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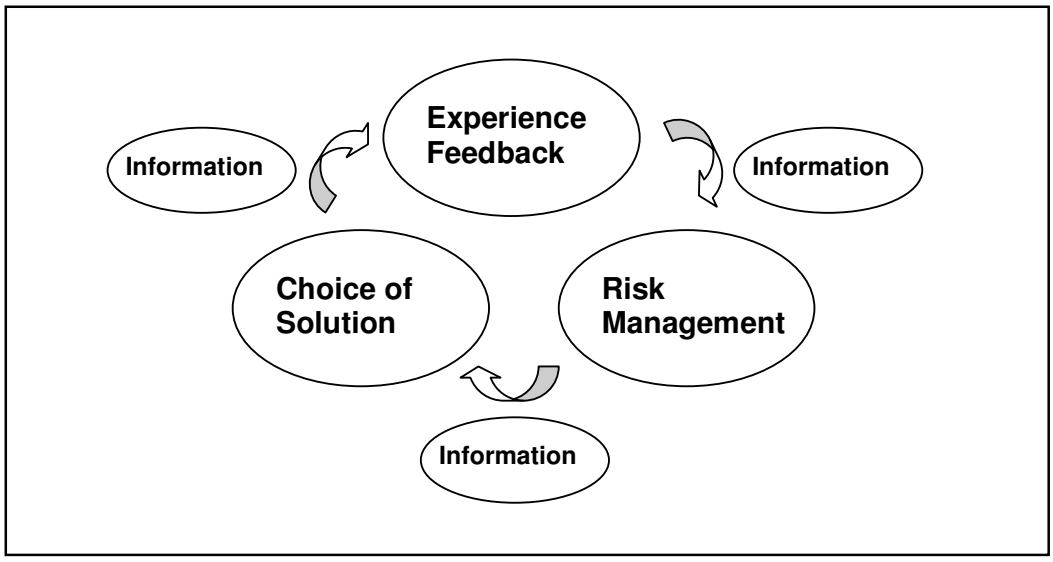

Risk Management in the Conceptual Design Phase of Building Projects

Master's Thesis in the International Master's Programme Structural Engineering

JOANNA GORAL

Department of Civil and Environmental Engineering
Division of Structural Engineering

CHALMERS UNIVERSITY OF TECHNOLOGY
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Cover:
Relation between experience feedback, risk management and decisions in the conceptual design process

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ABSTRACT

Everyday thousands of building projects are realised all over the world. Each phase requires good decisions in order to take a step further towards the successful finish of the project. Negative consequences of made decisions or activities that can have different probabilities of occurrence and impact on other phases of the project are defined as *risks*. The purpose of *risk management* is to predict, reduce and avoid the risks and their consequences. Risks can also be transferred to other parts of the project in order to achieve the best final results in each area of the project.

The goal of this Master's project was to show how important risk assessment and management in different phases of building projects are, especially in the conceptual design phase. The purpose was also to show how risk management can be improved or developed in a consultant company such as GF Konsult. At the beginning of the Master's project the theory about building projects and risks in various phases was studied. Afterwards, two building projects realised by GF Konsult and Norconsult were observed to see how the risk management was implemented in the organisation of work and project management, and how it is related to the theory about risks. Additionally, the utilisation of risk management in the design phase of a project in the car industry was studied on the basis of information gained from the Volvo Car Corporation. This was done in order to compare this sector to the building industry.

The observations of the two building projects show that critical events and their risks were not always considered carefully and identified by the team members. Also the risk management was not fully integrated with organisation of work on the projects in the consultant companies. In order to improve the risk management in GF Konsult, the author proposed a strategy of introducing new issues in risk management such as new system of classification and analysis of risks, new division of responsibilities in risk management, database, meetings and risk education for employees.

Key words: critical event, risk, risk assessment, risk management, conceptual design, building project, risk probability and consequences, organisation of work

Contents

Preface

This Master's project has been carried out at GF Konsult in autumn 2007. The project was realised within the International Master's Programme in Structural Engineering at Chalmers University of Technology.

I would like to express my gratitude to my supervisor Ljot Strömseng at GF Konsult and my supervisor and examiner Björn Engström, professor of Concrete Structures at the Department of Civil and Environmental Engineering, for a great support, valuable advice and motivation during realisation of this Master's project.

I would like to thank everyone, who has contributed to my project, especially My Lierud who was always willing to answer my questions and who helped me a lot during the time spent on this Master's project. I wish to thank all the interviewed engineers at GF Konsult and Norconsult, who gave me support and all necessary information about the studied building projects. Furthermore, I would like to thank the civil engineers and project managers Lars Hammarström and Anna Margitin at Volvo Cars Corporation for their time and help.

The realisation of this Master's project in GF Konsult was a great experience for me and a chance to meet very kind and interesting people and develop my knowledge about consultant companies in Sweden.

Göteborg, December 2007

Joanna Goral

1 Introduction

1.1 Background

Everyday, people stand in front of situations where different decisions have to be made in order to take a step towards desired success or goals in every field of their life. To do that, risk identification and analysis are necessary in order to foresee consequences of chosen solutions.

A building project is a process where each activity and phase includes different risks that should be handled by the project participants. Nowadays, when the building market is developing very fast and it is important to deliver the project to the client on time and within the budget, each decision made in the conceptual design phase can have an impact on other phases and bring consequences that could be negative for the building project.

The conceptual design phase is an early part of the building project where the general solution of the project is chosen from many alternatives that are competitive and fulfil more or less the requirements of the project. This is the phase where the risks connected with the decisions might have an impact on the result and success of the project. To minimise the negative consequences of the decisions made during the conceptual design phase and to achieve benefits of the taken actions, a proper risk management should be used from the very beginning of the building project. However, it is common today that the risks in decision making are not considered by the project participants very deeply, because abilities in the risk identification, assessment and management are not fully developed. Knowledge and experiences possessed by all the project participants are utilised largely in the building project design and realisation, but rarely associated with risks in the decision making process. New building projects are not always considered as unique and the routines and the working schemes are transferred from the previous projects without careful consideration of risks and the need for innovation in order to make the final solution more attractive and competitive.

1.2 Aim of the Project

The risk's concept has a large scope and may be considered in all fields where decisions are going to be made. In this Master's project the risks are considered as factors present in the building project from the initial phase until the client receives the building and starts to use it. Due to this fact, many questions rise and need to be answered. How to manage and handle risks during various phases of a project process? What kinds of risks can be identified at the beginning of the project and how can they be managed? What are decisive factors in taking risks and what issues can be helpful to identify risks properly?

The main objective of this project was to study the risk management in GF Konsult and which improvements regarding risk management could be suggested in the process of a project task realisation. To simplify analysis and give the clear vision of risk management in the conceptual design phase, the problem should be studied mainly from the structural engineering and project management point of view in a building

project and in project tasks realised by consultant companies as an integral part of the building project.

The Author's intention was to point out these aspects of risk management in project tasks realised by GF Konsult where the improvements could be introduced. The information about how to use these recommendations and who should be involved in risk management in order to raise the efficiency of decision making in a conceptual design phase of building project was also given.

1.3 Scientific approach

The Master's project should be carried out in three steps.

The first part was a literature study, which was done in order to gain general information about the concept of a building project; its phases, participants and the contract forms. This study was helpful to understand the structure and organisation of the various phases, and the existence of critical events in all of them.

A literature study about the risks in building projects was the second part of this Master's project. The theory includes information about exposure of building projects on risks and presents different types of risks in structural engineering and project management in the design process in general.

The third part concerns observations of two building projects realised by GF Konsult and Norconsult. Questions to the project team members were asked to know the way of working with risks in design teams. Then it is possible to compare the reality with the theory in order to useful information or advices for future risk management.

In addition, a small study of risk analysis and management in the design phase of projects carried out in Volvo Car Corporation was done. A comparison of the organisation of work in the conceptual design phase in the car industry and in the building industry was provided.

The information from the practical point of view was compared to the risk theory studied at the beginning in order to draw conclusions and make suggestions on how to improve the risk management during the conceptual design and other phases of building projects.

Finally, the relation between experience feedback, risk management and decision making in the conceptual design phase of a building project was studied in order to check how these three important issues depend on each other and what kind of benefits can be achieved if these three actions together are emphasised.

1.4 Limitations

Although, a building project consists of various phases and many different types of risks, mainly the design phase, especially conceptual design, and risks connected with

the decision making and cooperation between participants in this initial phase were studied in detail. The limited time made it difficult to analyse deeply risks in every phase of building projects.

Furthermore, observations of the projects were limited to the risk management and the structural parts of the buildings in order to focus and simplify the comparisons.

The suggested solutions of improvements for the risk management have not been implemented at GF Konsult yet, so it can not be clearly said whether these recommendations turned out to be useful for the company in practice.

1.5 Structure of the Report

In order to make the information included in the text more accessible to the reader, the structure of the report is presented below.

The theories about building projects and risks in building projects are presented in Chapters 2-3. The purpose of these chapters is to present the exposure on risk in different phases of the project life cycle and to explain the importance of risk analysis in the decision making process and the building project organisation.

In Chapter 4, the observations of two building projects realised by GF Konsult and Norconsult are presented. Information about how the consulting firms work with risks during the conceptual design phase and implement the risk theory into practice and aware of risks was included.

Chapter 5 is complement to the knowledge from Chapters 2-4 and presents the design phase in the car industry in order to show how the concept of the solution is developed with consideration of project risks.

Chapter 6 describes the correlation between experience feedback, risk management and decision making in the conceptual design phase. The analysis of how these three functions are used by the team members in the project work was based on the information gained from the interviews of the people involved in the observed projects.

Suggestions, based on the projects observations, on how GF Konsult can improve the work with risk management within the company are presented in Chapter 7.

2 Building Projects

A building project is a process where several groups of people – project participants work on the development of a building from its conceptual idea to the real structure. The building project is divided into phases where the project members focus on the development of the building according to the roles prescribed to them.

Assignments in a building project, such as conceptual design, construction *et cetera* performed individually by a project participant according to the role, can also be referred to a project or a project task, because it contains the parts that the project teams work on within a company. The risks related to critical events in the project task are managed by the project participants according to their responsibilities defined in the contract form. The risks managed in the project task are an integral part of risks existing in the building project.

To understand the concept of risks in building projects, it is worth to study how a typical building project is structured and how it works in practice. A good knowledge about the forms of building projects, its phases and organisation is a first step to start working on risk analysis, and helps in identification of risks in the beginning of the conceptual design stage, in pre-design stage and the construction process.

The structure of a building project, depending on its scope, varies with the number of project teams, and form of management. Also the form of contract plays an important role regarding what kind of risk that should be taken into consideration and how to handle it.

The aim of this chapter is to clarify the organisation and structure of a building project with regard to risk management.

2.1 Project Life Cycle

The best way to present how a typical building project is structured is by help of the project life cycle. A typical project life cycle is divided into phases, each with a predetermined purpose and therefore an identifiable scope of work. The project begins with an idea, and then it is developed in many steps and at the end closed and terminated. Every project has its design phase, construction phase and closing-termination phase, which are partly overlapped from phase to phase. The phases can be defined in different ways. Below an example of how a typical building project can be divided into several phases is presented in Figure 2.1.

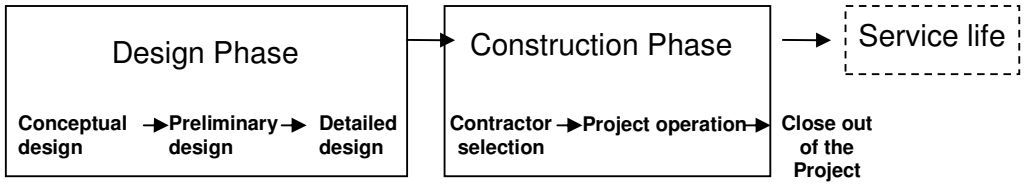

Figure 2.1 Project's life cycle

At completion of each phase the progress in time is controlled and forthcoming actions are identified.

2.1.1 Conceptual Design Phase

The conceptual design phase is the initial phase of the building project. Most important decisions about the planning, organisation, design and type of contract take place in this stage. The initial ideas about the project turn out in various concepts. The alternatives are evaluated and the final conceptual solution is chosen.

The design stage is, next to the construction phase, a main part of the whole project time, where the conceptual design stage plays an important role for further development. It is essential to understand that the conceptual design phase has a great influence for the further stages of the project and bad decisions can have decisive impact on the work in the future. That is why good management is needed when the alternatives are discussed, and the final solution is selected. Also important aspects of the project and good stated and answered questions of what can be expected and unexpected in the project should be considered.

Need and vision

Firstly, the need of a certain building should be identified. A clear vision and objectives of the project should be stated to clarify what the task is, so the participants know their responsibilities and roles in the process. The task statement is the consequence of the need, but it does not represent the vision of the product itself. Forcing ready solutions or technical parameters at this stage is a mistake, since this can cause unnecessary problems in future creation of alternatives.

When the need has been identified, the idea should become a real issue so the purpose is considered first, and then design requirements are checked to analyse it from the technical point of view. Important questions about the structural behaviour and the reliability should be stated and the answers discussed in detail by persons with good experience and knowledge. Sometimes it is essential to engage a specialist, if some issues are doubtful and require further expertise.

Very often during the concept development, old examples and experience are used without any space for creativity and improvements. This might result in less innovative ideas in the project and less quality for the client. Creative thinking with proper usage

of experience feedback makes the project better and gives the possibility that more efficient and valuable alternative is presented.

Black box

The creation of possible alternatives is the next step of the conceptual design stage. According to Niemeyer (2003), the black box principle can be used for this purpose. The black box contains many ideas of the project concept that can be taken into consideration, but only those alternatives that meet the project objectives and are possible to realise should be selected. First the inputs on which possible alternatives are going to be stated and known should be completed, and then outputs to which the inputs are going to be transformed are stated. At the beginning of the conceptual design phase there is always room for innovations and creativity.

Constraints

When the set of alternatives are going to be created all constraints should be identified to know the boundaries of possible solutions and to asses the solution space. There will always be some limitations that reduce the solution space (see Figure 2.2), so the task is to maximise the solution space taking into considerations all important restrictions that show up at the beginning and during the need analysis.

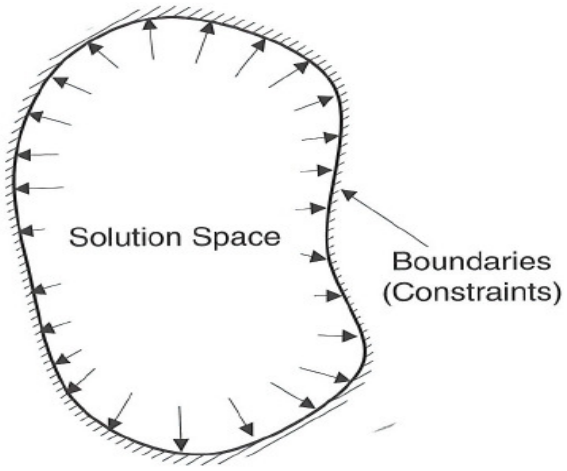

Figure 2.2 Schema of solution space bounded by constraints. Kroll (2001)

Kroll *at al.* (2001) propose to classify of such limitations into two groups, explicit and implicit constraints, so the solution can be more exact according to stated boundaries. Table 2.1 presents short characteristics of constraints depending on their class and the correlations to other issues in the project life cycle.

Table 2.1 Explicit and implicit constraints Kroll (2001)

Explicit constraints	Implicit constraints
- come from task statement - easy to identify - approved by customer if changed	- based on studies of life cycle environment - generated on need analysis - possibility of causing problem should be studied - re-examination and revision necessary if not fitted to requirements

Explicit constraints are easy to identify because they come from the statements that are known at the beginning of the conceptual design stage. These come from stated "wishes" from the customers, obvious constants (gained for example from knowledge and experiences) that are listed first, thus easy to identify. However, every change in the boundaries should be approved by the customer. It is connected with economical risks (e.g. different solutions, different funds) that have to be discussed by all project participants. Otherwise it might cause misunderstandings in the future.

Implicit constraints are not known at the beginning of the project. They are the result of later studies in the project life cycle, and calculations in progress of need analysis. As a result, they can limit the solution space later on than explicit constraints. However if there is a probability of causing problems, the engineer should revise and re-examine the implicit constraints again.

Design requirements and key parameters

The design requirements form the basis that every design engineer should determine before he/she makes next step towards the key parameters identification. Design requirements are a set of criteria that every solution must satisfy. The design requirements are the connection of need analysis result with constraints of the solution space. They should be defined as precisely as possible to minimise the risk of conflicts and misunderstandings between participants. The requirements should not be too general, because it disturbs selection of design alternatives.

The choice of proper alternatives is made by using a set of key parameters, which decide if a certain alternative is worth to go further to the next step. To clarify the parameters, boundaries of the project should be known. It allows reducing the critical events and risks in design and construction phase of the project.

However, proper parameter identification is essential. The task should be simplified by clearly pointed objectives and needs, which make identification easier in conceptual design. The parameter could be a factor, issue, information or concept, but not a dimension or property. A set of well chosen parameters requires good knowledge

experience and innovative thinking, which help to develop new ideas and solutions for stated questions and problems. The point is not to act in a schematic way, because the new project could turn out to be different from the ones that are known from the experience. On the other hand, some successful methods already known from experience in realisation of activities in projects, would streamline the process of finding a final solution.

The process to create a good solution is presented in a Figure 2.3 to clarify the theory with practice.

Engström and Lierud (2006) propose in their Master's Thesis a five-step methodology, Figure 2.3, based on the theory by Kroll (2001). The process starts with a task definition, which is a result of need analysis. It is a very important step to begin with, and a good task statement minimises the risk of potential mistakes in the further development. The task definition is not a simple activity but a closed loop where the final alternative is chosen and if the result is not sufficient then the process of finding a new solution is repeated until the final required outcome is found. A clear vision, creativity and proper design requirements are essential for good key parameters identification. Afterwards the concept is configured and evaluated. If the evaluation of the final solution is adequate then the chosen concept is further developed in a building project. A good sequence and plan of work from the beginning ensure the fluency of work in the conceptual design phase of building projects; make the identification and analysis of critical events more efficient where the needs, boundaries and requirements are known.

