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Innovations for Building and Construction

Towards a better, stronger and sustainable future using advanced ICT

Edwin Dado
Reza Beheshti
Khaldoun Zreik

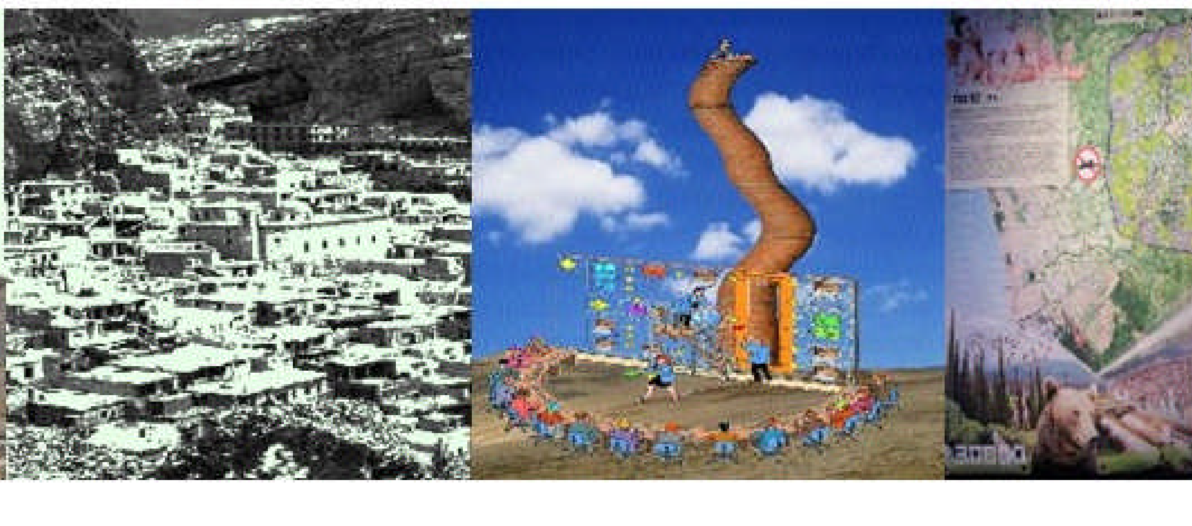

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Table of Contents

Innovations for Building and Construction: towards a better, stronger and sustainable future using advanced ICT …………….…………………… 11
Edwin Dado, Reza Beheshti and Khaldoun Zreik

Research Vision for Building and Construction ……………...……… 29
Hennes de Ridder and Reza Beheshti

Sensory social networks to motivate sustainable behaviour ……..…… 45
Jos van Leeuwen, Ian Oakley, Nuno Nunes, Valentina Nisi and Vassilis Kostakos

Designing and Manufacturing in Digital Design: the case of Jakob+MacFarlane 57
Anne-Sophie Delaveau, Caroline Lecourtois, and François Guéna

Towards business process improvement: a construction case study 73
Bhargav Dave, Lauri Koskela, Mike Kagioglou, Robert Owen and Joseph Tah

The impact of future climate scenarios on decision making in building performance simulation: a case study 91
Christina Hopfe, Fried Augenbroe, Jan Hensen, Aad Wijsman and Wim Plokker

COLAB and collaborative design of sustainable buildings 105
Hans Hubers

An immersive, multisensory and interactive approach for landscape stu in virtual environments: the wind turbines' case 121
Jihen Jallouli and Guillaume Moreau

A sustainable collaborative approach to promote publications related to advanced design sciences and technology in the domains of Architecture, Construction and Urban Planning 141
Rachel Kamga and Khaldoun Zreik

A control framework for a biomimetic structure 153
Ian Smith

Incorporation of mitigations on the run in probabilistic network planning 173
Lex van Gunsteren and Rien de Graaf

A decision-based design approach for collaborative construction 185
Ruud Binnekamp, Jeroen Burger and Peter-Paul van Loon

The communication of heritage spaces within a sustainable context using ICT 205
Nada El-Khoury and Giovanni De Paoli

Bayesian Networks for commissioning and decision making-aid in low energy building design 219
Nazila Hannachi-Belkadi and François Guéna

The mapping of conceptual structure by star topologies: a case study on community 235
Lanting Clare Tseng

Model-based CE-performance assessment in BC industry 259
Nesen Surmeli, Jan-Willem van de Kuilen, Wolfgang Gard and Reza Beheshti

The Value of a Public Private Partnerships 277
Raymond Turner, Hennes de Ridder and John Ratcliffe

The usage of evacuated solar tubes for heating purpose in residential buildings: Green Energy Benny Farm Montreal as a sample 299
Meltem Yilmaz

Web-based feedback system for construction: features, demands and content 313
Sami Kärnä, Juha-Matti Junnonen and Mitri Häkkinen

An innovative knowledge structure for supporting collaboration in building design 331
Gianfranco Carrara, Antonio Fioravanti and Umberto Nanni

The Living Building Concept as design tool for safe buildings 351
Shahid Suddle, Hennes de Ridder, Tufail Ghauharali and John Stoop

Framework for supporting sustainable design 373
Tajin Biswas and Ramesh Krishnamurti

The ubiquitous design environment for structural engineers 387
Martinus van de Ruitenbeek and Reza Beheshti

Composing smart houses 413
Yi-Pin Huang and Sheng-Fen Chien

3D activity representation and analysis, as a basic unit to construct development process models, considering complex characteristics 425
Javier Pereda, Arturo Molina and Godfried Augenbroe

Towards a holistic model for effective knowledge management for the building and construction departments within the Dutch defence organization 449
Edwin Dado and Tim Grant

IT domain ontology map as an access to scientific corpus for advanced learners 461
Gérald Kembellec, Imad Saleh and Catherine Sauvaget

Construction project requirements and needs elicitation by prioritising wishes 479
Saban Özsariyildiz and Reza Beheshti

StructuralComponents: parametric associative structural design tools for high-rise 491
Janwillem Breider and Jeroen Coenders

Author index 501

Organization and place index 503

Subject Index 505

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The Living Building Concept as design tool for safe buildings

Shahid Suddle,[1] **Hennes de Ridder**,[2] **Tufail Ghauharali**[3] and **John Stoop**[4]

