition will analyze the information and translate this into a resource allocation scheme. Coverage of unit call-out bases will be fully deployed, facilitating a 5-minute turnout time schedule throughout the country.

Information on local infrastructure, temporary and permanent deviations, enables the guidance of crash tenders to navigate through dense traffic. Accurate estimations for a dedicated allocation of resources are possible regarding team composition and equipment.

Call out

Due to a centralized concept, transfer of information between operation rooms will not be necessary. The available amount of information in vehicles is abundant, requiring selective use of the available amount of information. Overkill in mobilizing workers to guarantee sufficient presence at the scene will be obsolete. Interactive communication will ascertain adequate availability and expertise. Introducing a GPS link enables mobilization of individuals depending on their actual position. All equipment will be integrated in regular telecom equipment and miniaturization will be introduced. Since volunteers will diminish in numbers, almost every individual will be a career officer on consigned or barracks base, which will guarantee maximum attendance. It is an open question whether all-round basic units will be applied in a dense network or a system of specialized units will be favored. An upgrading model is possible in which specialists are mobilized on request.

Turn out

Due to extensive computer analysis, all relevant information of object and environment will be available on screen in the vehicles. The computer determines size and nature of the unit. Keywords are speed, dedicated equipment, suitable for the local situation and equipped with specific means, depending on the incident requirements. A remote control information analyst supports the unit leader and maintains oversight over the situation. All equipment will be fitted with chips to facilitate their tracking and maintenance status. In 2010 a close cooperation between all units will be established, covering all shackles in

the chain, including police and medical services. In addition to fire fighting units, other rescue and emergency disciplines will be involved. Formal authorization to fulfill certain tasks will be expanded, based on certification, training and skills. This will increase the flexibility of the workers across the various disciplines. Almost every road infrastructure will be fitted with automatic vehicle guidance, supplying blockage for other traffic to give right of way to emergency vehicles.
Sensor equipped clothes for the unit members do not only give status reports about heat, contamination, wear and tear conditions, but also supply integrated techniques for online operational performance indication and physical condition monitoring. Helmets are integral communication devices for speech, active sound filtering and auditive and visual data supply.

Arrival
High fidelity position devices will facilitate the tracing of addresses, as well as internal routing through buildings. Extinguishing techniques will be improved, eliminating to a high extend the application of hoses and replacing water supply by chemical substances for fire retardation or dedicated water shells.
In case transmission of vital information concerning building characteristics, population at risk or location of fire sources from the operations center to the vehicles on site is impossible, the commander on scene can apply a hands-on electronic downloading. He will have access to a data source connected to the building data bank, which can be transmitted to the helmet visors. Online linkage to the analyst/controller in the operational center will support the task of the commander and reduce the necessity to have redundancy in personnel at the site.

Reconnaissance
Analyzing the presence of hazardous substances will follow a standard procedure by sensors or probes. Substance analysis will calculate the probability of explosions, survivability and preparation strategies for rescue of victims. A image analysis is made by heat and infrared sensors integrated in helmets, which provide an adequate image of the situation, despite smoke or reduced visibility. These images can be observed by other on-scene fire fighters or even by the controller in the center due to wireless transmission of the data. These images are recorded for training and evaluation purposes. Robots, carrying additional equipment for fire fighting, substance analysis or other hazardous tasks perform unmanned reconnaissance missions. Electronic tracing can mark routes, which are reproduced in the visors of the helmets and compared with the planned routes as suggested by the computer in the operations center. All reconnaissance units will receive the available information and markings of hazardous situations on their visor. Due to the enhanced image processing, the reconnaissance period can be reduced and its quality improved.

Rescue
Public information systems and local support facilities will be readily available to improve self-relianceness and to ensure adequate responses of the public during rescue and emergency activities. Inside buildings a Safe Area concept is applied with

autonomous ventilation and communication facilities where victims can safely survive waiting for their rescue.
Advanced frequency scanning techniques will identify people and other living creatures inside buildings and indicate the direction for a search mission. After contacting the victims, a remote controlled diagnosis is possible by an interactive device between rescue worker and the operations center where specialized medical care is available. Such a device will facilitate advanced life support and rapid medical response, once the victim is transported to a safe haven.
The application of anti-noise will eliminate the sound of the fire, enabling the workers to intercept and identify voices, gas leakage and other hazard indicators.

Extinguishing
Since water is only applied for major fires by developments of fast fire retarding chemical substances and improved supply techniques, the need for water transport on a large scale is eliminated, especially where sprinklers have become mandatory.
Due to the fact that the speed of operations has increased significantly, ventilation can be applied from the first moments on, reducing heat load and increasing visibility and survivability rate for the victims. Due to the use of robots, extinguishing fires at the source can occur from a short distance without risks involved for the workers and commitment of a large amount of individuals.

After care
New extinguishing substances and equipment will considerably reduce the amount of damage and required salvage efforts. Immediate recovery may occur, while video recordings assess the damage for insurance purposes. A specialized unit will immediately start forensic investigations for criminal and litigation purposes as well as evaluating the efforts of the fire fighting and rescue activities.
After returning to the barracks, data recorders will be analyzed at the level of units, vehicles as well as individuals for reasons of performance, lessons learned, accountability and reporting. Personal data recorders will analyze the physical loads to which the workers are exposed and the results will be filed in their medical dossiers.

Final remarks

In a pilot project, the fire brigade of Eindhoven developed new approaches regarding downsizing of equipment, mechanization and automation of task elements and stimulation of flexibility and remote control. The project analyses the role of ICT throughout the operational processes, developing new concepts for technological innovation. During operational practice as well as in training and simulation environments, new strategies are developed. Opportunities for further technological and organizational developments are indicated, based on the first experiences in the pilot project.
A follow-up of the project is planned on a national basis, supported by the Ministry of Internal Affairs by funding and creating a consortium in which fire fighting organizations, researchers, local and national governmental organizations and other stakeholders will sign an agreement to pursue innovation on a national level.

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