To sum up, the methodology of choosing the alternatives can be presented as below:

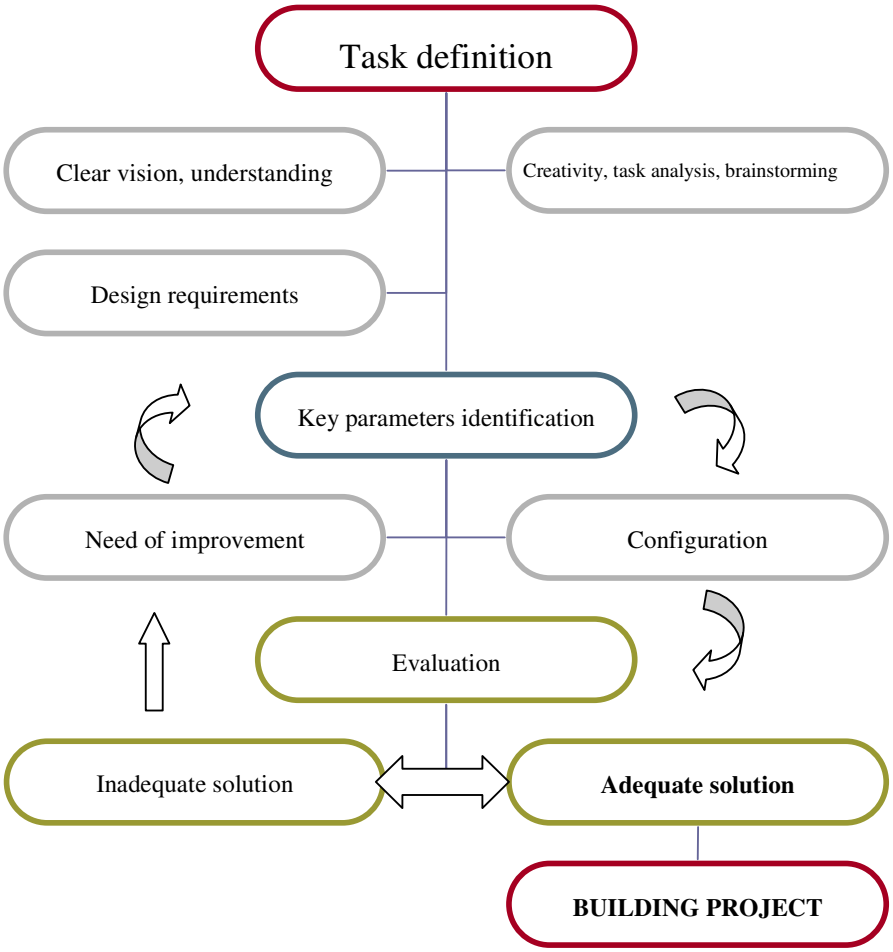

Figure 2.3. Five- step methodology, adopted from Engström and Lierud (2006)

As an example of key parameters, the influence of a construction site on conceptual design is discussed below.

A visual inspection of the construction site can often provide useful information not only for the construction planner but also for design engineers who should know the conditions where the new structure is going to be implemented. This kind of analysis shows which critical events and risks can be expected from different points of view when the construction work is planned.

Water course accessibility could for example be decisive when the method of excavation is chosen. Then the surface level drainage pipes or near surface distribution water mains should be protected from possible damage or pollution. Also boundary conditions like for example safety of the public, height of adjacent buildings and trees or public areas nearness are any parameters which could play an important role in equipment work planning and safety regulation implementation.

Below in Table 2.2 some examples of parameters for a site investigation are presented which could be considered in the evaluation of alternative concepts:

Table 2.2 Example of key parameters on the construction site in alternative selection process Illingworth (2001)

Access	**Boundary conditions**	**Noise**	**Surface and ground conditions**
Media (electricity, water supply, road etc.)	Adjacent height of buildings and trees	Nearby Hospitals, Schools, Offices	Weather conditions
Ground level obstructions	Adjacent public areas (schools, playgrounds etc)	Restrictions on night work or weekends	Examination of boreholes
Underground obstructions	Safety of the public		Lie of the land and flow of watercourses
Buildings and trees	Adjacent mains and sewers		
Watercourses	Rights of access for others		
General	Adjacent watercourses		

In building projects key identification parameters can differ, but each of them is related to critical events and risks which have to be identified and handled in further stages of the project. This problem is described in detail in Chapter 3.

In conceptual design many aspects have a great impact on the successful run of this phase not only in time but also in efficiency. This part of a building project is also a process where different problems should be solved, and good decision making should take place. The experience, risk awareness, good management, communication between participants, environment of work and adequate knowledge build up the system of efficient thinking. It is important not to be stuck in old solutions, but try to search for new ideas and possibilities, which can turn out be better than the ones from the previous projects and have influence on continuous improvement of the design process, which is important in form and development of quality of the company. These issues allow reduction the risk in the conceptual design phase, or improve the ability to identify critical events at the beginning of building project.

It can be said that the conceptual design phase, its purpose and role, is a gate to the project development, and most important decisions, and risk identifications are done in this phase. This is why risk analysis in the conceptual design stage is going to be further developed in this Master's Project to show the great importance and influence of risk management on other steps of building projects.

2.1.2 Preliminary Design

After the conceptual design phase, where one concept is chosen, this is further analysed, taking into consideration technical requirements. More details are considered, a project brief is developed, and preliminary cost estimation is prepared in order to assess the economy of the project and of the chosen solution. The concept is not a ready project in this phase, still detailed studies are going to be done to identify potential risks, plan for a proper organisation and prepare a sufficient space for changes.

2.1.3 Detailed Design

The detailed design is the next task to solve after the final concept has been chosen and the preliminary design has determined the initial cost and 'constructability' of the project. The designers use information from the final concept evaluation in order to prepare final drawings, select materials, determine component sizes, determine methods of construction *et cetera*, in order to make the project cleared and ready to implement and construct. The technical specification and requirements together with drawings are the set of documents for potential contractor who is selected in the contractor selection phase.

2.1.4 Construction Phase

The selection of a contractor is the initial part of this phase. Depending on the form of the project roles and responsibilities of the contractor are prescribed.

After the contractor has been selected, the necessary agreements, licenses and insurances must be secured. The critical events and risks in this point depend on the type of construction. If this is a highway or a road for example, then the accessibility of private properties where the road is planned should be checked in the conceptual design stage, and if the owner will not agree to project development on his/her ground, then other solutions should be proposed.

The construction phase should be carefully planned and placed in time and duration of the project. Each delay is connected with money, which the contractor has to pay to the client. Monitoring and control of the work progress and the budget are essential parts of the construction phase in order to avoid future problems and punishments according to contract.

The construction phase is the part where many different critical events can occur. However, a proper risk identification and management in the conceptual design phase might reduce the risk to level an acceptable and preserve from unexpected events on site.

2.1.5 Closure of the Project

The closure is the final phase of a building project. According to Bennet (2003) inspections and maintenance should be scheduled before the object is taken into operation. During this phase a pre-final inspection of the building is made by the designer, the client and the contractor. Depending on the project it takes one or few days in order to check or test the individual components or parts of the structure. If some defects are found or need of improvements is identified the contractor has time to make corrections until the final inspection takes place.

In this phase, the final payment to the contractor and cost control completion take place and the certificates of the guarantee are given to the client. It is valuable that the contractor makes feedback visits to the building/structure after some time from the closure of the project, to hear the opinion from the owner about the usage of the owned structure. Such kind of activity gives the possibility to keep the contact between the project participants and may result in further cooperation concerning new projects in the future.

2.1.6 Service Life

The service life period is the time when the constructed structure is operated and should be durable and maintained after the building project has been closed and the structure delivered to the client. Service life design prepared in a good way ensures that the durability and intended functions as load-bearing capacity of the structure will last the period as it was assumed in the design phase. The service life design might have a large influence on the economy of the building after the project's completion. Sometimes it is a matter of discussion between the client and the designer whether to use more expensive solutions in the project to ensure a better quality during the service life. The client considers the risk in making such decisions, taking into account the costs of the project and the service life costs in the future.

2.2 Participants

Depending on the form of building projects, see Section 2.3, the number of participants can differ, and might have different responsibilities, but mainly some few important roles can be defined as shown in the Figure 2.4:

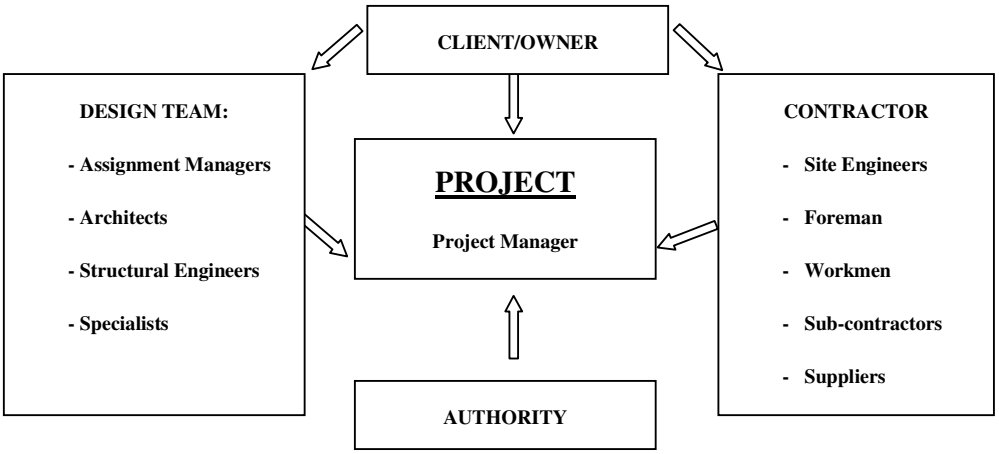

Figure 2.4 Examples of project participants

The Project manager is a person who coordinates the work on a new building project from the initial phase to the end. The project manager motivates discussions with the client about the objectives of the project, needs and requirements. He/she also gives advice to the client about important technical solutions, costs, schedules, safety, construction process etc.

The Client is the person / company who owns the property and orders the project for realisation. It is very important to discuss in detail the needs with the client at the pre-project phase, to learn what the owner expects from the new construction. The client should participate during the whole process of design and construction to be informed about the work progress and economy and to inform about the needs and priorities of the project.

The Design team is a board consisting of a group of consultants such as assignment managers, architects, structural engineers and specialists. The design group takes responsibility for development of ideas of the owner to the completed set of drawings and calculations, which then are going to be introduced into the implementation phase of the project. The design team may be divided into smaller teams working in the same business area in the company. The designers may be involved during construction in quality control inspections, and as advisers in case of some problems with the construction realisation according to the project prepared by the consultant company.

The General contractor is a company which in the selection process / tender process is chosen to execute the construction of a building project. The general contractor is responsible for entire work on site and cooperation with sub-contractors (a company which is responsible for a specialised part of the construction work (foundation, ventilation, electricity etc.) and suppliers of materials and equipment. The general contractor cooperates with the project manager and the design team to ensure proper development of the building project, and in case of some problems or doubts, the questions are explained on common meetings.

The relation between participants of building projects is widely described in the literature on the construction management process [Boyd (2006), Bennett (2003)]. The reason is that the good communication between client and contractor, designer and client, and members of the teams participating in the process plays a key role in understanding of the project's objectives, tasks. The open dialog has influence on work fluency and potential better identification of critical events and risk reduction, because in this point sharing of experience and knowledge between participants is essential.

2.3 Forms of Building Projects

Depending on the form of a building project, the relation between participants and their roles and responsibilities can differ. The three most popular forms of contracts are described below.

The Design-tender-build contract is known as the traditional form, where design and construction parts are provided separately. The responsibility for each part of the project is also divided between designers and a contractor. Another characteristic is that the construction part will not start until the tender process is successfully finished, which sometimes makes the whole project duration time consuming.

Some advantages with this kind of contract have been described by Gould and Joyce (2002) and are presented below:

- Contractual rules are known and understood by owners, designers and contractors
- Approved by many professionals, reduces level of risk and uncertainty- well defined relationship
- The allocation of risk for the construction performance depends completely on contractor and the sub-contractors, which is an advantage for the client.
- The cost is known from the beginning of construction, and the risk of cost overrun is borne by the contractor

This type of contract has also disadvantages:

- The contractor is not a participant of design process, so it is not possible to share information with designers and assess constructability of the structure
- Design of structures that could be build in a more economical way or more effectively often results in higher costs by using more expensive technology or materials
- The risk of higher costs depends on the accuracy and completeness of contract documents. If they are unclear or badly prepared, it raises the unexpected costs drastically

- It is difficult to reduce the time required for design and construction because realisation of both fields in parallel is impossible

The Design-build form of contract is also known as *design-construct.* One general contractor is chosen by the owner, and takes responsibility for contract parts, design and construction. Because of this contract form these parts are overlapped very often, so the design phase has not to be finished before the implementation stage starts. Lawrence Bennett (2003) noticed that in this type of contract there is seldom a lack of integration between these two parties compared to the traditional *design-tender-build* method.

Some advantages of design-build form of the building project in comparison with the design-tender-build contract can be noticed:

- First of all a singular responsibility takes place, so the contractor takes care of the schedule, design, structure, methods, technology *et cetera*

- Time saving due to overlapping of design and construction phases and elimination of time for a second tender process

- The organisation of a design/build team which is responsible for the whole project, can manage more of the risks than the owner in design-tender-build. The factors like costs, schedule and quality are clearly defined

- Potential risks and problems can be identified and solved quicker in the same environment, due to the ability to use available experienced engineers, and better communication between the participants

Some disadvantages in organisation and system of work can also occur in design-build contract forms:

- The owner has less control over both project parts than in the traditional contract form, because both of them act simultaneously and participating in design and construction at the same time is difficult

- From the economical point of view the real price for a contract can not be estimated by the client at the beginning. For this purpose a preliminary budget is used without the guarantee that the price will not be higher

- If the price is fixed by the owner, then there is a risk of sacrificing quality to fit in the desired price

- Also the division of work and price could be more difficult for the contractor

- A poor identification of the owner's needs and requirements and also a project brief understood in the wrong way by the organisation, can cause main problems during the project realisation

Partnering is one of the newest forms of contract. Both the design and construction teams are involved in the project from the beginning, because the tender process for contractor is done at the beginning of the project before the detail design phase. The

cooperation between the project participants is essential and a continuous dialog is held during the whole project process. Overall, separate companies or individual form a project team that works together to deliver a project of good quality. This type of contract allows each member of the project team from a subcontractor to the client, to read and understand the project easily. Additional advantages are ability to exchange the experience between the members, and possibility to make decisions together. This way of working helps to clarify the objectives of the project and avoid misunderstandings and conflicts, which can have great influence on risk potential as it was mentioned in Section 2.1.1.

2.4 Conclusions

A building project is a complex process where each phase should be carefully planned and discussed. First of all a good understanding of the project's objectives and good relations and communication between the participants form the basis of a successful cooperation during the project progress.

The project participants, depending on the contract form, take their responsibilities for risk consequences in their project tasks. The strategy of risk management and the time schedule should always be prepared for potential changes and the additional time for completion of the project under unexpected circumstances should be planned. Budget control and technical inspections during the project's duration allow identification of critical events connected with economical and technical situations on site.

Identification and handling of potential risks in the building project is an issue, which should be considered carefully and controlled during the whole project life cycle. However, the decisive point to analyse the risks in the building project and minimise its impact on its different phases is in the conceptual design phase. It is not an easy task for the project manager and the assignment manager. The risk identification and analysis require adequate knowledge about risk management and the awareness of risks of all the project members during the whole period of building project realisation.

3 Risks in Building Projects

To begin discussion about risks in building projects, the question "What is a risk?" should be asked and answered.

According to Smith (2006) the terms risk and uncertainty can be used in different ways. The word risk has its origin from the French word 'risqué', and it started to be used in England around year 1830 during insurance transactions. From the beginning, 'risk' was defined as something unexpected and fatal, which causes injures or tragedies. The word 'risk' was also associated with the probability of such events in case of their effects on projects. The knowledge about risks is more or less documented and risks are defined and identified on the basis on collected works, practice or so called know-how developed in the companies and from old experience.

The author perceives the risk as consequences of a critical event and their probability to occur in building projects. The critical event can be identified in advance before decisions are made, and risks related to this event can be handled by project participants in risk management process.

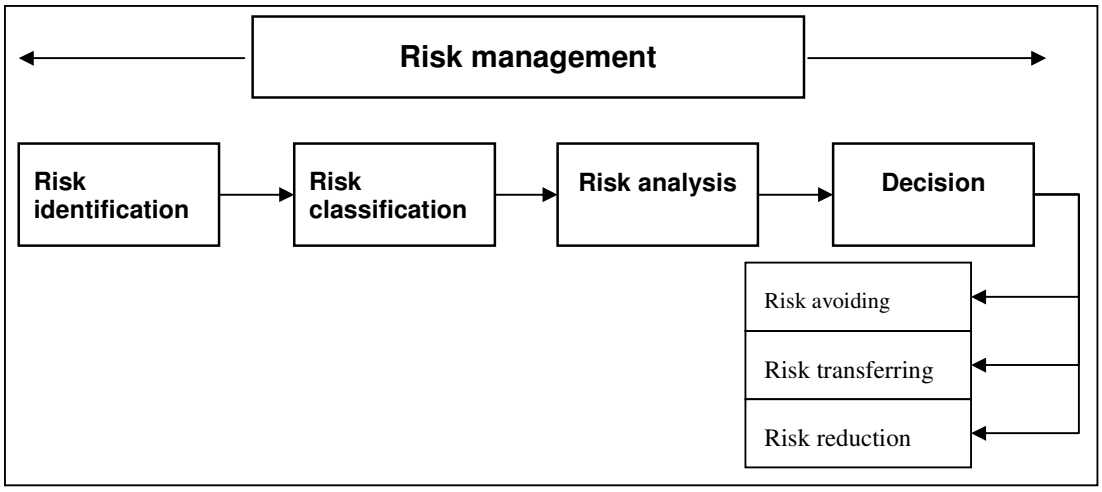

Figure 3.1 Activities in risk management

To start working with risk management the individual activities should be known.

Figure ***3.1*** shows the activities that the risk management consists of.

In *Risk management,* risk identification and classification are needed in order to analyse the risk and start to treat process in the project. Risk management also concerns the decisions that are made when the results from the risk analysis are obtained. The decisions can be made towards risk reduction, avoiding or transferring to another phase of the project task, the building project or the project participants.

Risk identification – is a first activity that has to be realised to start the risk analysis in the building project. During the risk identification sources and reasons of risks are stated and implemented to the risk classification. Information about possible risks is

mainly gained from the experience feedback or from documentation if a database is available. Risks can be identified during the meetings where project participants are able to point out the critical events that may occur during the current project realisation and occurred in previous project. The information gained is stored in reports or checklists in order to be classified.

Risk classification- is the step in the risk analysis where the identified risks are classified according to their types, categories, correlation with other risks and impact on other phases of the building project. It also defines whether the risk in the project is worked out in different business areas of the company.

Smith (2006) divides risks term into three main categories:

1. Known risk – includes slight deviations that are mainly connected with project activities or costs and occurs in each building project. The known risk is planned and consciously taken.

2. Known unknown risk – is foreseeable and can be predicted. The knowledge about this risk is a result of gained experience and knowledge gained during similar projects.