Due to a shortage of space, large urban development projects are realized adjacent or above transport routes of hazardous materials, causing external safety risks for people present (living or working) in such an environment. In The Netherlands, the decision making on land use planning regarding safety is traditionally based on a risk acceptance, and safety is in this respect not more than a test tool. However, no design standards for land-use planning in multiple and intensive used areas are given by the legislator. This paper presents a new look on coping with risks. One of the main purposes of the paper is to consider safety as a design parameter at an as early as possible stage in the development of urban locations, in stead of a test tool, resulting in safety measures taken within the project budget. The design tool should also be used at different scale levels: urban level, area level and building level. By doing this, safety integrated design and engineering is introduced in development of complex projects, which are currently confronted with the continuous changing demands of the users and legislators. Resulting from these changing demands, flexibility and clear insight in the lifecycle processes with a focus on design is very important. In this regard, we discovered that the Living Building Concept (LBC) can be used as a tool regarding safety integrated design and engineering, through which the relation between urban/land-use planning, civil engineering, environmental engineering and risk and crisis management can be strengthened.

Keywords: Living Building Concept, integral safety, risk analysis, urban planning, safety integrated design engineering

1 Introduction

Safety is nowadays one of the main items on the agenda during the planning, realization and management of most large-scale complex projects, particularly in infrastructure and building projects in intensively used areas. In The Netherlands, large urban development projects are realized adjacent or above transport routes of hazardous materials, causing external safety risks for people present (living or working) in such an environment

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(Figure1). In order to regulate the (economical) benefits of the transporters of hazardous materials and urban development projects, a so called risk based policy is used in The Netherlands. The main advantage of such a policy is to preserve the remaining “empty” areas as long as possible if alone to provide recreational area’s for the inhabitants of the congested cities. The main disadvantage is that “extra” safety precautions should be taken to realize that project. If these precautions are taken in a late design stage of the project, extra costs and an overall process delay is mostly the result. If these safety aspects are properly considered at an as early as possible lifecycle stage of a project, then the project can still be realized without extra costs, except the investments of the safety measures. This concept is called *safety integrated design engineering* (Suddle, 2007). However, this strategy does not always work in practice. Usually safety measures are taken afterwards along with a large investment, because the design of that project is almost finished and construction is being started, resulting in non-available design option are in this late stage of a project. The reason hereof is simply the aim of the external safety policy in The Netherlands: safety measures are required on the outcome of risk analysis and not on design grounds of an urban plan.

Figure 1 An impression of the Bos en Lommer Office buildings with transport of hazardous materials

Summarizing the previous, it can be stated that on one hand safety is approached traditionally, in which a risk analysis is conducted and possible safety measures are derived afterwards. On the other hand, safety is associated with life cycle processes, such as requirements analysis, design, implementation, integration, operation, maintenance etc. The first traditional approach can be widely found in literature and currently executed widely in the Netherlands. The second approach is an unrevealed phenomenon where safety integrated design and engineering in relation to land use planning adjacent to transport routes of hazardous materials is propagated. It is a topic on which not much research has been done. Almost no proper scientific references in literature can be derived on this topic. Stoop (1990) urged in his thesis to implement safety measures in the design stage of every project. Stoop (1990) considered particularly safety integrated design engineering in the aviation safety regarding aerospace engineering. However, Stoop (1990) did not consider safety integration in urban planning and transport of hazardous materials. In this respect, safety measures should be implemented in multiple use of space projects from different viewpoints (Suddle, 2004). Vrijhoef & Koskela (2000) observed a large quantity of waste in complex projects, since different design aspects are not properly investigated at an early stage of a project. The report of Suddle (2007) is one of the less empirical surveys on this topic, in which this issue is emphasized and explored for the first time. Suddle (2004, 2007) suggests considering safety as a part of an urban development (plan) strategy and ambition, enabling optimal and safety integrated land-use planning.

In this paper, we will focus on whether the Living Building Concept (LBC) can be used as a tool regarding safety integrated design and engineering, through which the relation between urban/land-use planning, civil engineering, environmental engineering and risk and crisis management can be strengthened. For this to occur, we will analyse what integral design and engineering is, what safety is and how it is considered and managed in complex projects where buildings are designed and development near transport routes of hazardous materials. In this regard, some missing links of the Dutch external safety policy are analyzed in this paper. Additionally, the external safety policy will be evaluated to provide the relation between safety, life cycle processes and information. Finally, this will provide the answer to integrate safety by means of LBC in complex projects.

2 Integral design engineering

Integral design is a difficult task. Integral design in relation to structural safety is a more difficult task. Integral design of an object in relation to external safety, in which influences of the vicinity are considered, is perhaps the most difficult task. Integral design in situations where the space is utilized intensively or in multiple ways where transport of hazardous materials take place underneath or adjacent to the buildings is almost an art, yet not surely impossible.

However, design standards for such cases are not (yet) given by the legislator. Neither the owner nor the developing parties (supplier) have knowledge on how to deal with safety aspects in the design stage of a project. Even the legislator of the national government doesn't have that knowledge. The legislator expresses particularly the norms for the acceptance of risks in relation to external safety, as presented in chapter 3. The legislator doesn't support solutions or design concepts in which safety is taken into account. It is even worse: providing supporting design methods in situations like mixed land use along with integral safety, are unfortunately beyond the scope of the legislator. Consequently, the design is more a trial-and-error design on the base of an ad-hoc method, through which the ultimate design becomes sub-optimal. In such designs, all relevant aspects (noise, air quality, external safety) are tested afterwards, i.e. at a very late stage of the design stage of a project. Such a working strategy doesn't contribute to both the process efficiency and transparency.

In the Netherlands, design standards for buildings are formulated by the government, enabling the structural engineer to make a safe and reliable design for buildings against wind loads, rainfall and / or heavy load of the main bearing structure of the building and its subsystems. This kind of safety is called in ante safety or internal safety. These standards consist a lot of standards for escape possibilities and reliability and safety of structural elements of buildings as well. However, no standards or design criteria are unfortunately formulated by the government or the legislator for the realization of buildings above or adjacent to the infrastructure with transport of hazardous materials. This kind of safety is called ex ante safety or external safety. In regard to external safety there is even also no judicial base for example the functional design of land-use planning in the vicinity of risk full locations, i.e. transport routes of hazardous materials or chemical installations. One should be aware that such circumstances will occur and such projects will be utilized frequently in the future, due to shortage of space. So, what is safety all about and how it is currently implemented in projects?

