The introduction of the Living Building Concept in Land Use Planning and External Safety Issues

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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. 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 (see e.g. Vrijling et al., 1998). The subdivision of figure 1, here ranked according to increasing benefit to the persons at risk is frequently found.

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. So, subjective and objective components of safety play a roll as well and are related with aspects of rational behaviour (Bouma, 1982). Subjective safety is related to psychological aspects (see also 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.

Integral safety	Physical safety	Man-made hazards	Internal safety	Internal safety of buildings
				Traffic safety
				Labour safety
				Tunnel safety
				Fire safety
				Transport safety
				Construction safety
			External safety	Stationary installations
				Windmills
				Aviation safety t
				Transport van hazardous materials
		Natural hazards		Floods
				Earthquakes
				Meteorites
				Remaining climatic factors
				Diseases and epidemics
	Social safety			Terrorism
				Criminology
				Institution
				Design
				Sociology
				Perception

Figure 1: Integral safety aspects.

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 center 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 (see Figure 2, right). 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 (see Figure 2 left). 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 / advise. Figure 2 (right) shows two diagonal curves which represent the orientation value for GR installations (below) and transportation risk.

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).

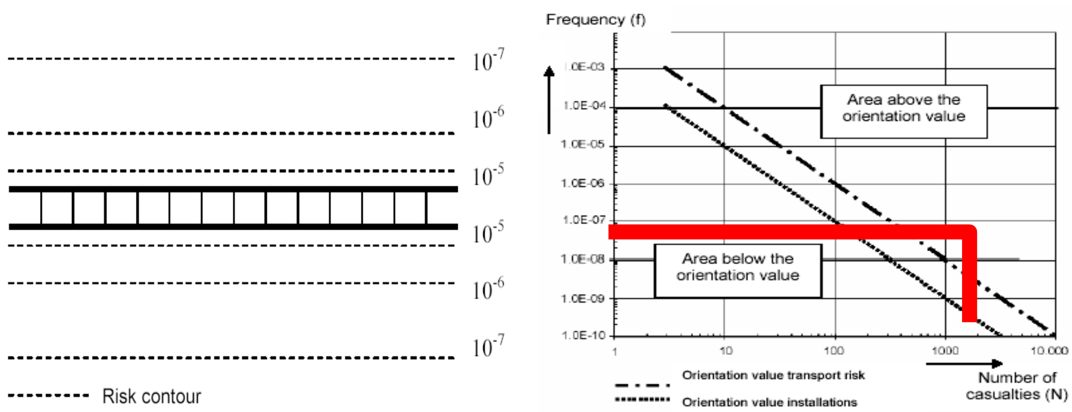

Figure 2: Right: Schematic visualization of Individual Risk near a railroad. Left: Schematic reproduction of an exceeding of the Group Risk criterion.

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 3. 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.

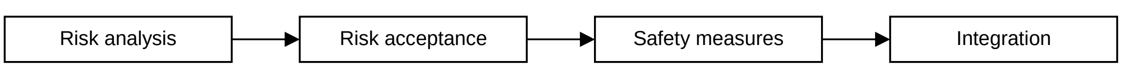

Figure 3: The traditional design method for external safety risks.

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.
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 4). 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.

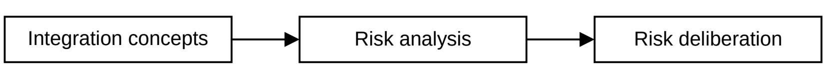

Figure 4: The improved design strategy: the LBC in safety integrated design.

6. 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 c.q. 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, than 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.

7. 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.

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