3. Unknown unknowns – is the risk which impact and occurrence cannot be predicted or foreseen not even by the experienced project members.

Risk analysis – is a stage where the classified risks are analysed according to probability of occurrence, costs or other consequences that they can have on different aspects of the building project and the project task in the company. In order to analyse the risks, qualitative and quantitative methods are used, see Section 3.4.

Reduction of risk – is about making improvements or decisions in the project in order to minimize the consequences of critical events and the probability of such events.

Risk avoiding – is about modification of a realisation plan of the project in order to eliminate the critical events from the tasks or to change the conditions related to risks. In practice it is difficult to omit risky situations. However the activities in the project can be modified in such a way that the critical events are reduced.

Transfer of risk - is an activity where the responsibilities for risk consequences are prescribed to another project participant.

Risk management is also connected with controlling and monitoring the efficiency of the work with risks in the project, the changes made according to the risk analysis and decisions that were made consequently.

However, taking the risk does not always mean that bad consequences will take place. It can be successful and have a good impact on the project realisation. For example, an approach to reduce the time of the design phase is a risky situation when the scheduled time is going to be decreased according to client's wishes. This kind of action requires a maximum concentration on organisation of work and quick, right decisions, because any disturbances can delay the work. As a profit, when the approach is successful, the team gains the client's satisfaction and task fulfilment and the time are saved for other unexpected or required future changes in the project.

In general, every project motivates discussions about the risks and the methods of effective risk management. However, many project managers do not introduce risk management to the project as an integral part of the project management. This way of working leads to surprising events, even if the knowledge and experience of the managers is adequate. It is still common that the risk management process is used only if a risky situation already takes place.

3.1 Project risk exposure

To be more involved in the nature of risks in building projects, a definition of risk exposure should be given to realise the importance of risk management in projects. The question is how the building project is exposed to risks? Where we should expect the largest risks, and when the unexpected critical events could occur.

Every project, as it was said before, is exposed to critical events and risks. Saying that the risks are not a matter of our project is a wrong way of thinking and shows incompetence.

A project is exposed to risks in every aspect, from economical to structural safety. At the beginning of each project, the alternative assumptions are prepared to be used in the project work if the essential information about uncertainties will appear with the project progress. Sometimes this information will be different from what was expected, so the engineer must be able to adjust the existing project by changes [Smith (2006)]. It is also necessary to assess the impact of these modifications of the project (Figure 3.2). The project starts with the minimum need of change that brings the highest efficiency in estimated costs of the project. This is the desirable situation for the project manager and participants, where everything goes according to the plan and the assumptions are sufficient to realise the project according to the schedule. The more advanced progress of the project, the higher impact on costs has a change of the project, in the same time due to this, the efficiency is decreasing.

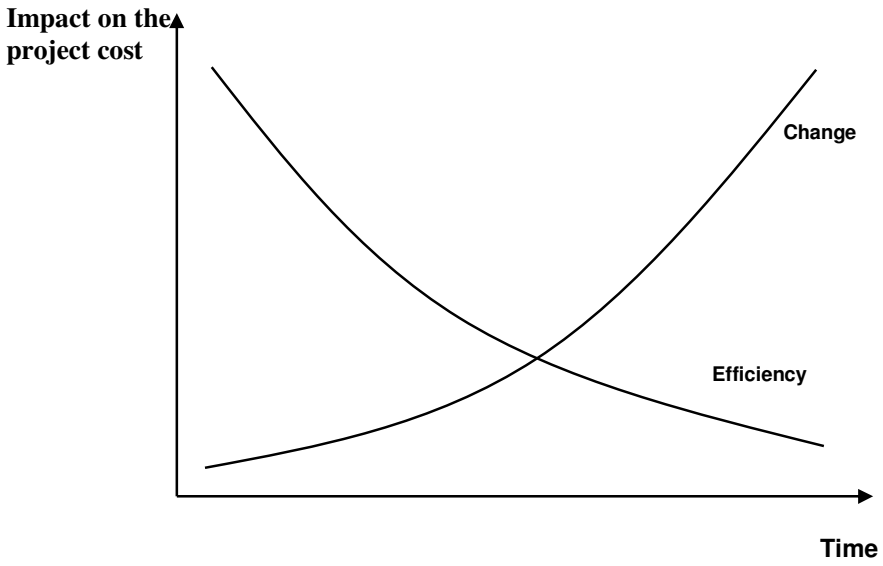

Figure 3.2 Relation between effectiveness and cost of change over time, Smith (2006)

From time to time unknown unknown risks occur (see p. 18) that have an influence on the project plan and make it essential to deal with them quickly, introducing new changes in the project. In the same time it is important to remember the previously predicted risk, to ensure that nothing has been omitted due to the unexpected critical events occurrence and think about economical impact of the change.

Smith (2006), states that the risk should diminish with the project's progress. This claim could be a matter of discussion and deeper analysis of the problem. In the author's opinion the risk is not always progressively minimized with time. There is always possible to find a new critical event not only in the conceptual design phase of the project but also in other phases, that automatically enlarges the amount of risks in the project to handle. This is the project participants' common decision, which can result in additional costs in order to improve the efficiency or bring additional profits during or after completion of the building project (service life). There is also a possibility that the expected profits of new handled risks will not be achieved, so an alternative in case of any failure in the activity should be formulated to minimise the undesired result.

The systematic upgrade of information about risks is necessary to have a clear database of already handled risks and cases that still have to be taken care of. One of the methods is a checklist that is revised during the meetings with the clients and team members. The checklists streamline the design process before the production starts. They help to evaluate the idea of risks and improves the information exchange between the participants at the conceptual design stage and in detail design later on. However, the time has an influence on costs of changes with project progress. The later the need of change occurs, the more impact on the economy and schedule it will have.

At the beginning, it is not known where and when a critical event appears. It is sometimes a complex process, and this situation should be quickly noticed by participants of the project. Different critical events can take place in the same time and it depends on the engineers' competence if they are going to handle the risks related to such situations in the project. Each assignment even if it is similar to the previous one in the past, can vary and bring new risk characteristics. However, utilisation of gained experience and proper knowledge management is necessary to accomplish the successful risk analysis and management.

At the start of every project the unknown unknown risk amount is large, because many unknowns and objectives are not clarified yet, and then the decisions have a large impact on risk reduction. The risk exposure decreases with good decisions and progress of the building project, but still new unknown unknown risks can occur with time, so readiness for quick reaction and new decisions should exist in project realisation.

According to Smith (2006) the peak of risk impact on the building project is when the design phase is finished and the construction phase is going to be started. Then the theory becomes a real structure, and every mistake made in the previous phase will have an influence on the construction phase and the service life. To minimise this impact two parts; design and construction should be overlapped. Very often the final design of the details takes place during the construction phase duration, with consultation of contractor engineers. It results in gaining more economical solutions, enlarges ability of potential need of change in this point without project disturbances and develops the cooperation between the project participants.

Allan Mann (2003) reflects on the phenomenon of risks in structural engineering and defines this as risk=probability x consequences. This relation Smith (2006) presented as a matrix (Figure 3.3).

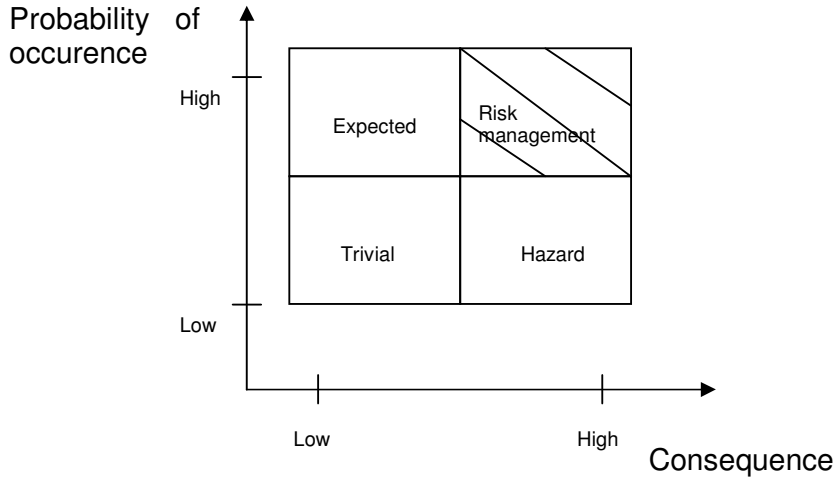

Figure 3.3 Risk matrix in building projects, [Smith (2006)]

The events that have low impact on the project can be treated as trivial or expected. The situations that can have high influence but their occurrence is rather low are the hazards. They can be seemed as too remote to consider but still should be taken in plans because of the high impact characteristic. For example the risk that a ship will hit in one of the pylons of a bridge has a low probability of occurrence, but a high impact on safety and structure of the bridge. Due to this, a need of additional protection of the structure should be considered.

Smith (2006) presents the events that have both high probability and high consequence on the project as the ones with the highest priority to identify and assess in risk management. However due to the previous author's observations, every event that brings potential risk to the project, without the classification in terms of the probability and consequences, should be involved in risk management. Handling of risk management only in case of high priority risks is misleading and reduces the belief that risk management should be present in every aspect of potential risk in the building project. According to this, replacement of 'Risk management' in the Figure 3.3 with 'Risk of high priority' is proposed.

However, at the beginning of a project the probability of critical event occurrence is difficult to assess, so the engineers stay in front of dilemma whether the risk is probable to happen and what is the chance of its occurrence. It is a matter of well chosen probabilistic method and good skills in risk assessment and classification. It is also sometimes a matter of money, because an economical effort for risk analysis put in the beginning of the project can bring good results and allow saving money in the future. It is a kind of 'economical investment' in good decision making.

3.1.1 Typical Risks in Building Projects

Different projects bring different risks to consider, although, among different types of risks in the projects, the typical construction risks can be distinguished with the groups and classification according to the allocation in individual project phases.

Conceptual design phase – the risk can be related to incorrectly selected alternatives for final solutions, lack of information or information transfer with wrongly estimated objectives of the project, system of organisation process, utilisation of gained experience and knowledge management, bad decision making and risk identification and environmental risk.

Detailed design phase – risks can occur in badly estimated or incomplete designs, difficulties in dealing specification and standards concerning existing conditions and client's requirements, prediction of possible changes in design during the construction phase, weak or lack of knowledge about technical conditions.

Construction (Implementation phase) – relations between participants, damage and failure of structure or equipment, delays, construction organisation and techniques, technology, type of contract, quality, resource management, labour, weather conditions, ground conditions, physical obstructions.

As it was mentioned in the beginning of this chapter, next to defined and known critical events, many unknowns and uncertainties can occur in the project. Their identification and allocation are essential to deal with effects in the whole project life cycle.

Examples and methods of how to identify and manage risks in a building project are described below.

3.1.2 Risks and liability for the Structural Engineer

In building projects not only the assignment manager or the construction manager is responsible for risk management. The structural engineer takes part in this process by taking responsibility as designer cooperating with the client and managing the risks depending on his/her skills to the given task. The ability of providing the design process with proper care and information requires connection to risk analysis and adequate communication with the client.

Wright (2003) describes very briefly responsibility of structural engineer in the design stage of a project. The negligence in risk management committed by engineers can have a great impact on work during the conceptual design phase of building project and can lead to hazardous situations in construction, which consequences could cause damage, injury or even accident or death. So, it is important for the engineers to know their duties and to be aware of the possible critical events which can occur in the construction process.

Skill and care

"Right person on right position" could be said when the problem of structural engineer's liability is discussed. As it was stated previously, the experience and knowledge in design and division of the tasks among engineers has a decisive impact on proper decision making during the design phase. Very often designers specialised in one field try to work with similar fields in the area. For example the structural engineer responsible for a steel bracing in a structure, also analyses the problem concerning reinforcement of concrete structures, using only basic knowledge about concrete structures and his/her own experience. This action can be a source of design mistakes, which can cause service failure on site or during the life of the structure. Wright (2003) emphasises that the structural engineer is always obliged not to cross their competences and consider things that he/she has only basic knowledge about. This kind of situation where inexperienced or incompetent engineers are responsible for project tasks and advice given to the client, risks the health and safety not only of the people working on the construction site, but also threatens the users of the structure in the future.

If the structural engineer is not able to provide the expertise which could fully solve the existing problem, a good solution is to ensure the engagement of a specialist. However, it is difficult sometimes to define with any precision the areas for a 'specialist' and the competence border for engineers during the project work, so the structural engineer should carefully realise the work he does and not stray beyond his areas of expertise and competence.

It is also worth to remember that the allocation of engineers to various tasks should preferably be done before the project is performed, not later. However, new technologies and solutions can be introduced during the project but decisions about it should be done in conceptual design phase. The space for introducing new skills and technologies should then be kept, to allow for development of knowledge among structural engineers. In such circumstances the information about innovative solutions is extended so the designer should always consider how far to go beyond the codes of practice and current knowledge.

Working with risks

Working with risks is not an easy task for a structural engineer who takes a great liability with regard to safety minimising the probability of failure of the structure. Firstly, awareness of existing critical events and risks in every project is essential. There are no projects without risk. In all projects even if they are similar, new risks can be found. Risk identification and analysis could be useful tools for the decisions in the design process.

Duckett (2004) describes working with the risk as connection analysis with management exercise in the project. When the risk analysis has been completed by the engineer, the results should be check, acceptance criteria and measures to minimise the risk should be taken. Sometimes, reconsideration of the design concept would be necessary. It is also worth to remember that the risk assessment done by the engineer is a personal judgement based on limited knowledge and experience, so the real risk can differ in reality.

The structural engineer should always use old experiences and knowledge from practice together with codes and standards to make good design with regard to all possible critical events. Theory only, is not sufficient to minimise project and design risk. Engineers must be trained to think a step further.

Cooperation

Good cooperation between project participants could be an issue to minimise risks in building projects. The visits on site of an architect or a structural engineer allow recognising and comparing the design conditions that have been assumed behind the office desk with those existing on the place of project operation. This kind of visits improves the interpretations of the contract documents and reduces the risk of misunderstandings. Doran (2005) perceives regular visits on site as an opportunity to observe the realisation of the design work, to identify unexpected situations straight away, and to gain experiences for other members of the design team.

Very often designers omit visits on site and contacts with contractors, which makes it more difficult to communicate between design and construction teams. Unfortunately, the designers do not observe construction practices, and different working conditions. Such experience feedback information, can be used in future design, and will also improve the awareness of risks and risk assessment in the conceptual design phase.

Responsibility for design of structures of a structural engineer does not finish with a close out of a building project. Service life of a building starts after the structure has been delivered to a client. From this moment the building maintenance, durability and

safety depend on how the structure was designed and constructed and how it is used by the client. If the critical events related to this phase were identified in conceptual design, and proper actions were taken to minimise risks related to these events, then the service life of a building will proceed according to assumptions and requirements.

3.2 Uncertainty

In a building project and in the service life there are many situations that cannot be predicted. The execution of the construction process can become even more difficult than it was assumed before and unexpected events can take place. This state of lack of information is called *uncertainty*.

In almost every field in the construction process there are uncertainties. Even the best prepared risk management, organisation of work or good decision making will not protect the project from uncertainties. The uncertainties can be related to new critical events, so also to risks that these events represent. It is important to bear in mind that not only known critical events exist in building projects, but also these ones that were not identified and can occur unexpectedly.

The amount of uncertainties is largest at the beginning of a building project, because of lack of detailed information see Figure 3.4. However, the amount of uncertainties decreases more the project is advanced and it reaches minimum in the end of the service life.

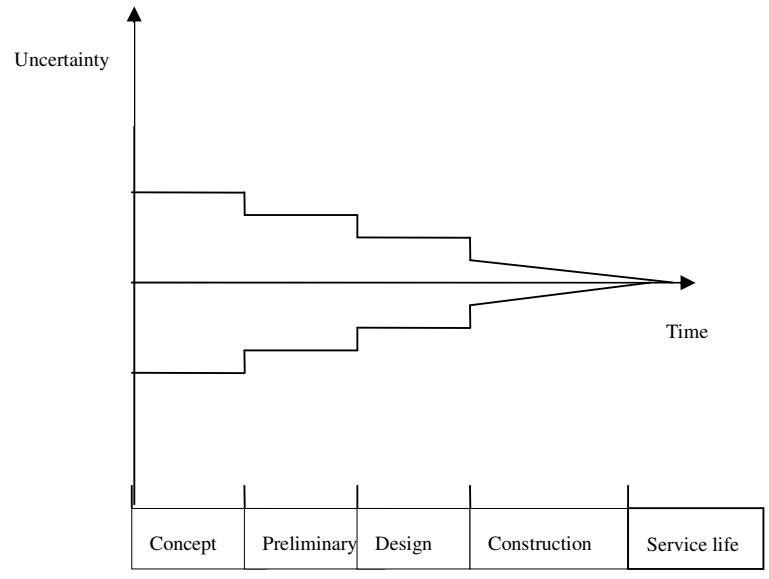

Figure 3.4. Uncertainty in building project, adopted from Smith (2006)

Kwakye (1997) lists different kinds of uncertainties mostly related to building projects. However, due to the scope of this Master's Project only those connected with conceptual design are mentioned.

1. Task uncertainty – Even very similar tasks can contain issues to consider, which are unique and specific for a certain project. This can cause some problems to the design team to solve, because it is not possible to transfer experience from one project to another, which makes every project unique. The inability to foresee all problems associated with new construction tasks that are more or less unique creates a task uncertainty.

Each project's participant should be aware of uncertainties, and this consciousness should be developed systematically in the project, especially in conceptual design. The inability to see all problems in advance, enlarges the risk that previously made assumptions will not be good enough to manage consequences due to new critical events.

2. Organisation uncertainty – When a new project begins, also a new cooperation between new participants is started (new client, new contractor, manager, engineers). The cooperation between them, like the system of exchanging information, needs to be created from the beginning, and it is also more or less unique for each project. This aspect creates uncertainties between the project participants, until some kind of routines is generated.

It is not an easy task to make the organisation functioning well from the beginning of the project. However, as it was stated previously, good relations and cooperation between project participants are essential to minimise the risk of misunderstandings and conflicts in each stage of the building project. The ability to cope with organisation uncertainty is essential to ensure the progress of work in such important phase as the conceptual design.

3. Uncertainty concerning agreement between the theory and reality on site – The production process in construction projects contains many hidden variables that cannot be judged in advance, neither by the contractor nor by the client. Consequently, these unknowns become visible when site production starts. For example, the ground conditions can be different from the documentation, which could create problems with the excavation.

Of course during the conceptual design phase, the ground conditions are possible to predict basing on theory. However it is recommended to think about alternative solutions in advance, in case of unexpected situations during excavation.