3 Safety and risk

Safety is a wide notion. Vrouwenvelder et al (2001) defined safety as the state of being adequately protected against hurt or injury, free from serious danger or hazard. If the philosophy of safety is considered, safety can be classified into social safety and physical safety (Suddle et al, 2008). Social safety constitutes mainly of the (perception) behaviour among persons. Crime incentive factors, spatial factors, institutional factors and social factors of an area are characteristics of social safety (Durmisevic, 2002). Social safety aspects are beyond the scope of this paper and therefore will not be discussed further.

In contrast, physical safety contains both the probability of a person being killed or injured by natural hazards, such as; bad weather, an earthquake, floods and the probability by man-made hazards, like traffic, calamities by transport of dangerous materials, calamities by nuclear reactors etc. It should be noted that several effects of failure like cost increase, time loss, loss of quality, environmental damage, also form a part of physical safety. In some cases, like fire or terrorism, it is difficult to classify the safety. The subdivision within physical safety divides into internal safety and external safety (Vrijling et al, 1998). The following subdivision, here ranked according to increasing benefit to the persons at risk is frequently found (Figure2).

<table>
<tr><td rowspan="22">Integral safety</td><td rowspan="16">Physical safety</td><td rowspan="11">Man-made hazards</td><td rowspan="7">Internal safety</td><td>Internal safety of buildings</td></tr>
<tr><td>Traffic safety</td></tr>
<tr><td>Labor safety</td></tr>
<tr><td>Tunnel safety</td></tr>
<tr><td>Fire safety</td></tr>
<tr><td>Transport safety</td></tr>
<tr><td>Construction safety</td></tr>
<tr><td rowspan="4">External safety</td><td>Stationary installations</td></tr>
<tr><td>Windmills</td></tr>
<tr><td>Aviation safety t</td></tr>
<tr><td>Transport van hazardous materials</td></tr>
<tr><td rowspan="5" colspan="2">Natural hazards</td><td>Floods</td></tr>
<tr><td>Earthquakes</td></tr>
<tr><td>Meteorites</td></tr>
<tr><td>Remaining climatic factors</td></tr>
<tr><td>Diseases and epidemics</td></tr>
<tr><td rowspan="6" colspan="3">Social safety</td><td>Terrorism</td></tr>
<tr><td>Criminology</td></tr>
<tr><td>Institution</td></tr>
<tr><td>Design</td></tr>
<tr><td>Sociology</td></tr>
<tr><td>Perception</td></tr>
</table>

Figure 2 Integral safety aspects

Generally speaking, safety consists both of subjective and objective elements. It does not automatically imply that, when a person experiences that he is safe from a psychological point of view, that he is automatically safe from a mathematical point of view and vice versa. The relation between subjective and objective components of safety with aspects of behaviour is presented in Figure 3 (Bouma, 1982). Subjective safety is related to psychological aspects (Stoessel, 2001) and thus can hardly be assessed objectively, while objective safety components can be assessed in objective terms if mathematical grounds are used. Note that sometimes the objective safety (measure) is based on subjective estimates. To define and to judge the objective elements of safety, it is vital to link safety with *risk* (*the combination of probability and consequences*), since safety cannot be quantified itself (Suddle, 2004). The advantage hereof is that risk can be quantified and judged whether it is acceptable or not, while safety itself cannot.

	Subjectively Safe	**Subjectively Unsafe**
Objectively Safe	*Healthy unconcern*	*Unhealthy anxiety*
Objectively Unsafe	*Unhealthy unconcern*	*Healthy anxiety*

Figure 3 Aspects of behaviour

In this paper we will consider external safety risks, i.e. risks of transport of hazardous materials to buildings adjacent to these transport routes, since this kind of problems are occurring increasingly in The Netherlands, due to shortage of space.

4 Dutch external safety policy for urban planning

In the Netherlands, regulations for land-use planning in the vicinity of major industrial hazards are explicitly risk-based. This implies that potential adverse physical effects of incident scenarios are considered along with their probability of occurrence and their possible impacts. One of the main reasons for implementing the risk policy is simply the shortage of space, as a result of which the optimal space according to the effect distance of a worst case scenario between a risk generating activity and urban development cannot be achieved. Three main elements constitute the Dutch regulatory risk framework. These elements are: (i) quantitative risk assessment, (ii) the adoption of individual and societal risk as risk-determining parameters and (iii) acceptability criteria for individual and societal risk. Besides these criteria, the ALARA-principle is adopted, implying that although in a certain situation the formal risk standards are met, efforts should be made to further reduce the risks up to levels that are as low as reasonably achievable. Whether additional investments in risk reduction are reasonable is determined by implicit or explicit societal cost-benefit analysis (Vrijling et al, 1998).

Basically, according to Kaplan & Garrick (1981) risk consists of three components: the scenario, the probability of this scenario and the consequence of the scenario. Risk is described in the Dutch policy practice as a set of: the probability of an accident as a function of its effects. This is the most frequently used definition in risk analysis. In practice, transportation risks with hazardous materials are estimated with several mathematical Quantitative Risk Assessment (QRA) models, resulting in a presentation of the risk picture. One of these QRA models used in the Netherlands is the so-called RBMII model (Ministerie van Verkeer en Waterstaat, 2006a). This standardized model is free for use and distributed by the Dutch Ministry of Transport, Public Works and Water Management. This is done to satisfy a need for a relatively simple, standardized and validated method to calculate relevant risk values (Ministerie van Verkeer en Waterstaat, 2006b). This model is assumed to be the benchmark model for all risk analyses to be made regarding transport of hazardous materials, except for highly complex non-standard situations, such as risk calculations in case of a building realized above the infrastructure (Ministerie van Verkeer en Waterstaat, 2006a; Suddle, 2004).

The RBMII model uses many more assumptions in its calculations than just probability and effect, but it basically boils down to the standard formula of risk of Kaplan & Garrick (1981). The model considers input parameters such as accident frequencies, the speed of the train on the considered rail track, the amount of level crossings, the amount of track switches et cetera. The effect of e.g. a possible derailment is calculated by such variables as the amount and the type of hazardous materials released, resulting in physical effects on people, which depends on the amount and duration of people living in the adjacent area and the distance between the centre of the track and the built up area.