3.3 Standard Risk Management Model

There are many situations where critical events appear suddenly in building projects and in the service life of buildings and it is necessary to handle the risks in the best, possible way without high impact on other important issues. The purpose of risk management is to predict the critical events and their consequences, reduce, avoid or transfer the risks to another parts of the project. It is not an easy task, and the whole process requires good methods and an organisation.

Nowadays, when new technology is developing fast, new solutions appear and the need on the market and competition are large, the building project must fulfil the client's requirements and be managed and planned bearing in mind possible critical events that can happen during the project and the service life.

What is good risk management then? The answer of this question has a large scope and would take a lot of time to answer, because there are many ideas and methods for good risk management. The general characteristics of a risk management model are described in these Chapter and the activities presented in Figure 3.1. Following this general scheme, project participants could develop and create the system of work on the project that includes the risk management activities that are helpful to handle risks successfully.

It is worth to say that risk management is a part of the project management, so the leadership and organisation play an important role when risks are to be identified, analysed and allocated.

3.3.1 People Involved in Risk Management

As it was stated previously, every project is unique. Even projects similar to previous ones require separate considerations from the risk point of view. Very often the companies do not put so much effort to develop the risk management strategy and risk awareness among the employees and during the contacts with other project participants. Frequently, the work on the project is concentrated on handling the effect of risky situations, rather than identifying the possible critical events and their consequences in advance. Risk management is still not a so common part of the project management, and the team members are not prepared properly to handle risks in the initial parts of the project, where the scope and uncertainties are the largest.

According to Smith (2006), there are generally speaking two groups of people in connection with risks, risk avoiders and risk takers.

Risk avoiders tend to overrate risks by means of trying to avoid any risky situations, since they only see difficulties in handling the projects in situations where critical events can occur.

Risk takers are not afraid of taking risks in their everyday tasks and working tasks. They prefer to underrate risks and that makes them risk more easily than people who are risk avoiders.

Both groups can be found among project participants' teams. That makes the management situations balanced in risk assessment. Then the risk can be analysed in an efficient way and a first step in project management is taken. However, the general opinion about project management is that its purpose is to keep the project on time, at budget, and within the schedule, no matter what obstacles take place. However, project management is not only about realisation of a project within budget and time plan, but risk management is also a part of good project management, but very often omitted by the companies.

Risk awareness

Good risk management develops risk awareness among team members. The participants should be aware of risks in all the phases of project development. Understanding of risk and knowledge about the risks among the project participants enable them to take appropriate actions, measures and decisions to identify, minimise, and to handle the risks it in an efficient way.

Project Manager/Assignment Manager

The project manager and the assignment manager are key persons in the team, who take care about the overall risk awareness among the team participants and the quality and management organisation. Everything depends on the skills and abilities of the manager, who should motivate team members and pay attention to good communication and openness in sharing information and relations between the participants. The qualifications, experience and knowledge of the project manager are essential for efficient leadership of the project team, and the team's motivation. The project manager must help to create the project environment, express the goals and expectations, actively be a part of the project management process, and make sure that all the team members are ready to work with the risks.

3.4 Qualitative and Quantitative Methods of Risk Analysis

The risk analysis is the next step to handle risks in projects. The key is to analyse the identified risks in such a way that the knowledge about the existing critical events, their risks and impact on further stages of the project would be utilised in selection of promising concepts.

The risk assessment can be qualitative or quantitative.

The quantitative risk assessment defines the probability of critical events and their consequences in the project as a key for good decision making. During the risk assessment it is worth to think about the consequences in different ways in the project process, for example time increase, costs increase, or quality and performance reduction. The situations where critical events can have influence on other parts should be identified early to avoid a chain reaction in project progress.

There are many methods for risk analysis, depending on the risk level and stages of a project. However, different methods can give results in different formats, but the inherent level of risk is not changed whichever method is used. It is always a question which method to choose? It is not a simple answer. The best way is to start with simple methods of risk analysis and then, when it is needed, develop work with more advanced methods.

Probability analysis –determines the probability of critical events. For this purpose, special calculations are needed. The complexity of the calculations depends on the project, the kind of risk and the conditions in which the critical event can occur. In most cases, risks in the conceptual design phase are hard to calculate by means of numbers, and the judgment about the probability is based more on feelings and old

experiences than on mathematical formulas. However, when typical technical risks in structures are analysed, like the risk of explosions, crack risk in concrete structures, special computer programmes are used. [Adopted from Kwakye (1997)]

Monte-Carlo technique is called so because of its imitation of the randomness of a roulette wheel, and is one of the most popular techniques of probability analysis. A random process of developing data is based on selection of different values from a range that was defined by the probability distribution. For each uncertain variable (input), definition of a possible range is made taking into account statistical properties of this variable. A chosen value is run through the model, by usage of an iteration process. Outputs are presented in histograms.

It is important to choose a probability distribution that is representative of the range and the way in which the values of a variable might vary. The shape of the probability distribution chosen is often based on historical data. However, historical data is not always available, so the choice of the probability distribution shape depends on decision of the risk analysts and other people involved in the risk analysis and the project. [Smith (2006)]

An example of Monte- Carlo technique in practice is presented in Section 4.2.2.

Qualitative risk assessment is based on different issues that describe the nature of risks. In this point it is worth to consider the stages of the project when a critical event occurs, elements of a project that can be affected, factors that influence the risk, relationships with other risks, its probability, and consequences on the project.

The understanding of when a critical event can occur and how to allocate it properly in the project is supported by the means listed above. Consequently better decision can be taken, which makes it easier to develop the contract strategy at the beginning.

The Delphi method can be treated as qualitative or quantitative method of risk assessment. The general procedure is to form a team of experts that represent all aspects of the project .They formulate a definition of the risk that is going to be considered. Each expert is asked to assess the risks individually and estimate their probability of occurrence and their impact on other phases of the project. The cost estimation of the risk can also be included in the analysis. Afterwards, the experts are informed about all the estimates and are asked to give a revised estimate. This process is continued until a consensus estimate is achieved. The team of experts should be interdisciplinary, in order to obtain objective and useful results.

Since the Delphi method is a very subjective technique, it relies on the opinions of people who are deemed to be experts. Due to this, the solutions should be treated with caution. The procedure is time consuming because each expert has to have time to provide several analyses individually. It is possible to organise their meetings at once, which would reduce the time of realisation. However, it could be difficult to set the date of such meetings due to the differences of availability of each expert. Also the project team members should be present during this estimation in order to hear the opinions of the experts and make comments if necessary. This method can be used if the company has little experience in realisation of similar projects. [Adapted from Smith (2006)]

Sensitivity analysis –considers the change of one risk's variable and influence of this change on the whole project. Each risk in this method is considered separately and independently, to study the effects of such changes on different issues in project life cycle such as time, cost, schedule etc. However, this technique is constrained, because the variables changes individually. They are independent on other variables and can have influence on each other, which makes the result uncertain. This method is helpful for project participants to identify the importance and levels of risk factors and see the ability to transfer the risk to different stages of the project. Sensitivity analysis is used in case of a large number of risks to enable identification of high sensitive risk factors on which efforts should be concentrated. [Adopted from Kwakye (1997)]

The method is easy to obtain by computer analyses. However, experienced people are needed to create the model for this analysis.

*Decision tree*s are diagrams that represent a sequence of decisions and critical events defined by the decision-maker. Decision trees contain decision nodes that represent decisions that have to be made, and critical events that might occur. A decision tree starts from the 'decision point' and is developed from the left hand site to the right and the information is also conveyed in this way. At the time represented by a specific node all prior decisions, or decisions to the left of the nodes, have been made and the uncertainties related to prior critical events have been removed. Each decision node should have at least one alternative that is represented by arrows-branches. The branches indicate the alternatives and the quantitative risks connected to them (cost, probability of occurrence) are placed above the arrows. However, it depends on the decision-maker and the project whether the quantitative risk analysis is going to be incorporated in this method. Otherwise it is considered as qualitative method only.

The main advantage of this method, whether is used as a qualitative or quantitative method is that whole project should be considered and set out in logical sequence. This ensures that all the options available in the project are considered at the early stage. Other advantages are that is understandable and clarifies the sequence of events that are considered to make a choice. Everyone involved in the project can take part in creation of decision trees. However, it does not point the ready solution, but the alternatives that can be chosen. It is a very useful technique for getting information across to those involved in the project. Decision trees are cheap and easy to produce, since they only require the use of one person that has good understanding of the project, the alternatives and the chance events. However, a presence of more project members is advisable in order to develop the trees and to make it more objective. In more extended projects the decision trees is not useful and creation of them would be time consuming and difficult. However, it is a good technique to match and understand the relation between decisions and their alternatives. [Adapted from Smith (2006)]

3.5 Conclusions

A building project is a process where each aspect in organisation and work should be carefully considered and planned. To achieve the final result with a well designed structure and completed construction work on time within budget and schedule, adequate knowledge about critical events, systematic work and management skills are

necessary to coordinate the whole organisation from the beginning of the building project.

Risks of different kinds in this whole system of activities, decisions, meetings, brainstorms and evaluation of possible solutions are present from the start with a first idea until the end of the building service life. Even the best management methods, good knowledge and adequate experience in the building project are not successful if the risk awareness among project participants is not present.

Since the range of uncertainties is largest at the beginning of a building project, it is important to have a clear picture of the risks and to identify the situations where the risks can have an influence on further phases of the building project.

The adequate skills, knowledge and experience of the assignment manager who is responsible for coordination of the project work play the key role in a process of risk management. That gives the ability to develop the methodology and internal system of handling risks in building projects. However, it is essential to remember that every project, even if it is similar to another, is unique and brings specific risks, so acting with risks based on routines or schemes is not a good solution in risk management.

It is hard to point out one adequate method of risk analysis, and to judge which one is a most suitable for a most realistic risk prediction. Various methods exist and the projects and the way of working with risks are not possible to define directly.

Critical events exist in each aspect of a project from the beginning to the end and it can be managed in different ways by reducing, transferring or avoiding the risks that refer to these events. In the conceptual design phase, the potential effects that risks can have on the solutions and how risks are going to be handled in risk management should be discussed. Even if the probability of critical events is hard to assess at the beginning of the project, each doubt should be presented and discussed during the meetings, and even small signals about different risks should not be omitted but considered in the project team and with the other building project participants.

Meetings and abilities of sharing and exchanging information between project participants conduct to good decisions, reduce the risk of misunderstandings and delays, or risk for changes. Constructive meetings improve relations between the members of the building project, and have an impact on risk perception and identification. It is important to keep fluency of cooperation with the client, through the whole building project process in order to obtain efficient work and current information exchange.

A systematic upgrading of knowledge about risks in the progress of the building project is necessary to ensure organised work in handling the risks. In this case data collection is advised. Databases or checklists are huge sources of information of issues that need special attention or decisions that were already taken during the project realisation. Information storage and checklists about risks help to keep a logical order of work. Highlighting these issues that need to be discussed and fixed, is a good source for younger engineers without large experience and knowledge about risks.

To sum up, during the building project realisation, risks exist in each step that engineers take in their everyday work. The point is to identify possible critical events

and their consequences in the beginning of the project, in the conceptual design phase, to make the risk assessment easier and choose the adequate solutions to be developed in further phases of the building project and result in a building service life. Also unexpected critical events related to uncertainty that could make the realisation complicated, cause problems or disturb in good relations with the client or team members could be avoided in this way.

Risk identification and analysis require good competences from the designers and the project manager. Natural introduction of risk management into the project management brings benefits in this field by successful decision making, better prediction of risky situations and mistakes in the project's life cycle.

4 Risks in Building Projects – Observations

Understanding the nature of risks in a building project is not only connected with literature study and theory. The best way to learn and compare the risk both in theory and practice is observations of already realised projects or the projects in progress. For this purpose two project tasks realised by the consulting companies GF Konsult and Norconsult as parts of the building projects were analysed from the risk point of view.

4.1 Project 1 – Teknikhuset

One of the projects realised by GF Konsult, which is going to be described below for purpose of this Master's Project working with risk in the project life cycle is Teknikhuset building design started in March 2007.

The project belongs to design-tender-build contract. The new concept of the building is done by GF Konsult, and then in tendering process the contractor is going to be chosen to finish the detailed design and be responsible for construction phase. However, when the project is being described in this Master's Project, the main contractor was not selected yet and the conceptual design phase is being finished by GF Konsult.

The building is financed by the Ministry of Finance (Finansministeriet), the client is Fortifikationsverket, and the user of the building will be Försvarsmakten Tekniska Skola (FMTS). The date of completion of the design phase of GF Konsult was scheduled in November 2007. The work on this phase took nine months, but it was originally planned to take ten months. GF Konsult reduced the time to completion of the design task of about one month that was valuable for the client.

The aim of the project is to re-design a building located in Halmstad in Garrison area, where the technical school owned by the Minister of Defence will be located and the special training for military service are going to be organised. The idea is to re-locate the base of old school in Östersund to the new building in Halmstad. Reduction of the gross area was a main task for designers at GF Konsult in already existed project made by another company. The architect and structural engineers managed to reduce the gross area of the building with 2000 m^2 that make it cheaper and faster to construct. In the second stage of design the task was to prepare the drawings and technical specification for the tendering process.

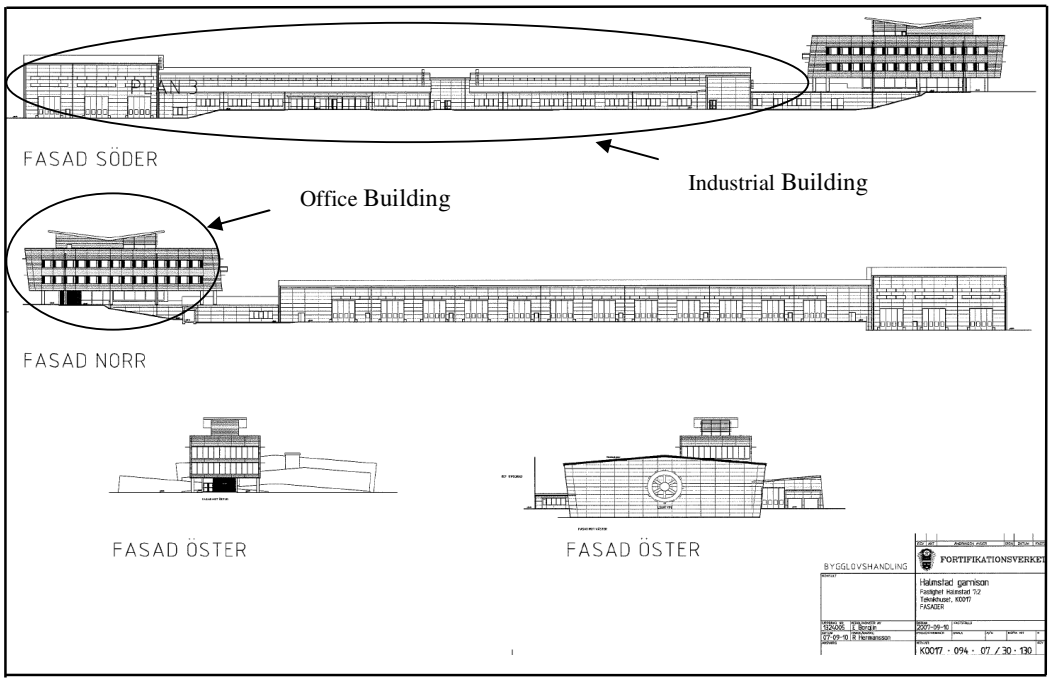

Figure 4.1 Facade plans of Teknikhuset, GF Konsult AB (2007)

The building includes two parts. One part contains industrial buildings with halls including military equipment for training, classrooms, computer rooms, storage rooms and personal rooms, and one room for training with weapons. Second part is an office building with four floors (see Figure 4.1.). There were no special requirements according foundation concerning ground conditions in the Halmstad area, why a concrete slab was chosen.

The structure of the first part is made of steel columns and concrete slab. The roof structure is made of steel trusses. The steel columns were chosen instead of concrete ones in order to design columns with smaller cross section and achieve the span between the columns of 9 m (see Figure 4.2) that were additionally strengthened in case of impact of the vehicle. In addition the horizontal HEB beams were designed to be installed on the columns (see Figure 4.2) to carry steel beams for small cranes. These special beams were designed according to guidelines from the client and specialists. Moreover, heating system in industrial halls was placed in the floor. It is equipped in special suction system that allows reduction of the pollution from the vehicles.

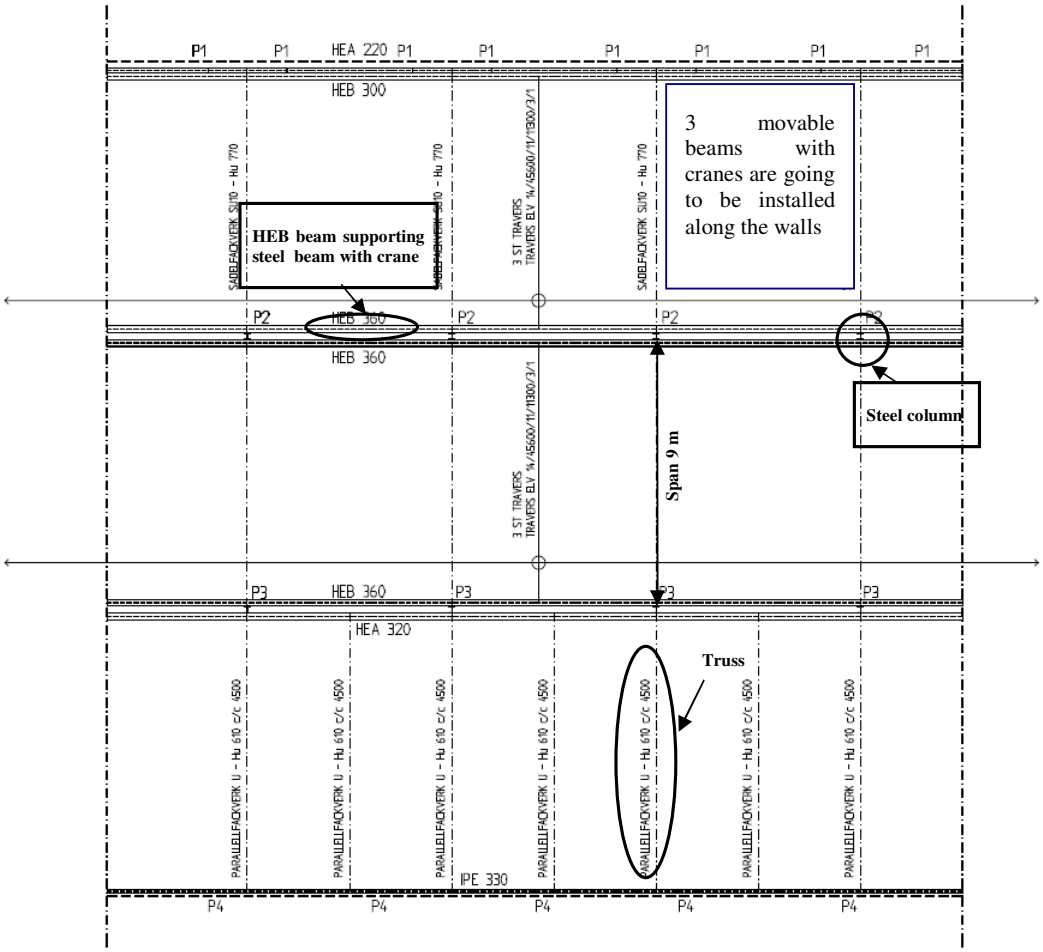

Figure 4.2 Industrial building, GF Konsult (2007)

The second part of the building - the office is made of prefabricated concrete columns and hollow core prefabricated elements with light steel structure of the roof top floor. The concrete as the structure was chosen due to higher durability in case of fire accidents.