When a quantitative risk analysis (QRA) is conducted, the calculated data can be ‘visualized’ in two different ways. The first one is called Individual Risk (IR). This is the probability that an unprotected person dies due to an accident with hazardous materials per year on a certain spot when this person resides here a full year. The individual risk depends on the geographical position and is displayed in the form of iso-risk contours on a geographical map. The individual risk is thus not characteristic for any person, but only for the location for which it is calculated. Thus, the individual risk contour maps give information on the risk of a location, regardless of whether people are present at that location or not (Figure4). The maximum allowed risk as laid down in Dutch law, is $1*10^{-6}$. This means that an additional involuntary risk which is lower than once every million years is found acceptable according to Dutch policy. The second risk indicator generally applied in the Netherlands is Group Risk (GR). GR is defined as the probability per year that in an accident more than a certain number of people are killed. Group risk is usually represented as a graph in which the cumulative frequency of more than n fatalities is given as a function of N, the number of people killed. This graph is called the fN curve (Figure5). The calculations made for the IR and the GR are based on all possible scenarios. In the Dutch risk policy, the risk acceptance standards for the IR are included in legally binding rules. Therefore, vulnerable objects (such as hospitals and schools) cannot be built within the 10^{-6} contour. However, the GR is rather an indication criterion with a so-called orientation value as decision standard / advice. Figure5 shows two diagonal curves which represent the orientation value for GR installations (below) and transportation risk.

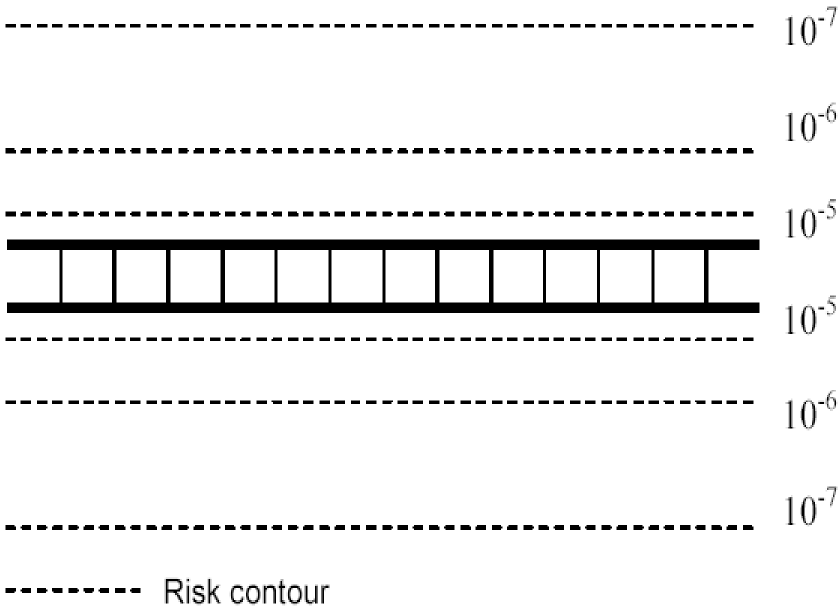

Figure 4 Schematic visualization of Individual Risk near a railroad

When a calculated GR exceeds the orientation value, the acceptance of the GR must be motivated by local authorities. Economic aspects and repressive measures are widely considered in such a motivation. So, the orientation value is not binding by law and acts more as a guideline for policy makers and planners to review their (urban) development plans including safety aspects.
Moreover, the decision-makers - mostly the local municipality - can weigh

the risk (qualitatively) with e.g. economic or environmental aspects. It should be noticed that the decision-makers are juridical responsible for accepting the exceeded risk. In practice, the GR orientation values are generally taken into account when deciding upon new projects with relation to urban planning (Van der Heijden & Van der Vlies, 2005; BEVI, 2005).

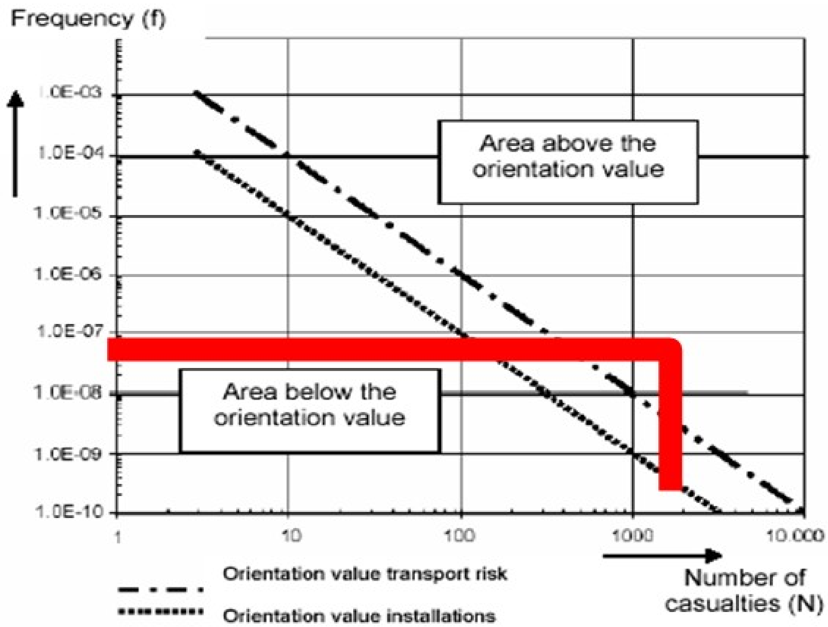

Figure 5 Schematic reproduction of an exceeding of the Group Risk criterion

There are around 40 to 50 spots (railway tracks and urban locations) in the Netherlands where the standards for group risks are exceeded (AVIV & Royal Haskoning, 2005). These situations generally contrast with the following rule of thumb. Due to safety considerations and given an acceptable level for group risk, there is in general an inverse relation between the population density and the number of transported dangerous goods in a specific area. This means that the higher the number of transported hazardous materials, the lower the population density that can be allowed (Figure 6). Suddle (2004) suggests also that a different population density means different functions to the development plan. In this regard, Vlies & Suddle (2008) suggest that if safety measures are taken, a larger amount of hazardous materials can be transported or a higher population density can be allowed.