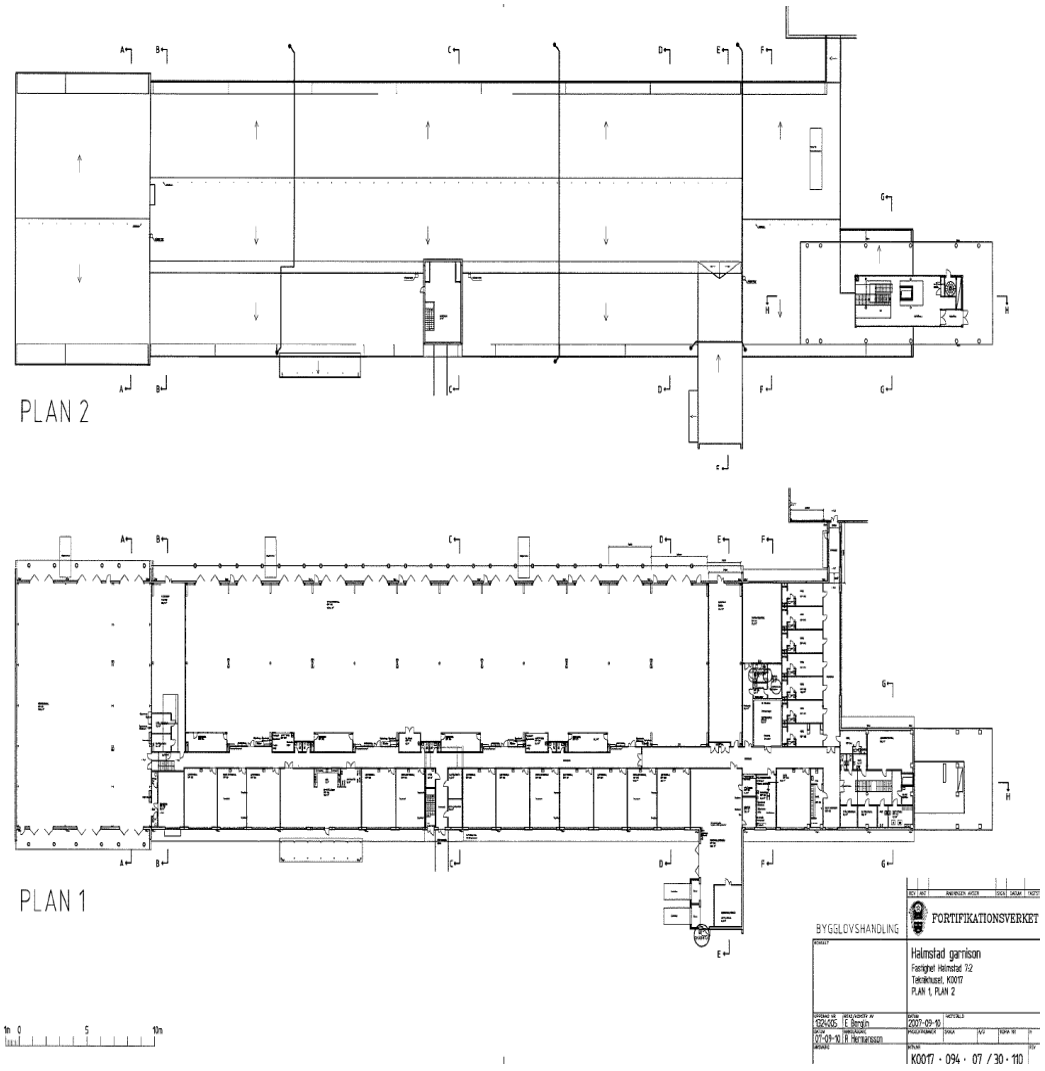

Figure 4.3 Plan of industrial and office building in Teknikhuset, GF Konsult AB (2007)

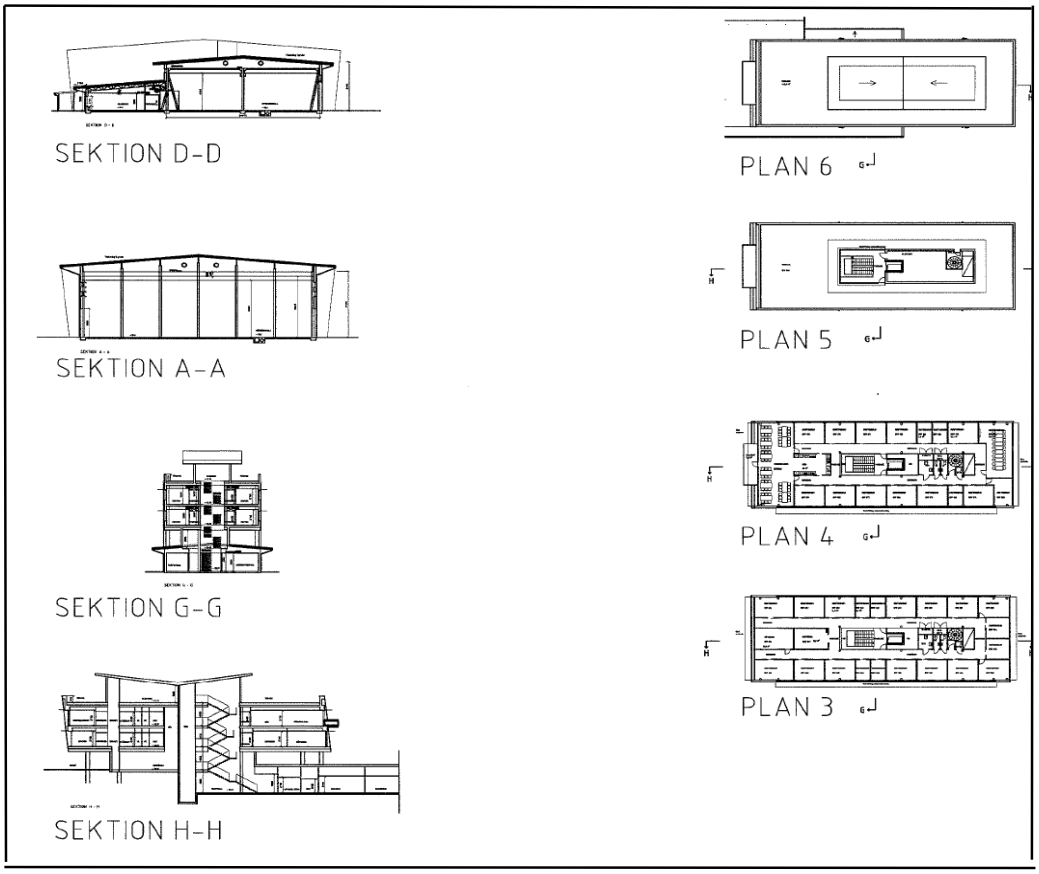

Figure 4.4 Office and industrial building sections of Teknikhuset, GF Konsult AB (2007)

4.1.1 Organisation of Project 1

The first steps to design the building, were the meetings with the client. All the requirements and technical specification were discussed. The client presented to the assignment manager necessary materials needed to go further in design phase. Every meeting was carefully registered in form of protocols to document all decisions during the meetings in case of any doubts and re-negotiations.

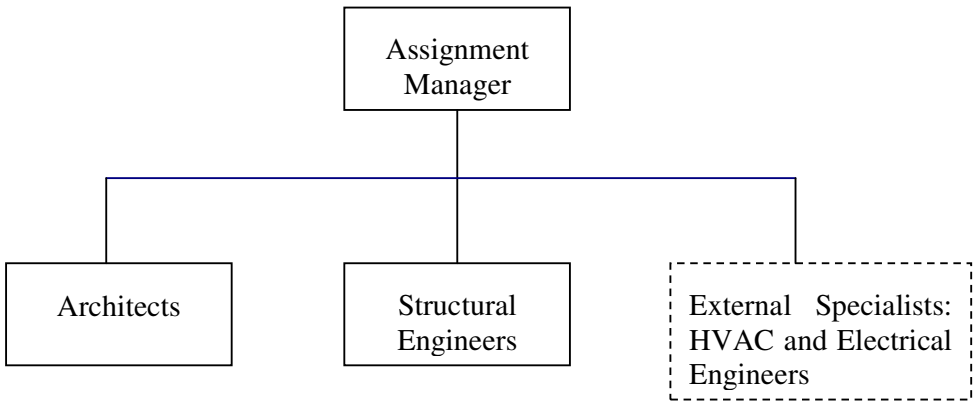

Figure 4.5 Organisation of the design team in GF Konsult for Teknikhuset project

The assignment manager from the beginning of the project task took part in all meetings with the client. He discussed the important decisions with the customer, was the coordinator of the communication and the information exchange between the design engineers and the client. Because of the risk of delays in making decisions that may have impact on further steps in design, the client was informed about the critical events of the project in advance. The group of external specialists, HVAC and Electrical Engineers, in case of complex design like ventilation, heating, air conditioning, fire, electrical and sound installations et cetera was consulted to ensure the minimum of possible mistakes at the beginning of the design process.

The consultants' team from GF Konsult met every third week of the month to discuss, compare and clarify the important parts of design, and exchange information between the client and the team members.

The meetings with the client were held every fourth week of the month. As it was said before, the assignment manager was a representative person, who contacted the client and was responsible for negotiations and kept him informed about the progress of design.

The detailed design was not the part of the contract at GF Konsult, so only the structure, façade of the building, and installations were included in the design task of GF Konsult. The details of connections and all complex technical solutions are going to be designed later by a company that is going to be chosen by the contractor. There is a possibility that GF Konsult will be chosen to finish the design phase.

The assignment manager prepared the environmental and organisational plan of the project that included also critical events and their risks in the project (Table 4.1). Careful analysis of the values that need to be checked and properly controlled progressively and identification of critical events, give the clear action plan and minimizes the probability of mistakes in calculations based on geotechnical analysis, wrong cost estimations and puts effort on properly prepared safety analysis and protection from pollution of environment. As it was mentioned in Chapter 3, changes made during the progress of work on the building project might have a large impact on the project cost and if done too late will not bring desired effect. Due to this the well identified critical events and their risks eliminate oversights during design process and reduce the need of change in later parts of the building project.

It is important to highlight the need of good organisation of work in the team. The potential human mistakes in the activities that always have a right to occur enlarge the risk of failure in different fields of the project, even if numerical analysis was prepared precisely. Well developed cooperation helped in successful identification of critical events and assessment of risks that should be analysed. That is why it is important to pay attention to identify the important and influential issues in the beginning of the project task to work with them later and achieve desired results in well designed building.

Table 4.1 The Environmental and Organisation Plan, GF Konsult (2007)

	Critical moments	**Measurements/ suggestions**	**Control**	**Control plan**
1.	Delivery of geotechnical background	- analysed early - questions stated if needed -completed geotechnical investigation	Early technical consultations	Detailed information from initial meetings and other meetings
2.	Project costs and regulations, reports about expenses	-revised calculations - risk analysis -analysis of alternative solutions	Documentations and cost breakdown	Realised according administration guidelines
3.	Possible pollution in ground that needs further consideration	-deep ground's environmental analysis -laboratory analysis -actual reports and improvements	Important decisions documented	Discussed at design meetings, documented in protocols.
4.	Safety and environmental work	- work with hazardous material and risk analysed	-controlled in internal meetings and design meetings	Protocols from the meetings.

To deliver a good project plan, the experience from previous projects was utilised and the content discussed with the consultants and the client. The time schedule was tightened of one month that made the completion on time a critical event because the too late made decisions could cause delays in progress. However, properly controlled and scheduled task, turned out to be successful and the design project was delivered on time.

At the beginning of the project, objectives and aim of the task were stated in a document prepared by the assignment manager. In several points the main interests of

work organisation, important issues regarding work environment, administration, and costs were included in these objectives. Some of them are presented in the Table 4.2:

Table 4.2 Objectives of the project, GF Konsult (2007)

GF KONSULT AB Box 8774, 402 76 Göteborg Tel 031-50 70 00 Fax 031-50 70 13	**Objectives of the project**	Project no. 1324 004
	Halmstad Garnison, K0017.094	Date: 2007-03-27
	Teknikhuset	Revised by: Åke Thunberg

1. Time is an importance, the revision of time schedule should be done immediately, if needed and consulted with client's project manager.

2. Ministry of Defence requires and hopes that all connected technical, environmental and economical solutions will be fulfilled. In case of risk of conflict the dialog with client is going to be held and possible solutions discussed.

3. Administration of work will be done in such a way that the client will be satisfied and firstly the scheduled time will be handled, economical revision, information (oral and written) will be included in protocols from the meetings. An open dialog concerning objective's fulfilment will be continuous, and experience meetings held in the end.

4. Initial cost calculation is given at the beginning from the client to GF Konsult. Further calculations of cost and regulations are prepared after approved time plan and even in case of large needs of changes.

5. Work environment has a high priority that regards consultants and workers on site. The critics about work environment will be done to omit accidents and hazardous situations.

6. Geotechnical conditions and actions will be delivered from Ministry of Defence (the client) by the consultant. Discussions are going to be held in case of needs to complete the documentation or information, and will be done frequently.

7. Proposed solutions will include best possible environmental adaptation seen from overall perspective. Environmental work goes towards security of good balance between technique, environment and economy.

The group work is also a good idea to match the competences and good organisation in objectives of the project. The official statement of 'how we do' and 'what we do' constitute the initial rules of the organisation of system in which the clients needs, rules and creativity of the team depend on each other. The reliability and skills of every member of the design team were taken into consideration during the division of responsibilities in the project. The responsibilities regarding the design and technical solutions were divided according to the competences between architect, structural

engineer and HVAC and Electrical engineers. Because the main task was to reduce the gross area of the building, the architect took the responsibility of gaining the information about the system of exploitation of the building by the client. Negotiations and meetings were the tasks of the assignment manager and held to present the possible solutions in the conceptual design phase to the client.

The documentation is an essential activity to utilize the experience feedback and prepare information for risk identification and analysis. The client's requirements, well defined scope and vision of the project, environmental and organisation plan generate the coherence and bring the input for risk model shape. The key was to skilfully use the collected values and transfer them into the understandable management process in connection with decision making. This activity required time for preparation and consideration which was the task of the assignment manager.

In the concept creation of re-design, the architect initiated the idea of the building but the final solution belonged to everybody involved in the project. Of great importance were the meetings and common sharing of information and brainstorming resulted with the reduced area – according to client's needs, and confirmation of build ability and functionality of the school. The landscape architect was consulted also to clarify the vision of outdoor design in the building area. The company that delivered the origin project of the building was not consulted because the GF Konsult architects and engineers have not found the need to do so.

4.1.2 Work with Risks in Project 1

Depending on the responsibilities and function in the project work, the team members perceive risks in different ways.

The risk in organisation and management in this project work was according to the architect's opinion perceived in means of complexity in communication between the project participants. Their range of duties made the time schedule very tight so it was sometimes hard to contact the co-workers, discuss doubts and make good decisions in short time. It could result in delays of design phase, because most of the solution required careful consideration, so ability to consult and share experience and knowledge between project participants was decisive to safe time for finding good solutions. An example would be a system of corridors in the office building that would allow for good communication between the employees sitting in separate rooms. This solution requires not only appropriate technical and architectural consultation, but also information from the client about system and organisation of work in the office.

In the structural engineer's opinion, the communication in the project team was not a problem and no critical events occurred in this case. Structural engineers work in opened landscape, so the open dialog and good communication was held everyday. Only the meetings with the assignment engineer and the architect were specially scheduled. The structural engineer did not meet the client as often as the assignment manager or the architect did. These meetings were held in case of need of consultation.

The risk in the structural engineering was considered mainly in economical balance in costs of the project task and cost of the building. This part was prepared together in the

group and each expense was taken into consideration, the economy of solutions was clearly discussed with the client. Information in this case was valuable, because the cost of the project and the building is one of the main parts in every project. Small mistakes in calculation would bring losses to the project participants, and would be a source of misunderstandings or conflicts.

Technical risk in structural engineering was not considered so much in the conceptual design of Teknikhuset. The following of the codes and regulations together with utilisation of experience feedback was enough to omit the technical problems in this phase and ensure the stability and safety of the structure. Also any specific methods of risk analysis were provided for this purpose and all assumptions were based on knowledge and experience of engineers.

4.1.3 Conclusions from Project 1

The interview with the architect, the structural engineer and the assignment manager was held to gain technical information about solutions used in Teknikhuset and risk identified during this work (see section 4.1.2).

Looking into the scope of the project task of Teknikhuset of GF Kosnult, the design phase was limited to concept and basic proposal of technical solutions for further development. Due to this, the tasks and responsibilities in structural engineer's opinion were not difficult to divide and coordinate between the design team members. The possibility to finish the project in short time was very probable and any special risk of delays or disturbances were not identified by any of interviewed person.

However, a strong dependency between a position in team and a risk perception was noticed:

- The architect work requires continuous communication and consultation with specialists and structural engineers from other team. The interviewed architect identified the risk in the project as potential difficulties in coordinate unscheduled meetings or discussions in time.

- The structural engineer noticed the risk only in cost calculation of the project. For this purpose meetings with assignment engineer took place. Regulations and design codes give, in structural engineer's opinion, the certainty in well designed structure and assumptions, so there was no need to provide the risk analysis for this issue.

- The assignment manager's responsibilities was to coordinate work between all the project participants, controlling schedule and economy and point out the most important and critical events during whole period of conceptual design of Teknikhuset. The idea of implementation of the environmental and organisation plan and objectives of the project was very useful for better identification of important activities for each team member involved in the project.

According to these individual visions of the risk it can be noticed that any special system of critical events identification and risk analysis does not exist in this project team in GF Konsult. The risk is associated as potential unexpected problems and

consequences, and the knowledge about the risk management seems to be limited. Experience feedback based on team learning and exchanging information and technical knowledge are the main values used during realization of the project. Most of decisions were made straight away on the basis of consultation and meetings with other members of the project group. However, what seems to be missing, is a relation of the experience feedback with risk management which causes that the project is not prepared for the bad consequences of the decisions that could be omitted if the risk assessment would be done.

Although the team learning and consultation took place, the documentation about newly gained information about the risk or experience from this project was not prepared for future use. The interviewees found a reason of this in limited time of the project completion and they admitted that they do not do that at all. Engström and Lierud (2006) pay attention to properly organised and collected documentation in experience feedback utilisation and list many advantages from this kind of information storage. One of the suggestions to improve the information flow was an accessible web-based project database, but still motivation and engagement of the project members is needed to fulfil the idea.

4.2 Project 2 – 6th Floor of the Norconsult Building

Norconsult is a consulting engineering company in Norway with head office in Sandvika, in close location to Oslo. GF Konsult belongs to Norconsult Corporation from January 2007. Norconsult employs about 1350 specialists in engineering, planning, management and consulting.

The company's headquarter is located in a five storeys building that is being extended with an additional 6th floor on the top (see Figure 4.6) with area of about 1700 m^2. The contractor of the project is AF Bygg Company from Norway. The client and consultant of the project of 6th floor is Norconsult.

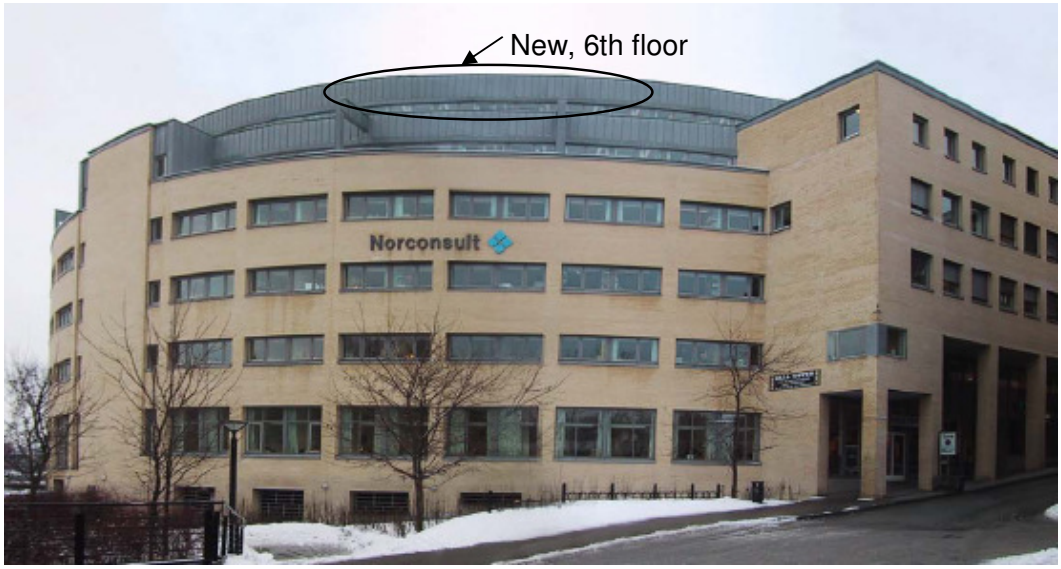

Figure 4.6 Norconsult building, Norconsult (2007)

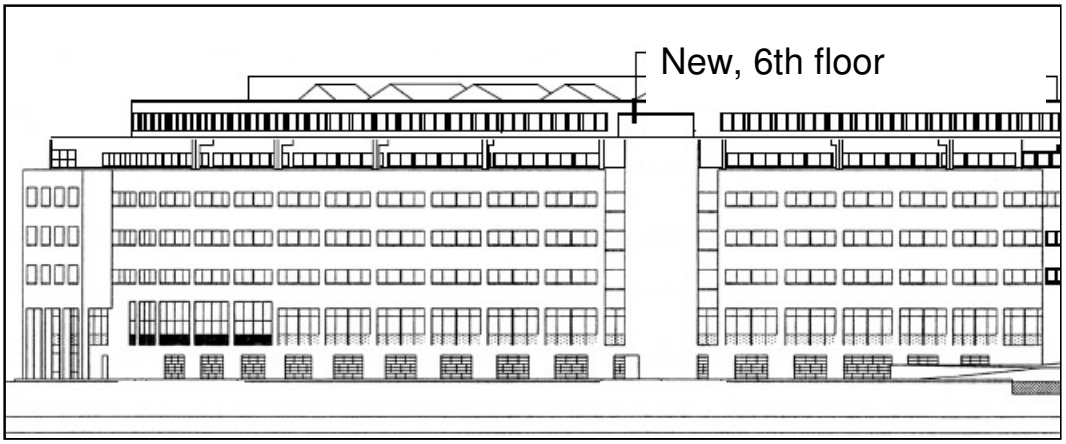

Figure 4.7 Façade from north, Norconsult (2007)

The structure of load bearing walls of the 6th floor is made of steel columns, wooden studs and light concrete. The columns are placed directly on the steel beams on the floor. Additional bracing of the walls was constructed. The roof is designed with the span of 12 m, with the light structure of steel girder, insulation and steel sheets on both sides. In the room where air-condition machine is placed, the additional sound insulation of the walls was used to protect next-door offices from noise.

During realisation of the project, a problem with rain water occurred because the drain on the roof of existing building was clogged and not properly cleaned. Flow of the water was hindered, which resulted with flood of water to the office on the 5th floor and caused damages in the structure and delays in the project.

Another issue that needed special consideration was moisture in glass parts of the ceiling. Due to temperature changes outside, there would be a risk that water would condense inside the building. To protect from this kind of natural phenomena, special ventilation system, (see Figure 4.8), has been designed in these parts of the roof.

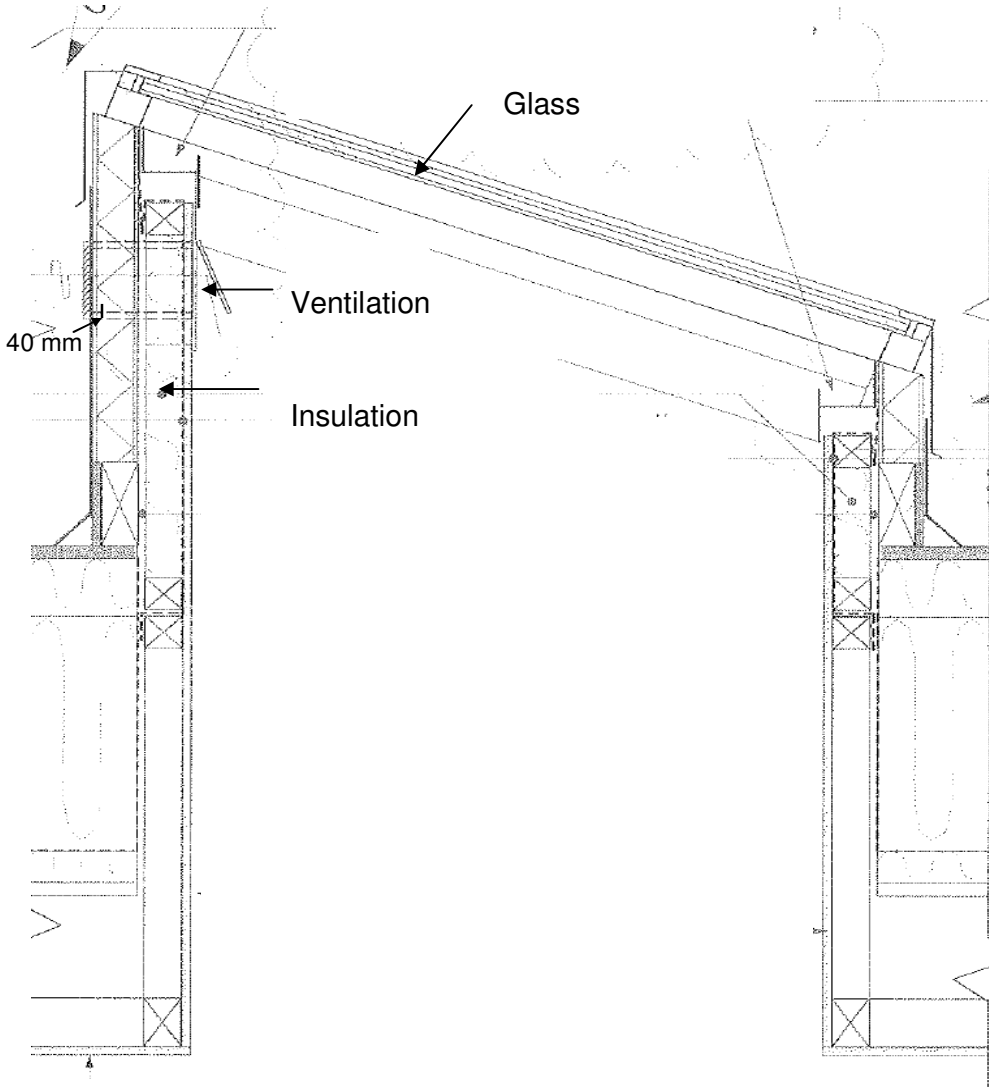

Figure 4.8 Ventilation solution for glass part of the roof, Norconsult (2007)

Ventilation system was placed with spacing of 40 mm between the boarders of ventilation and walls, to ensure movements of load bearing walls due to changing of load conditions.

4.2.1 Organisation of Project 2

The organisation of work in this project is different than in the project of Teknikhuset. First of all, the Teknikhuset project was in the conceptual design phase, where project

of 6th floor is in the middle of construction phase of project life cycle. Observations on the second project were done on basis on the interviews with the site manager and the assignment manager responsible for administration and the economy of the contract.

The planning of the project was started in Autumn 2006, then necessary information were collected from the client (Norconsult) in order to consider needs and prepare a vision of the project. Meetings with the employees were organised to hear their suggestions about the plans of the office. Then in cooperation with architects the 6th floor of the building was designed. The technical specification and cost estimation were done in the beginning to prepare the project for choosing the contractor.

The design of the project was done by two companies: Base Arkitekter and Norconsult. The plan of the building and facade was designed by Base Arkitekter, technical details, installations, fire protection by Norconsult.

The form of the contract was a partnering contract (see section 2.3). To choose the contractor, a competition was announced. The contractor companies interested in the project sent their references and information about qualifications to the client. Norconsult considered the capability of each candidate to choose the most adequate to the requirements and needs. As a result AF Bygg Company from Norway was chosen as a contractor of the project. The construction period was scheduled from March to December 2007.

Communication between the client and the contractor during the project realisation is facilitated with the localisation of their office on the construction site. Because Norconsult has the office in the same building as the new built floor, meetings and dialogs with contractor took place everyday. Cooperation between contractor and client/consultant was assessed as very good in opinion of interviewees. For this purpose two types of meetings took place during the project.

Planning meetings – Participants analysed the concept of the project and compared it with the work progress. They checked the schedule, the quality of the construction work, considered problems and made solutions for them. Norconsult was a consultant during these meetings.

Client meetings – Here Norconsult was present as a client. During the meetings the issues connected with the contract, the costs and extra costs were discussed with contractor. The decisions about changes in the project according to the economy or critical events were made. However, any changes in the concept of the project were made in the construction or design phase. All assumptions come from the conceptual design phase.

Detail design phase was overlapped with construction phase, which was a convenience for consulting both stages at the same time, if needed.

The construction work was scheduled in time taking into consideration sub-contractors capacity and individual parts of the structure. The program that was used for the construction phase organisation and time plan was MS Project by Microsoft. By using this planning programme it was easy to control the progress of work and prepare the alternative work's organisation in case of delays or disturbance in the project.

4.2.2 Work with Risk in Project 2

Information based on the interviews with the Site Manager and the Assignment Manager shows that work on critical events and their risk identification in different aspects of the project has been done.

First of the analysed subject was the economy of the project.

Costs of the contract were prepared together during the two-day conference with the contractor using of Monte Carlo simulation (see Figure 4.9) taking into consideration economical risk in the analysis (see section 3.4).

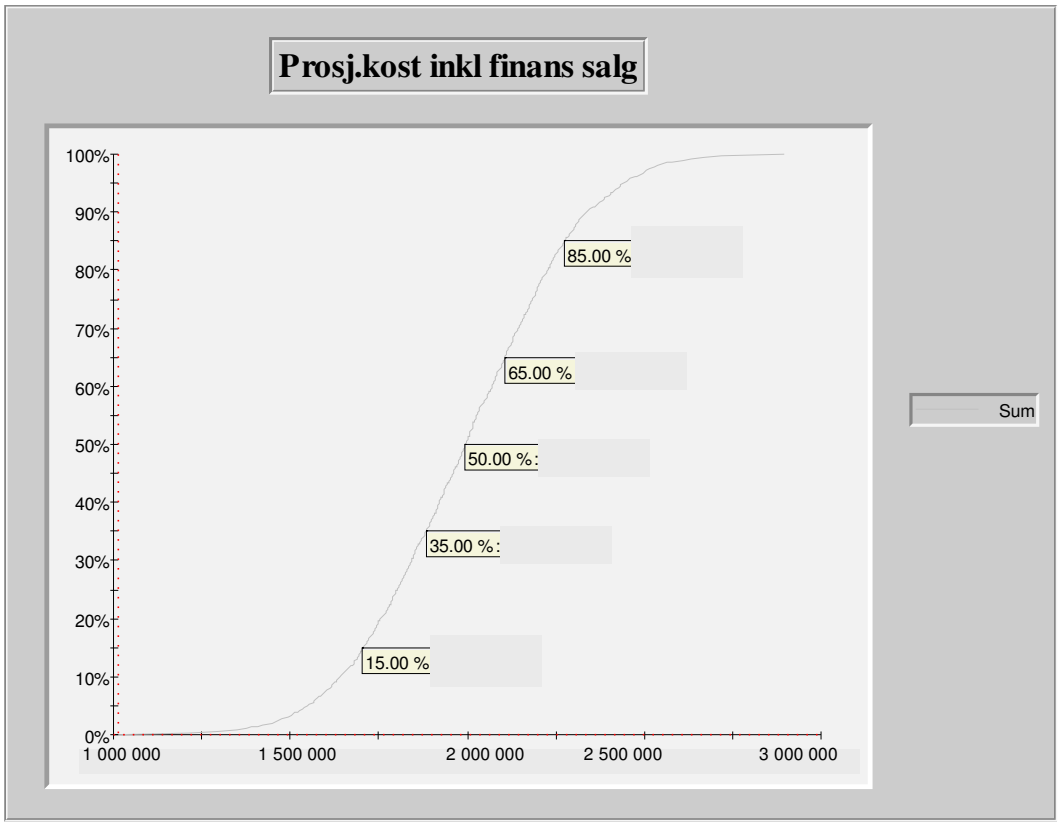

Figure 4.9 Monte-Carlo simulation of costs, Norconsult (2007)

The risks analysis has been done to predict the most probable value of costs and incomes of the project to estimate price and reserves for unexpected costs in the project. The simulation of costs and incomes that shows the changing of the value of funds depending on different conditions in the project that could be change with time progress. The aimed price generated from the analysis, included the basic costs and additional sum in case of changes or disturbances.

Eventual extra costs that will cross the aimed price of the project were divided between the client and the contractor in ratio 50% of extra costs covers the client-50% is covered by the contractor. Also if the total costs of whole project would turn out to be lower than estimated, then the difference would be also divided between these project participants in the same proportion. The aimed price and the extra costs generated the final sum of the project's costs.

One of the responsibilities of the client was a preparation of the schedule of the construction work in the conceptual design phase of the project. Since this type of the time plan is normally prepared by a contractor, the decision about giving this responsibility to the consultant was connected with a potential risk. As a result the contractor claimed about the schedule and some delays occurred in the construction phase. It was decided to keep the origin schedule but in consequence, additional costs related to it were paid by the client in 100%, because the Norconsult took a responsibility for this issue.

Critical events and their risks in the construction phase were also considered. It was done not only in means of the economy, but also the time, the quality of work and delays. The site manager controlled the work progress everyday for making good decisions in future work. The delays in a materials delivery and the unexpected water flood were the problems that needed fast made decisions and organisation. To be successful in this field, the site manager consulted the client and the assignment manager about economical consequences of the critical events. He also took care about development of risk awareness among the workers on site. They were encouraged to put attention to every aspect on site that could raise the probability of the unexpected critical events occurrence in other works.

4.2.3 Conclusions from Project 2

Observing the project of the 6th floor in Norconsult's building, the critical events and their consequences were considered by the managers, the designers and the contractor from the beginning. The detailed analysis of the costs in order to generate the most probable price for the project, helped to manage the project with a good control of economy.

The partnering contract allowed the project participants for searching for final optimal solutions together. The technical solutions were chosen in order to ensure the good economical way of realisation and according to the requirements both of the client and the contractor. The involvement of all participants in the project from the conceptual design phase resulted in a good cooperation and often consultation of the organisation of work on the project.

The awareness of the critical events in the project is noticeable, because both: the designers/the client and the contractor admitted that they work continuously bearing the risks in mind. Also the economy, the design and the work on site is planned taking into consideration the critical events that could occur in individual phases of the project, and try to identify their sources and consequences before the decisions are made.

Experience feedback is utilised everyday by all project participants. For example the site manager executes sharing of the experiences and team learning from the site workers. However, the problems with the work schedule prepared by the Norconsult could be a result of a lack of experience in this field. Because the Norconsult is not a construction company, the realisation of this task turned out to be not as successful as it was expected.

All the information from the two meetings mentioned in section 4.2.1 was noted in the reports. However, the interviewees admitted that any checklists system was provided during the project, which makes the work management more difficult.

4.3 Comparison of the Projects

The comparison of both projects described in this chapter, would be a good complement to previous conclusions and deliberations about risk in the building projects. Although both projects are the building projects, there are some differences between them in organisation and the risk perception by the project participants.

Contract forms are one of the main differences of these projects. Project of Teknikhuset (Project 1) belongs to design tender build contract, whereas the project of the 6th floor in Sandvika (Project 2) is a partnering contract. According to the theory in Section 2.3 it is very common that in the design-tender-build contract the integration of consultant and contractor is difficult to realise, because the phases of the projects are impossible to be followed in parallel. Project 1 was observed in the conceptual design phase only and it was obvious that GF Konsult designers could not have chance to meet a contractor in order to discuss the solution and determine the risk factors that could be significant for realisation of the construction phase but considered at the beginning of the project. At the beginning of the project, the critical events and their risks in different parts of the building project could be assessed only by the consultants that it may turn out to be not enough and re-consideration of the risk analysis would be necessary in further parts of the project.