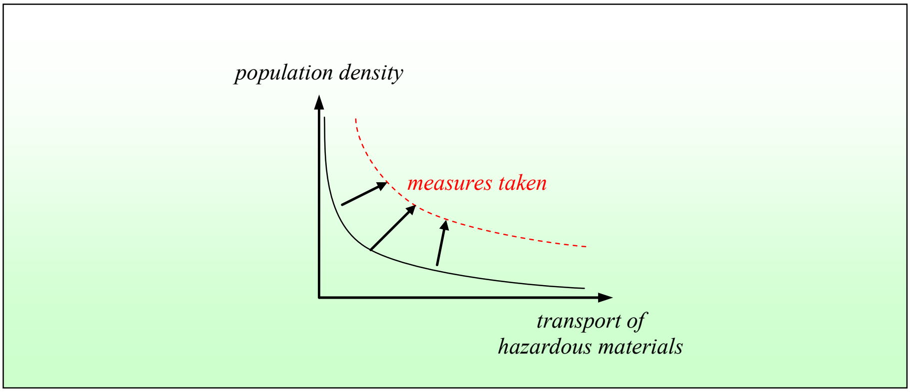

Figure 6 Inverse relationship between the population density and the number of transported dangerous goods (Suddle, 2004)

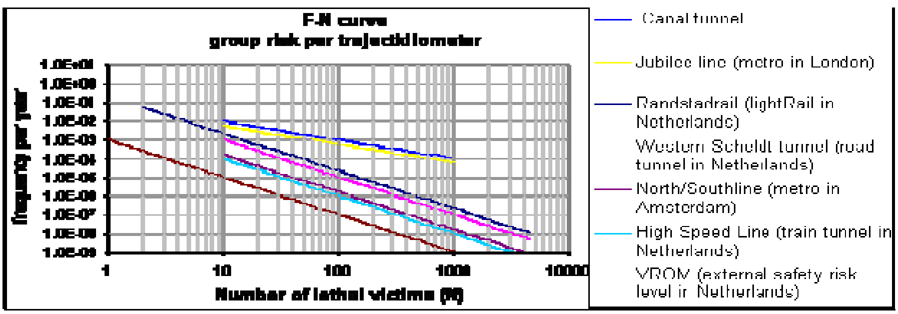

Figure 7 Orientation values for group risk for internal safety for different types of tunnels and for external safety in case of land-use planning in the vicinity of stationary installations (lower line)

It should be noticed from an urban development point of view that the link presented in Figure6 is one of the less relations between land-use planning and transport of hazardous materials, which is, as stated before, not a binding rule and thus in most cases rejected through motivation. Dealing with risks is more complex than shown, particularly when risk has different origins, through which the decision making process becomes more complex. We can illustrate the complexity in Figure 7, in which the internal safety i.e. tunnel safety for different tunnels are considered (Soons, 2005). Internal safety norms for tunnel safety are assumed to be less strict than external safety norms. The reason hereof is that the user of the tunnel accepts more risk, because he has direct benefit of voluntarily using the tunnel, while a person victimized by an exploding LPG tanker and living in the vicinity of a transport route with hazardous materials has no benefit at all. Yet, this all comes to the point that safety norms are used as norms and not as much as design tools. Interesting would be weather these safety aspects were automatically integrated in the design of the buildings and development plans. For this to occur, safety should rather be treated from different perspectives in stead of the QRA viewpoint. It is interesting to see how safety is related to design, process and information aspects.

5 Deliberating risks or safety as a design tool

5.1 Deliberating risks

The major question in a complex project is "how can safety aspects be integrated into the design and engineering of a project?" The first traditional answer of this question is of course: Determine the risks by means of conducting a QRA and subsequently deliberating the risks for risk acceptance, as shown in Figure 8. After conducting the QRA, the risk results have to be checked for risk acceptance criteria. When the results do not comply with these criteria or when risks are rejected or not accepted, safety measures can be required c.q. taken as far as possible by the decision maker.
In this traditional approach, the main purpose of a QRA is thus a basis for rational decision-making. Taking safety measures is mostly on ad hoc basis. There is no proper structure for which safety measures are risk-reducing or even cost-effective. Besides, sometimes measures are put forward to the wrong problem owner. These measures are adhered afterwards in a late design stage of a project. Hence, one may assume that there is not a bit of integration of safety measures in the design of projects. Safety integrated design is thus not a part of any design stage of a project in the current situation. Safety is not even recognized as a design tool or a design method.

Figure 8 The traditional design method for external safety risks

The problem using the QRA method is that it is a decision supporting tool for taking decisions, which is assumed to be in a rational manner. Although, this instrument has shown his worth in practice, this instrument also has disadvantages:

- Due the involvement of a large range of social parties, the decision process is not that rational. Emotions and experience aspects are also considered as elements for decision making. It is important to realize that not only technical and mathematical aspects, but also political, psychological, societal, economical, moral and emotional processes play an important role in decision making about risks (Suddle, 2004). Sometimes the hidden agenda may play a roll as well in the decision making. A strict rational-economic deliberation of risks complies partly with the wish of hidden social interests for coming to an acceptable risk level. One does not speak the same language. Unfortunately, investments for safety measures and their challenges are not distributed equally to all social parties involved: policy makers and managers prefer this kind of strategy of decision making, but neighbours and risk consumers think in economical damage and victims. They do not think in terms of scenarios and tolerate consequences. By this, the notion scenario is introduced, as already introduced and developed in disaster management and rescue management.

- Another issue of the early stated problem of the multidimensional character and its disintegration of the notion safety is that safety is divided into different policy fields on which the consequences become clear. Each safety aspect has its own review method and norms, which could differ from each other depending on the policy field. Additionally, the norms are formulated on the level of both detail-engineering and operational performance demands. In order to conduct a reliable QRA, detailed information of a project - like quantified design information and likelihood models for consequences - is at least required. In the previous design strategy there is almost no attention paid to safety as decision criteria.

Therefore the assessment of safety becomes visible in a late stage of the decision making process. The safety measures which can be taken in such a case are limited, almost impossible to implement and / or financial out of proportion, thus cost inefficient (Stoop, 2007).