Another situation was in Project 2 where the partnering was a binding form of the contract. Here the meetings and dialogue with the contractor were held everyday and the exchange of information between the project participants could help in solving the current problems and make fast decisions with consideration of both sides opinion. The fluent exchange of information was possible that helped to coordinate the work on the project effectively. However, even in this project misunderstandings or mistakes occurred. The example of this was a responsibility for the schedule for contract work assigned to the consultants that turned out to be inadequate to the contractor's requirements. This situation caused delays in the construction phase and could be omitted if the consequences of the critical events connected with such division of responsibilities was assessed properly and previously discussed by the contractor and the designer of the project.

The documentation of work is an issue that differs in both projects. Since the projects were realised in different phases, it is obvious that the documents have different form, but there are still some that could be universally used for both phases. The checklist is one of the examples and it have been noticed that only consultants from the Teknikhuset used this kind of notations at work. In the project 2, the checklists in construction phase were not introduced as a way to facilitate the coordination of work

on site and cooperation with the consultants. It was admitted by the employees that implementation of this kind of document could streamline the work and information exchange between the project participants and would be helpful in a better notification and classification of the risks of critical events that occurred during the project.

Taking into consideration perception and awareness of risks in both groups of the projects participants it can be said that it was similar, although the different ways of risk analysis and management were used. However, the interviews show that the risk analysis and management in both projects were provided only in some fields like economy or organisation, but individual awareness of risk among the participants is rather low and most of the activities are based on routines and schemas that worked well in previously realised projects. The interviewees do not try to search for new solutions at their work, because acting in already known ways makes them feel certain in the tasks they fulfil. Due to this they do not see the need of searching of new critical events in new projects and analysis of their risks. This way of thinking can be misleading though because, as it was said at the beginning, each project, even similar to previous ones is unique, and already known situations can turn out to be new in some aspects, and require reconsideration of new critical events and their risks, which may be hidden under the similarities.

5 Conceptual and Design Phase in Volvo Car Corporation

So far the main subject of this Master's Project was to study the risk in building projects, with observations of the projects realised by GF Konsult and Norconsult. To make the Master's Project more interesting, the idea of comparison of different industries was developed to see how the risk analysis and identification with careful work on product in design phase is done by other engineering fields.

Thanks to the Civil Engineers: Lars Hammarström and Anna Margitin, the interview could take place, making it possible to gain the information about the design process in Volvo Cars Corporation.

The design process of a car and its organisation is presented below with important aspects and rules that the engineers and project managers follow. The process was described beginning from idea of a product to the final car vision and detailed technical specification ready for the production phase.

5.1 The Client

First of all, a question who is the client of Volvo Car Corporation should be answered to know better the relations in the design process and cooperation between the project participants and the client. This is also worth in order to compare the client in a building project and in a project in the car industry.

The clients of Volvo Car Corporation are private persons that would like to have a Volvo car for their private use. Also the companies from the transportation sector that order trucks for their purpose or any other industries using cars could be the purchaser of Volvo products.

For Volvo Cars, safety of their clients is a priority. They intend to design and produce a car that would fulfil the requirements of people in every age. The matter is to match the function and structure of car for families, young people, businessmen, truck drivers and their passengers ensuring a maximum safety during the car's lifecycle.

Because of the large number and the variety of clients, it is almost impossible for the designers to meet them individually. That is why the corporation has created a Client's Centre where everyone can contact and express their opinions about current models, expectations and possible improvements that could be done for the future models. The Centre collects the information, which is later used by design team in creation of new versions of cars. In this way the style and brand is improved continuously to ensure maximum fulfilment of client's wishes with simultaneous following of standards and safety demands.

Clients also have a possibility to test the car and meet the Volvo representative that will provide them with information about the product. Volvo developed special program that encourage people from abroad to become the Corporation's consumers. For example for potential clients from United States the journey to Sweden is offered

in order to make an opportunity of try the car before it is bought by them. Then the free shipping to USA is offered if the client is decided to buy the Volvo car in Sweden.

These kinds of actions taken by the Volvo Cars Corporation, are not only connected with market development and winning the client. Information gained from car users help to develop the new solutions in the conceptual design process and take part in minimizing the risk of creation of the model that will not fulfil clients' requirements and will decrease the sale rates on the market in the future.

In comparison with the building sector, contacts with the clients are not so direct and detailed like during the design phase of the building. The client is not informed about the potential risk that is identified in conceptual and detailed design phase of the project, because until the production phase starts each risk is minimised almost to zero, and telling about it to the client is unnecessary.

It is obvious that aspects connected with design are not discussed with the client so deeply, because it requires special knowledge about the product that the customer normally does not have. He or she can only make suggestions about the functions or appearance of cars by contacting representatives or Client's Centre. This situation is different than in building sector where all important risk's aspects should be discussed with the client in conceptual phase or design phase when choosing solution for the project in order to inform, ensure the effective cooperation, decision making and avoid misunderstandings and delays in the future.

5.2 Organisation of the Design Department

In order to analyse the design process and work with risk in Volvo Cars Design Department it is worth to know its organisation.

The department has about 200 employees in three design centres situated in Göteborg, Barcelona and Camarillo outside Los Angeles. This large group of engineers consists of product planners, pre-production engineers and engineers so called "Competence Areas of Specialists" who work on quality, safety, risk, design, market and planning whether there is a need of consulting of specialists in case of important or critical issues of the project. The qualified engineers do a special investigation within the fields they are specialists. They are responsible for many technical and strategic analyses such as material test and risk assessment, fire and explosions, testing and any research that need to be checked to minimize the risk of failure, accidents or unsuccessful completion of the project. These engineers work within the areas of design called "lines" that the Volvo Company is divided according to specialisation e.g. electric line, architectural line, material line et cetera. Each line consists of consultants that work on a piece of project connected with their competence.

5.3 Design Process and Risk Management

Design process in Volvo Cars Design Department is divided into several parts until the production will be started. To explain it clearly, design of Volvo S80 was presented as a specified example. See Appendix B.

5.3.1 Annual Pre-Program Start (Annual Pre-PS)

This is the first part of the design process in which the milestones are decided for further product development. One of the milestones is achievement of great results in safety tests provided by European New Car Assessment Programme (Euro NCAP) that is commonly known in Europe. Euro NCAP has been responsible for a dramatic change to overall car safety. This is readily seen in how quickly manufacturers improve their safety equipment and the steps they take to do well in the tests. Real world injury studies carried out by SNRA (Swedish National Roads Aministration) and SARAC (Safety Advisory Rating Committee) demonstrate a reduction in injury risk for every Euro NCAP star received. Volvo's ambition at the beginning of the design process is to design such a care to achieve 6 stars in Euro NCAP classification. Finally the model S80 got 5 stars which is also a very good result, and one of highest grade that best produced cars could get in this test.

At the beginning of the Annual Pre-PS not many people are involved. The concept of the car starts to be created, and risk analysis and alternative solution choice is based on customer opinions and internal analysis made by special sector called "Clinic". The Clinic is responsible for preparing the concept of the car structure in many combinations by usage of so called 'soft tools' (structure that is not made of real materials, but is just a prototype used for testing). Engineers work on general solution that is going to be developed since the design programme starts until start of production – SOP. They meet once a week to develop the concept of the car, present clear vision of what they would like to create, concerning pros an cons, discussing potential risk and share information and experience together.

The critical events an their risks is present from the beginning of whole design process of Volvo car. Initially the risk is not identified in means of numbers or figures, the experienced engineer uses their knowledge and clients feedback to assess whether the S80 model will be interesting for the customer. The matter is also if it is product able, whether new complex system or technology is going to be used to raise the quality of new model. Risk analysis in this phase is rather an empirical judgement, and gives only rough estimation to further analysis.

5.3.2 Program Start (PS)

The design program starts to analyse the most important aspects of a car taking into considerations quality, safety, risk and technical solutions that would be used in the S80 model. In this stage the brainstorming of separate sectors responsible for designing different systems and tools starts. The answers about costs, dates and product delivery together with technical specification are prepared in this phase of design process.

However the overall appearance of the car and its function is still unknown and is going to be developed with further development. Each component of the car is carefully analysed within the design teams in order to prepare the part to next stage of design process – Final Data Judgement. Then it is going to be verified by numerical analysis and ordered in supply companies responsible for tools.

Experience feedback and quality assurance are the key factors to develop a new product that could be reliable, fitted into standards and according to client's needs. The knowledge from previous project is utilised to provide necessary information about technologies and proven systems that could be used in new model of Volvo. To create a new solution or to broaden the old technologies with advanced and innovative tools, the feedback from the specialists in Quality Department and Competence Areas is transformed into new product development that was created having in mind safety and satisfaction of the customer. The good utilisation of old experiences in this point minimizes the risk of mistakes in design, helps with taking quick, good decisions and reduces the need of additional analysis of already proven solutions.

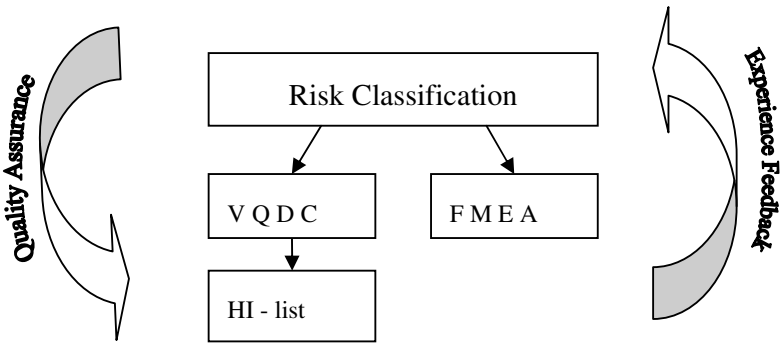

Figure 5.1 Risk classification scheme

During the whole design period of Volvo S80 the advanced analyses called FMEA - Failure Modes and Effects Analysis are provided to control the system, design and process.

One of the biggest risks that was a priority to omit are stopping the production line of the car after the ready project is implemented to be produced and sold or failure during the new model testing in production. This kind of disturbance brings big losses to the company so it is important to control and to be sure before SOP that every part was designed properly and the production will not be disrupted.

FMEA - Failure Modes and Effects Analysis is according to encyclopaedia is "a risk assessment technique for systematically identifying potential failures in a system or a process. It is widely used in the manufacturing industries in various phases of the

product life cycle. Failures are any errors or defects, especially the ones that affect the customer, and can be potential or actual. The effects analysis refers to studying the consequences of those failures.

In FMEA, failures are prioritized according to how serious their consequences are, how frequently they occur and how easily they can be detected. An FMEA also documents current knowledge and actions about the risks of failures, for use in continuous improvement. FMEA is used during the design stage with an aim to avoid future failures. Later it's used for process control, before and during ongoing operation of the process. Ideally, FMEA begins during the earliest conceptual stages of design and continues throughout the life of the product or service.

The purpose of the FMEA is to eliminate or reduce failures, starting with the highest-priority ones. It may be used to evaluate risk management priorities for mitigating known threat-vulnerabilities. FMEA helps select remedial actions that reduce cumulative impacts of life-cycle consequences (risks) from a systems failure (fault)."

By usage of FMEA, Volvo provides the risk classification (see Figure 5.1.) that ensures identification of hazards that can lead to failure occurrence. The risk classification is divided into three groups of importance.

R1 – is a safety risk, which is the most important to the designers and mission of the company. Failure in this case cannot take place. Doubts about safety in individual sectors are signalised by teams working in this area and discussed during the meetings.

R2- is a major risk that is related to critical events of any kind in the design process. It can for example be a problem with the tools, some installation that are important for the overall function of the car or risk delays or disturbance.

R3- is a minor risk with a small impact on the project. However, in order to minimize the risks in the end of design process, it is necessary to explain all the doubts, and situations that are uncertain and need the additional knowledge from the expert.

The rank of the risks in group R1 and R2 can differ if the probability of occurrence of risk is low. The risk classification is done before the database VQDC - Volvo Quality Deviation Control is used. This is a kind of bank with around 7500 kinds of problems. The system using computer simulations, light, movies and pictures consists of necessary information and is a sort of experience database for engineers. Searching for problem solution does not take much time, so the risk of delays in this situation is minimised.

The identified and classified critical events and their risks must be allocated in the project in a way that ensures working flexibility on it and that reduces it to zero until the SOP phase is going to be introduced. As it was mentioned before, each design sector is responsible to analyse, assess and solve the risk problems within their area. However, to ensure good coordination of work between the lines, meetings are organised once a week to discuss potential doubts, inform about the progress and compromise solutions of different sectors to one common result that is going to be used in the overall structure of a new model. For better organisation of the discussion, the company has compiled a checklist called *Heavy Item (HI) list* (Figure 5.2) where each line reports about critical events and their risks that need to be discussed together

with all project participants in order to ensure fluent cooperation and decision making trough the design process. The HI is revised during every meeting to check if these issues have been solved or if there are still aspects that need further consideration.

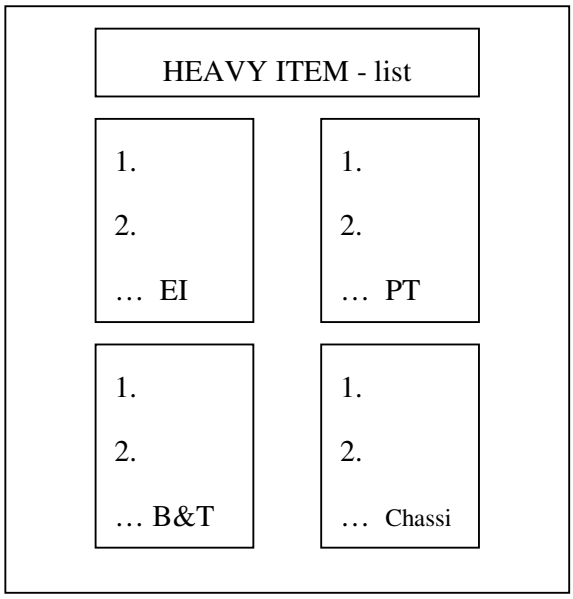

Figure 5.2 Heavy Item list

Moreover, the Volvo Company controls the work in the project by using checklists to ensure the milestones achievement according to the plan. All scheduled activities, important and critical values, and all kind of items that should be analysed are revised by checklists.

5.3.3 Final Data Judgement

When the final solution is chosen, it is transformed to a prototype of the new model of Volvo S80. The final decisions of what is going to be designed and how, is based on long discussions and analyses of possibilities, careful assessment of risks in each design aspect, feedback utilisation, forcing of ideas, control of checklists and searching for compromises. However it is not a ready version of a product that is going to be sold to the customer. The next step is to start the verification and tooling period, which is preceded by Final Data Judgement (FDJ).

FDJ is a very important phase in the whole design process of a Volvo car. The numerical analyses of the proposed solutions are going to be done in order to check the ability to put the car together and gain information about tools requirements for the suppliers. Because many tools for the car are produced and delivered by independent companies, the negotiations with them are necessary, so cost calculation, material and technical parameters have to be known and collected for order purpose.

Scalability of product

In the FDJ phase the final product is created, revised and ordered. The main task before the start of production is the verification and tooling period. For successful functionality of this phase and ability to handle the amount of work on a new model, a scalability of product is analysed. It is a rather complex system of analysis, but simply speaking, it is a comparison of the production line capacity and the demands of the new model or improvement introduction. To avoid disturbances in the production it is important to define and ensure a coordination of work between routines of forming and new demands of the model. For this purpose three parameters are analysed in the scalability comparison. The parameters are: X- Completion Car or Model year, Y – engine, new or modified, Z- plant – ability to put the car together. As the final result, the capacity of performance of required product, taking into consideration efficiency of production line is visualised, that ensures that the risk of disturbance would be minimized.

Verification & Tooling period

According to Appendix B, before the final version of the designed car model is going to be produced, research and experience have been made, the tools have to be verified and ordered from the suppliers. For this purpose the model of S80 based on the prototypes of components and tools is assembled to check the overall functionality, behaviour on roads, safety tests, standard fittings and whether it will fulfil desired requirements. This activity is called Series 3 in the Verification and Tooling period.

The verification of the design is divided into three steps as it was presented in the Figure 5.3 below:

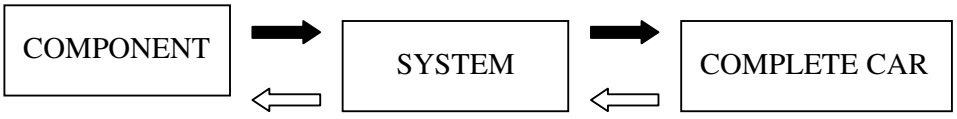

Figure 5.3 Verification system of designed model of car

Firstly, the individual component of the S80 model is checked according to standards, requirements, functions and design goals. Then the system of different components, for example an engine, is subjected to analyses in laboratories to verify the stability and function in overall connection. After the individual systems are verified, they are implemented in the complete car for final testing before tooling period.

The completed verification system is done in two ways. The first verification of Volvo S80 included individual testing of the components followed by the testing of the complete car. The second verification is done the other way around. The complete car is analysed deeply taking into consideration the systems in its structure and finally the separate tools. Entire process takes about 20 weeks until the production of tools is fully developed.

The last stage in the design process of the car is tools operation. Designed and verified components with all technical specifications and requirements are ordered and started to be produced. There is still a little space for changing some details or making improvements. However, the probability that any risk identified or unexpected occurs in the process should be equal to zero.

10 weeks after the advanced tools production started, the final tools operation is begins. This is the most critical part in whole design process where final solution is completed. Problems here would have a destructive impact on fluency of the complete process of new product creation, and could bring much of disturbance for SOP phase and as the result: losses for the company. In this point the probability of risk occurrence must be reduced to minimum. From the Annual Pre-Program start it was borne in mind to identify and manage risk in such a way that any problematic or dangerous situations occur at the end before the start of production that is why any mistake in the end is practically eliminated.

The Tools Operation process is the closing stage of the design process at the Design Department of Volvo. Afterwards, the designed model becomes a produced and assembled structure that is going to be a successful product for a demanding customer. Until this point in the project life cycle, the team members have concentrated on making successful decisions based on proper risk management and precision of the product verification. The styling and production is carried out in parallel, to ensure the accurate connection between functions and appearance. Afterwards it is delivered to the client.

5.4 Conclusions

The design process of Volvo S80 was presented as a successful model of organisation and management where creation of such complex product as a car requires maximum knowledge, clear vision, information exchange and management skills in every moment of this development.

The whole sequence of individual steps connected together in design is characterised with flexibility of making decisions or changes in almost every point of this phase in the project lifecycle. However, the best time for making decisions is between the Program Start and the Final Data Judgement. The company still works to be more effective in that period that would improve making key decisions earlier and minimize the needs of changes between FDJ and SOP. All changes mean extra effort put in work on the designed model and risk of delays in final part of the design process.