5.2 Safety as a design tool

From the viewpoint of cost effectiveness and efficiency of the life cycle processes, it should be much more interesting and cheaper to firstly involve and integrate the safety measures in the inception stage of a project and secondly deliberate the risks in the decision making process (Figure 9). The design freedom in such a situation is much larger and effects of different types of safety measures can be considered in the QRA. This new approach of integral design on safety should lead to a better deliberation of risk of different design concepts on different scale levels of development area: city, area, building and components of buildings. If safety measures are introduced in an early design stage of a project, decision making automatically becomes easier, i.e. the decision maker or buyer of that product can easily make a balanced selection of different designs. In such conditions, one can deliberate the pros and the cons and may also observe the (non) possibilities of safety measures and even the continuously changing circumstances. As a result, the decision making processes becomes more transparent.

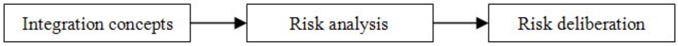

Figure 9 The improved design strategy: the LBC in safety integrated design

6 Relation of safety and design, process and information

In order to explicitly execute safety as a design tool in such complicated projects, safety should be related to design, process and information aspects. In such a case safety becomes a difficult to handle issue, since no method provides practicable solutions (Figure 10). In essence, on one hand safety is approached traditionally, in which a QRA is conducted through which IR, GR etc. are derived. This approach can be widely found in literature and currently executed widely in the Netherlands (chapter 4). On the other hand, safety is associated with life cycle processes, such as requirements analysis, design, implementation, integration, operation, maintenance etc. On this approach, which will be explored further in the paper, not much literature can be found.

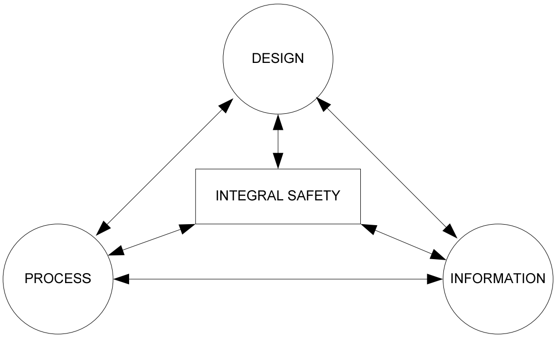

Figure 10 The relation of integral safety with engineering, process and information (Suddle et al, 2008)

Within these life cycle processes, information streams between teams, risk analysis and interface control is very important in order to provide the most effective solution to the problem within the project budget. Financial aspects therefore also become part of the life cycle, also called the cost-effectiveness of safety measures.

In the development of complex projects challenges can be categorised in the following themes, corresponding with the LBC (see chapter 7): engineering & design, process related issues and information & communication issues. In this regard, one may assume that safety can become a part of life cycle if the first three generic steps are considered, resulting in the fourth aspect safety and design:

1. Safety in terms of many stakeholders and transition;
2. Safety as a life cycle process aspect;
3. Safety and information i.e. communication;
4. Safety and design.

These steps are worked out in the following paragraphs.

6.1 The relation between stakeholders and safety

The urban design should be the primary level of design related with safety. Design and engineering of projects is becoming rather complicated, due to changing demands of suppliers, a growing lack of space in city centres and the increasing complexity of projects. A transition between the supplier's and developer's roles is taking place. Traditional forms of contracting where tendering on the basis of lowest price bid does not provide value for money in the longer term. This is because selecting the lowest price contract may result in a design that is more expensive to operate unless careful consideration is given to the engineering & design methods and the potential for it to be innovative. These considerations, among others, lead clients to try to mobilize the industry's creativity in terms of proposing more efficient solutions. At this moment, this is a missing link for the decision makers and the spatial development officials, since the integration of life cycle processes, such as design & engineering and safety is not their major part of expertise. However, the technical solutions are indispensable for a valid and a rational decision making process. More environmental aspects on engineering and safety should be considered in the design and engineering process, such as air quality, noise reduction, soil quality, safety, etc. Besides, it is important that these environmental aspects should be integrated at different scale levels of space (city, area and building level).

Redevelopment of inner city areas involves a great number of parties / stakeholders, each with their own interests and sometimes their own technical solutions. It takes a lot of effort to bring these parties together, especially where legal and financial affairs on landownership and air-rights are concerned. The government can act as a catalyst in this process by initiating and facilitating the projects. After all, the current projects in inner city areas have social benefits and help towards the preservation of green belts and rural areas. Especially in high risk urban environment, developers could be persuaded that the risks are worth taking, especially if the government provides subsidies for the gap between the costs and the profits of a redevelopment project.

In multiple use of space projects where safety is also an important issue, more stakeholders are involved, through which the process might be much challenging and resulting in extra costs. This is even amplified when buildings are realized adjacent to transport routes of hazardous materials. The interest of each stakeholder is to influence the entire design with his contribution, through which the process becomes more unclear and non-manageable causing a possibility of shrinking the quality of the design. Though it is essential to provide a comprehensive design where the interests of all stakeholders are taken into account. In order to achieve this goal, it is vital that from the earliest possible stage of the project (inception), attention is paid to explicitly performing the life cycle processes in order to integrate safety in the system to be built.

6.2 The relation between life cycle processes and safety

In order to fully grasp the notion of safety in the life cycle processes a brief systems theory explanation is given here. Every engineer structures and decomposes his work in order to manage parts of his work suitable to eventually manage his work as a whole. Decomposition in this case means dividing the work in smaller parts. In order to manage his work as a whole it is important not only to manage the different parts, but also to manage their relations. After all, the whole is more than the sum of the parts. 'More' in this case is of course the number of relations between the parts.

A civil structure can be seen as a system in, for example, a city area as environment. According to in 't Veld (2002), such a system can be subdivided (decomposed) into subsystems and aspect systems, as shown in Figure 11. Subsystems are physical parts of the system, for which the original relations are not changed. Subsystems for a building can be floors roof, elevators etc. Aspect systems are relational parts of the systems, for which the physical parts are not changed. Aspect systems can be safety, reliability, stability, etc.

The ISO/IEC 15288 (System Life cycle processes) moreover provides a list of technical processes to be performed during the life cycle of a system. These processes help defining the different stages of the life cycle, from inception (conceptual stage) to disposal. In order to clearly take safety into account, insight must be given in the input, activities and output of the life cycle processes in relation to safety.

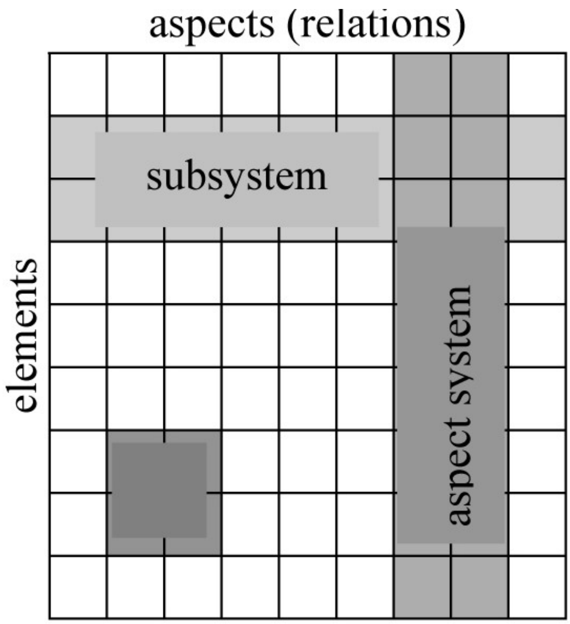

Figure 11 The relation between aspects, elements, sub systems and aspect

In order to manage safety as an aspect system during the system life cycle, a clear relation between safety and every life cycle process, starting from inception, must be given. During inception, safety is merely a notion which is defined in functional terms. During requirements analysis, safety is categorized and analysed in aspect requirements. During the design cycle the aspect requirements for safety are met by designs and probably new safety requirements are formulated as the system is designed top down. And so on for all of the life cycle processes.

In essence, it comes down to defining the relations between safety and project information, such as requirements, objects, risks, budget, time in order to visualize the system safety status during its lifecycle. This status report for safety provides insight in safety measures to be taken, safety risks to be mitigated, safety measures to be taken and safety requirements to be met, etc. all in relation to the system life cycle.

Safety demands, needs and eventually conditions, starting points, tolerances and requirements should be much more explicit in the life cycle processes, especially the design process. This explicitly provides traceability per process for the aspect system safety. A long with traceability, insight into effects on costs, risks etc. is also provided, which helps manage the system in terms of safety (measures).

6.3 The relation between information and safety

As both risk information and safety affect the land-use destinations of involved areas, safety distances can be considered as risk tolerability criteria with a territorial reflection. Recent studies (Basta *et al,* 2007) explored the suitability of using Geographical Information System (GIS) technologies to support their elaboration and visual rendering. In particular, the elaboration of GIS “risk-maps” has been recognized as functional to two objectives: (1) connecting spatial planners and safety experts during decision making processes and (2) communicating risk to non-experts audiences. In practice, the demand for information in safety surveys is large is, but this demand goes hand in hand with the non-transparent presentation of information. The suggestion of all stakeholders speaking the same language is an illusion till now, especially in the domain of safety. ICT-applications in the safety domain are in the beginning stage. However, these applications are fundamental for a few reasons:

- Process efficiency;
- Transparent communication between the stakeholders;
- Comprehensive design.

The potential of geographically based risk-informative systems, such as GIS, to represent major risks at national scale is thus essential. Accordingly, risk pictures can be show when using GIS. In fact, this is the language of the urban development officials, enabling progressively the process efficiency between stakeholders and rational decision making on safety. The accessibility of the digital risk map is large: all departments of municipalities as well as entire project group of stakeholders can use the map for further negotiations and synchronizations.

6.4 Safety integrated design

If the previous three steps are explicitly followed, safety can easily be integrated in the design of projects in stead of checking afterwards. This is a progressive approach, in which safety is considered as a design parameter and an aspect system in the development of urban locations, in stead of a test tool.

The design parameter tool should also be used at different scale levels: urban level, area level and building level (Figure 12). Safety integrated design is up until now a relatively new and an unprompted issue for project developers and municipalities, while these are currently confronted with the continuous changing demands of the users. Every building should be of course designed individually. It is therefore rather interesting to develop another type of working strategy, in which a few standards (prescriptions) are worked out, including an integral approach towards safety on different scale levels.

Therefore, one should consider integral design of projects in which safety is considered as a design parameter and aspect system in stead of a test objective. This strategy has the same ingredients as the LBC concept. In the following chapter, the LBC working strategy is presented as a design tool to integrate safety in the design of e.g. land-use planning. However, it may require a cultural revolution.

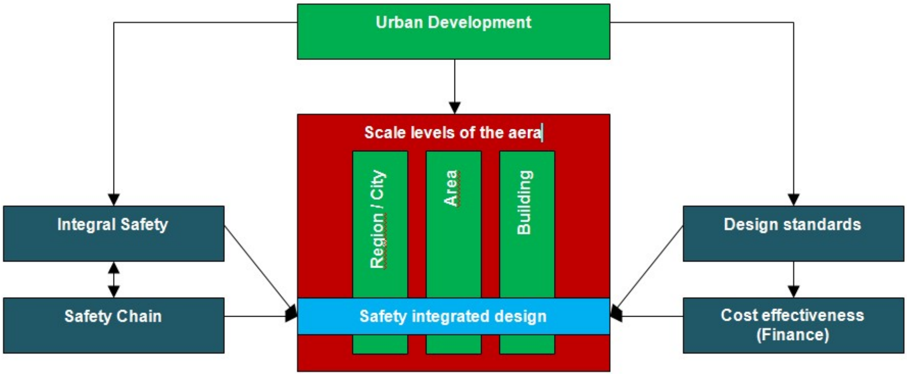

Figure 12 Relation between safety integrated design at different scale levels of the area for different policy fields (Suddle, 2007)

7 LBC as a dynamic integral design tool for safety

What exactly is LBC? Living Building Concept (LBC) is a new approach to life cycle management of built services that can potentially lead to a substantial reduction of risks and transaction costs. Key element in the approach is the change from demand-driven supply to supply-driven demand. The LBC can be used to integrate safety in the design of a project. The traditional safety approach is the demand-driven supply, while the progressive approach we are promoting is supply-driven demand, in which the safety measures are standardized into suppliers' requirements, since safety becomes a design parameter.

Safety as a design parameter or safety standards i.e. prescriptions regarding safety are exactly the formula and strategy of the LBC (Living Building Concept) introduced by de Ridder (2007). The LBC can be applied in the development of such projects, as an integral design method, especially in cases where internal or external safety is playing a major roll. Hence, LBC is introduced in the safety domain. If safety is offered by the supplier as a part of the assortment of the design, then safety becomes accessible for the buyer or owner. It is thus beneficial to see safety as a design tool in stead of a test parameter.

Unlike other industries, the building and construction industry is traditionally one where those who produce (the builders / supplier or the project developer) are not the ones who come up with the initial idea (the client, the government or architects). Therefore, the client doesn't get as much as he should or could get, and the builders hardly make any profit. Instead, within the LBC, builders come up with creative solutions and clients choose a builder that offers the best solution, also regarding safety, to their specific problem or demand. Furthermore, there is the added possibility of entering into a service contract that states the builder will adjust the building to future changes in function and use, but also to changes in technology, climate or building regulations. This way, the client gets a product that will suit his future needs as well, in which safety is automatically integrated, because applying LBC means that safety becomes a quality aspect for the suppliers. Additionally, a significant consequence of this on the practice of building engineering as a whole is large. Building engineers, clients and non-safety experts don't have to be familiar with safety aspects, since all safety requirements are now provided by the supplier in stead of the demanders.

When construction or consulting companies start to develop their own specific products, of which integral safety is a part, this will increase the quality of these products, i.e. urban plans, and clients know right away what they are paying for. Legal battles over warranty issues will be a thing of the past, and transaction costs for safety measures will decrease substantially, as builders now know exactly how much their product costs. In the traditional approach, project developers spend a lot of time calculating risks of things that are not their expertise, often resulting in higher than necessary costs. Such is the case where risks of transport of hazardous materials are determined, as mentioned in the previous chapters.

8 Conclusions and discussion

Although the notion (integral) safety is complicated and a much discussed issue, there are options to consider this notion as a design tool in the life cycle of a project. If this notion enlarges to an integral approach, than the decision making process must extend to more parties involved and different design levels and stages. In general, such an extension goes hand in hand with formulating additional criteria, followed by an extra procedure and the development of a decision supporting tool or a new conception. Hence, we did not reach the centre of gravity of that problem: there should be a problem owner whom is ultimately responsible for safety. Subsequently, the responsibility can be realized if a matching embedding for safety in project development can be found.

Applying the Living Building Concept for integral safety initiates prosperous views for safety as a strategic decision supporting and integration tool for large scale complex projects. In our view applying the LBC provides an interesting tool for safety buildings. However, it is not yet clear how the embedding hereof will shape itself. Furthermore, applying the LBC is a cultural revolution. The change from demand-driven supply to supply-driven demand has many years to develop in the construction and design sector. It is clear that designers and architects can benefit from this method, since they should not provide safety measures and solutions in each project. However, this concept has a significant consequence on several disciplines such as structural designers and managers, since these disciplines have to be educated in the relation between life cycle processes with a focus on design and safety. This is also a large time consuming process, through which the LBC and safety integrated engineering is a practicable method.

Bibliography

Bouma, H. (1982). Als het leven je lief is, Max Gelder Stichting

Ridder, H.A.J. de (2007). Living building concept for market dynamics, innovation and sustainable buildings. In: Ridder, H.A.J. de and Wamelink, J.W.F. eds, Proceedings of the 2nd International Conference World of Construction Project Management, pp. 1-10

Durmisevic, S. (2002). Perception aspects in underground spaces using intelligent knowledge modeling, PhD Thesis, DUP Science, Delft

In ’t Veld, J. (2002). Analyse van organisatieproblemen: Een toepassing van denken in systemen en processen, Noordhof Uitgevers

Kaplan, S. and Garrick, B.J. (1981). On the quantitative definition of risk, Risk Analysis, 1:1, pp. 11-27

Ministerie van Verkeer en Waterstaat (2006a). Nota vervoer gevaarlijke stoffen. Den Haag

Ministerie van Verkeer en Waterstaat (2006b). Wat is RBMII? [www.rws.nl/rws/bwd/home/www/cgi-bin/index.cgi?site=15&doc=2189]

Soons, C. (2005). De veiligheid in metrosystemen. Een opzet voor een kwantitatieve risicoanalyse voor de veiligheid in metrosystemen, TU Delft, MSc Thesis

Stoessel, F. (2001). Can we learn to accept risks? Conference Report, Safety, Risk and reliability - Trends in engineering, Malta

Stoop, J. (2005). Veiligheidsborging van grote infrastructuurprojecten, Achter-grondstudie voor de Tijdelijke Commissie voor de Infrastructuur, hoofdstuk 10. Tweede Kamer der Staten Generaal

Suddle, S.I. (2007). Veiligheidsgeïntegreerd Ontwikkelen, Ordenen en Ontwerpen, SSCM Rapport [www.SSCM.nl]

Suddle, S.I. (2004). Physical Safety in Multiple Use of Space, PhD Thesis, Delft University of Technology, Ipskamp [repository.tudelft.nl/file/354674/203416]

Suddle, S.I., Stoop, J. and Ridder, H.A.J. de (2008). Het Living Building Concept als ontwerpopgave voor externe en interne veiligheid, Externe Veiligheid, 5:2, pp. 4-7

Vlies, A.V. and Suddle, S.I. (2008). Structural measures for a safer transport of transport of hazardous materials by rail: The case of the basic network in The Netherlands, Safety Science, 46:1, pp. 119-131

Vrijhoef, R. and Kosklea, L. (2000). The four roles of supply chain management in construction, European Journal of Purchasing & Supply Management, 6:3-4, pp. 169-178

Vrijling, J.K., Hengel, W. van and Houben, R.J. (1998). Acceptable risk as a basis for design, Reliability Engineering and System Safety, 59:1, pp. 141-150

Vrouwenvelder, A.C.W.M. (2001). Risk Assessment and Risk Communication in Civil Engineering, CIB Report, Publication 59

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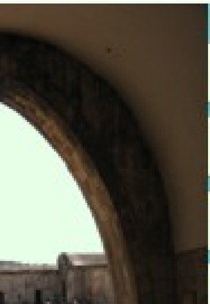

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