To make good decisions, clear vision and well specified goals are needed. The market search, gaining information from the client and experience feedback usage from the very beginning helps to obtain the detailed idea about the product even if the overall appearance is unknown in early stages. In comparison to the literature study, the early vision's development and time that is spent on it, lead to adequate awareness of what should be created. It facilitates further risk identification and analysis even if the final product consists of many systems and involves the large group of specialists.

In the car industry safety of the client is a priority, so the risk awareness of a product functionality is present from the very beginning. That is why the Volvo Company developed system of testing and verification of the project so widely, to deliver a car that passes the European tests with the highest scores. Each component of the car implemented into system and whole structure is carefully checked and designed on the highest standards. It minimizes the risk of any technical failure, because the material and production process is precisely discussed and planned in advance.

In means of risk management, the organisation of work is a key. Volvo Design Department is divided into several lines that minimize misunderstandings and number of critical events in the field. The project participants work on the project in speciality groups that improves sharing the knowledge and identification of potential hazardous aspects with high effectiveness.

It is worth to notice that before the design process starts, the extra phase Annual Pre-PS was predicted for concept development. This additional period of time, provides more space for effective brainstorming, precise critical events identification and gives more chances to understand the client's needs.

Comparing the organisation and structure of the design process in the car and building industry, the assumptions about the risk analysis are similar. The critical events are present in the project from the beginning and strong awareness of them is developed among project participants. However, analysing the work with risk is more common in car industry than in building projects. Because the safety is a priority in car design, the effort put on the risk and hazards in this case is more visible in car production than in building industry. In a building project risk management is not always an internal part of project management, and the need of risk identification and analysis is sometimes treated as task to do, without the continuous process implementation.

The possibility of assessment of risk probability by testing the product in means of technical behaviour in integrated systems and consequences brings additional advantage in design. The car industry uses a variety of possibilities in verifications to check the accuracy of made decisions. In construction, the opportunity to do such kind of analysis is limited. The building project can not be structured as a prototype for verification. The solutions offered by design engineers are mainly based on simulations made in computer programmes that may differ in reality. It makes the design process filled with uncertainties and enlarges number of critical events that can be eliminated or reduced mainly by complex risk analysis methods in well developed risk management.

Verification of the product (from individual component to complete model) brings much information about needed improvements or changes in chosen solution. It is used in building process also for example by combination of load conditions and forces acting on the structure, with parallel analysis of individual elements integrated in the structural systems. This kind of action reduces the mistakes of design, checks reliability of structure, and minimizes risk of disturbances during production/operation phase.

According to previous observation in Chapter 3.1, the number of critical events that have to be identified is the largest at the beginning of a project where a concept is developed and based on alternatives prepared on the general ideas. Then with design

development these events are handled and eliminated one by one until their amount reaches desired minimum level. Not every risky situation can be identified at the beginning, which is connected with project uncertainties, that is why the flexibility in time and changing decisions plays a key role in risk management for both industries. Due to this, utilisation of the checklist system would be very useful for risk evaluation during the whole duration of a project.

6 Risk and Experience Feedback in Practical Use in Building projects

6.1 Experience Feedback and Decision Making in Relation with Risks in the Design Process

The design phase is a process of transforming and converting information for making decisions and choices. It is important to use experienced people to flow of information from one project to another. Proper storage and organisation of using and gaining experience feedback improve the competence and quality of the company. Valuable comments and suggestions of how to use experience feedback properly can be found in Master's Thesis of Engström and Lierud (2006). In this chapter the connections between experience feedback, risk management and decision making will be described to point out the great importance of these three activities in the conceptual design phase.

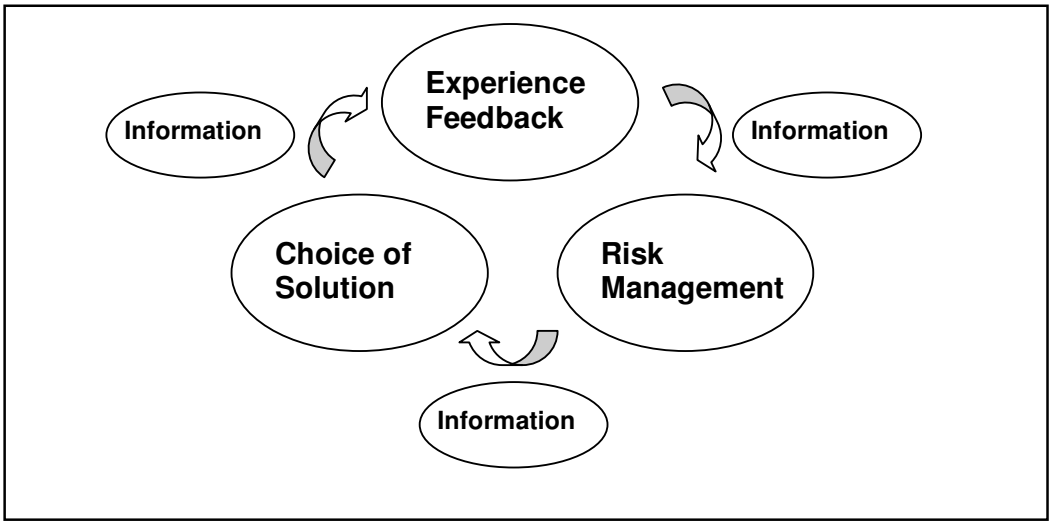

Figure 6.1 Relation between experience feedback, risk management and decisions in the conceptual design process

Figure 6.1 presents how experience, risks and decisions are related to each other in the conceptual design. Information is the basis for this relation. By learning from experience the participants can use their knowledge in risk perception, identification of critical events during solution searching. Skilful application of experience feedback into risk management shapes the system of work that is streamlined with logical thinking, association of facts, good communication between participants and database updating, which as a result reduce the time for analysis and decision making in the process of finding solutions. It is important that project participants act with maximum engagement in creation of clear vision with parallel usage of experience from previous projects and desire of an open dialogue and cooperation. This will lead to good choice of solution with regard to potential critical events in design, construction and operation. Decisions about solutions generate results and new information for current

and future projects and update and enrich gained experience towards better risk management. It is a closed cycle that with progress of time and amount of realised tasks grows up with professional and well structured work of qualified people. To achieve continuous improvement in this field well developed awareness of matching the experience feedback with risk management is necessary among the team members.

At the beginning of an assignment, project participants are faced to plan the system of work that would be characteristic for the project. Since each project is unique, different problems and questions appear during the task development. They can appear in every phase of the design process, and if they appear too late, a successful finish of the project would be in danger. To minimize the impact of problems an early identification of the critical events is advised to find solutions in risk management. To do that, the project team should involve experienced and qualified people who are able to use information from previous projects and introduce the team into the new task. Well created systems of collecting data, where all necessary information is stored, would be very supportive for fast and effective implementation of knowledge into new assignments. This is also a benefit for new participants, who possess not so much familiarity with the subject, and have a need of support from experienced colleagues. Acting in that way, the group becomes more efficient in further development of the design process.

Engström and Lierud (2006) present several disciplines of how the design team can achieve a learning development; system thinking, team learning, clear vision, mental model and personal mastery. Detailed information about them can be found in their publication, but the first three approaches are worth to analyse closer in connection with the risk management.

System thinking is a way to understand the building project process as composed of interrelated actions and tasks that are dependent of each other, and also the connections between different projects. It is very helpful for the project participants to see the logical connections between the individual tasks and makes the knowledge easier to implement in everyday work. This kind of project analysis streamlines the flow of information between individual parts and leads to an effective creation of solutions that would not be visible without logical connection of facts and knowledge.

System thinking helps in identification of similarities and differences between projects and, as a result, stimulates better utilisation of information in new tasks. The way of system thinking development in teams is a specific matter of the company, and depends on the needs of project organization. Taking risks into consideration, system thinking helps to coordinate the work of the whole team better and minimises potential discrepancy in project's organisation and dependencies perception, which as a result minimises the risk of design mistakes.

Team learning is a method that every project team and also entire companies could enrich and update continuously. This activity develops the need of dialogue between the participants and gives mutual help in omitting mistakes and identifying critical events. It teaches how to cooperate together and find solutions by meetings, brainstorming and database usage. The meetings in this case are one of the most important values of the idea. Discussions, open dialogues and common conclusions are held during meetings and are decisive for proper implementation of experience feedback in a present project. A strong commitment of the employees is necessary to

achieve good results at work. If there is a strong willingness to learn from experience and share information then the usage of experience feedback in risk brings desired effects by means of transformation of gained facts into creative thinking and detailed risk identification and searching for solutions. [Adopted from Engström and Lierud (2006)]

Experience feedback is strictly related to the proper perception of the objectives of the project that are the basis of the risk management, see Figure 6.2. In the end of this chain the decisions are made, so the absence of one of the links can result in wrong solution choice. Both communication and meetings and documentation are necessary to follow the design process efficiently with respect of the activities in the chain.

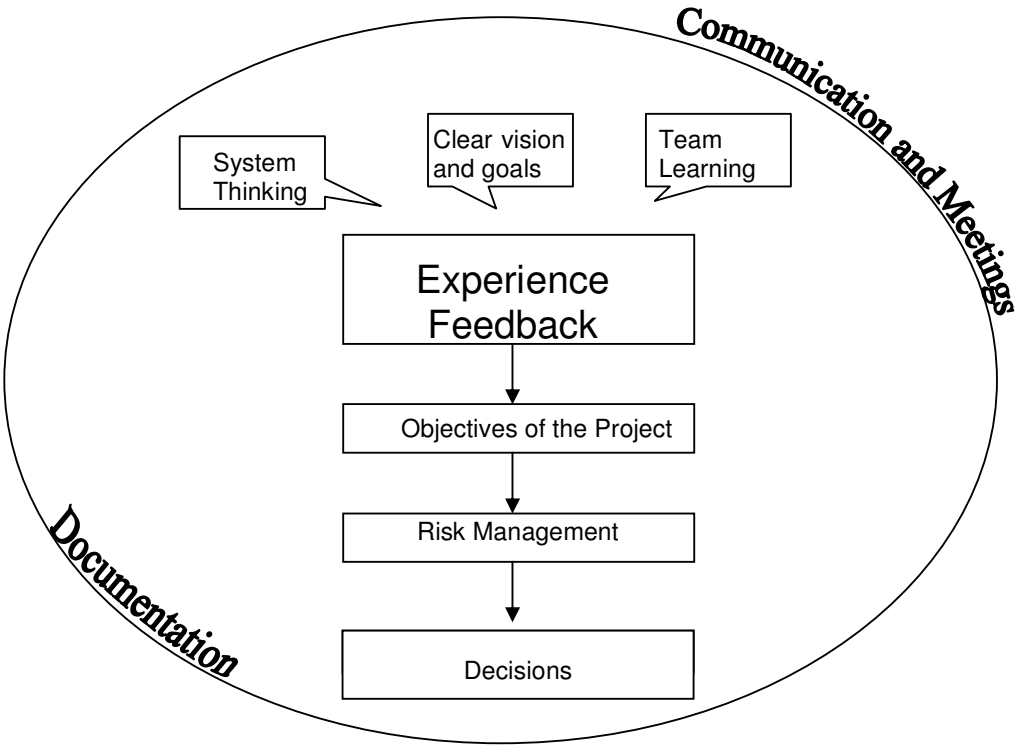

Figure 6.2 Experience feedback and risk management in design process

Essential documentation, information stored in a database and checklists are necessary tools for a good experience feedback. The same system of information could be used in risk management in the initial phase of the building projects. The idea of a building turns into a concept and the chosen solution is based on intuition, knowledge and facts taken from previous projects. It is important to select and organise the documentation in a way that makes it useful and easy to implement in the risk management.

6.2 How is Experience Feedback used in Risk Analysis in Practice?

The information received from the interviews and observations of the projects (both in the building and the car industry) is here analysed in order to describe role of experience feedback in risk management in practice.

Taking into consideration the work experience of all the interviewees, the period of time they worked in the building sector or the car industry varied from 7-30 years. It means that they all had a large experience in carrying out their duties. However, how much experience feedback is used in the work with the risks is a question to answer.

As it was described in Section 6.1, there is a strong relation between experience feedback and risk management in decision making. First of all the experience feedback should be integrated into the daily work together with strong awareness of risks. A good decision is a last result of a process where experience feedback and risk management, Figure 6.2, have been used. Each of the interviewed participants admitted that they use experience feedback everyday but without any special routine or developed method. They develop ideas together in teams, share knowledge and learn from each other in order to achieve good decisions. However, not all of them introduced the risk management in their everyday work. Hence, it seems that one link of the chain, which is the risk management, was omitted especially in the conceptual design phase of the project. The reason could be that they do not perceive the risk management as an important task in fulfilling their duties, especially at the beginning of new projects. The reasons for this could be implication of old routines or previously successful activities that allow for risk ignorance in the new projects and decision making. Since every project is unique, not considering risks at all, or in a very small extent, could have a great impact on the final solution and the decisions.

From the projects observations it was found that risk management in relation with the experience feedback was committed in every project that was described in Chapters 4 and 5. However, in the building projects the risks were considered only in some isolated parts of the project.

In Project 1, the environmental and organisation plan was prepared by the assignment manager in order to identify the most critical events in the conceptual design phase of the project. The risks assessment provided by the structural engineers and the architects seem to be not fully developed in this phase. They use their experience at everyday work by consulting and sharing knowledge with other colleagues in the team in order to make good decisions.

The objectives of the Project 1 were clearly stated and written in the documentation, see Table 4.2. However, identification of critical events before making any decision was not always discussed in the design team. The awareness of risks is borne in mind, but the information about critical events and consequences from previous projects was not stored in any documentation or database, which could be useful for future projects. The reports from meetings and checklists were the only known formal sources of information.

In Project 2, a detailed risk analysis with regard to costs and incomes using Monte-Carlo simulation, see Section 3.4 and 4.2.2, was done. Regarding other aspects of the building project, old experience was utilised in order to make good decisions in each phase of the building project, but the risks were not always analysed and discussed. Generally speaking, the project participants were aware of the need and advantages of experience feedback in good decision making, and would use it with willingness. However, risk management in connection with information gained from old experience was not always considered together as a basis for good decision making. Problems are solved directly, if they occur, but they are not predicted in advance. In Project 2 checklists were not introduced in order to organise the work and facilitate making decisions but the interviewees agreed that it would be very useful for further work in the project.

In the project of Volvo S80 in the Volvo Cars Company, risks were identified and assessed from the conceptual design phase, until the end of the detailed design. In order to choose a good solution and to prepare the project of this new model, the experience feedback derived from the previous models was utilised for identifying potential hazards and improvement of the S80 model development. The design phase in the care industry is slightly different from that in the building sector. The production of cars is done in series, so some of the solutions from previous series are used in new model design. Consequently, it is easier to name and identify the risks that can be connected with the new design. Due to this the old experience is utilised by all the project participants, and learning from the previous project is a source of information for risks identified in new projects. In spite of this fact, there is still a need to search for new improvements or ideas that can lead to the client's satisfaction and better quality and functionality of the car. To achieve a successful final version of new model, old experience is introduced into the searching process of new innovation and carefully analysed regarding risks in each aspects of the project. The interviewed project managers admitted that they still try to be more effective in risk assessment at the beginning of the 'Program Start phase'. They work on facilitation of decision making in this point of the design process to reduce the needs of changes in 'Verification and Tooling Period' of the Design, see Appendix B, in future projects.

6.3 Conclusions

Experience feedback and risk management in the building process generate a system where knowledge and information influence on perceptions of risks and decisions concerning structural concepts and their realisation. Actually it could be said that without a good experience feedback there could be no successful risk management and mobilisation of the team members to utilize their knowledge properly the conceptual design phase.

Experience feedback enlarges the potential of risk management among the project participants. Communication is of great importance when working with experience feedback and risks. The flow of information between the project participants, especially at the beginning of assignments, generates good strategies and decisions for a project realisation.

Meetings are organised to match experience feedback and communication in the same time. The team utilises knowledge, bringing back information from previous projects, learns at the same time from other colleagues, and creates a concept of the building based on consideration of risks, this generates a system of connections and chain reactions in the whole process.

To sum up, the observations of the studied projects show that old experience is used actively at the project work, but not always in connection with risk management in the decision making process. The risk management seems to be not fully integrated with the project management of the building projects in both of the studied projects. It is difficult to compare the use of experience feedback utilisation in the risk management directly, since the projects were observed in different phases of realisation.

The observation of the car industry shows that the risk management process is more developed, especially in the design phase of the project. In comparison with the building industry the product development is different in the car corporation, and the possibility to test the prototype before it is going to be produced is a great facility for the designers. However, some of the ideas developed by Volvo Cars could be introduced in consultant companies, for instance the database that includes the most common risks and their consequences in old projects. As it was described by Engström and Lierud (2006), building projects are treated by the participants as separate tasks, which causes that the transfer of information from one project to another is poor and good solutions and risk information are not fully implemented into new projects.

7 How the Work with Risks Can Be Improved and Developed in GF Konsult?

To be successful in introducing the following recommendations for GF Konsult, it is important to know that the engagement of all the employees involved in the project is essential in order to obtain a good result in risk management. Due to this, the engagement of the project and assignment managers is needed in order to motivate the engineers and the architects towards consequent learning and development of the risk perception in their professional life.

To start working with risks in project tasks it is important to know that risks do not always have negative consequences. A solution that involves risks may have a potential to bring benefits and advantages. However, the risks must be properly assessed, to verify that the risks are reasonably small compared to the potential benefits. Due to this the awareness of risks and their impact on different parts of the project should be consequently developed in the design team by the assignment manager.

7.1 The Strategy of Improving the Risk Management

To implement improved risk management in projects carried out in GF Konsult, a general strategy is needed in order to achieve successful results. To do that, an introduction meeting could be organised in order to highlight the importance of risk management in the design process and give the background for the development of improved processes.

First of all, the objectives and goals of the process implementation should be stated by the managers. It is important to explain and discuss:

- Why do we need improved risk management in our company?
- What are the main objectives and goals of the risk management?
- What kind of benefits may an improved design process bring to the projects, the employees and the company?
- How can every member contribute to development of risk management?

To answer these questions the advantages of risk management should be presented by the assignment managers or external specialists during the meetings before any decisions are made. It is important that every team member understands the need of risk management. It is obvious that awareness of benefits from the planned changes would be encouraging for everyone involved in the project.

Secondly, all the changes should be introduced consistently from the beginning and are related to each other. The plan of introducing new approaches in the design process should be prepared by the managers and consulted with the employees in GF Konsult. It is important to remember that the changes should not be a reason for total re-

organisation of work in the company but should be introduced systematically and with consideration of previous methodology of work.

The changes should not be treated as issues that replace old routines and introduce a completely new system of work in GF Konsult. The goal is to improve and develop the existing risk management in the design process with new approaches in order to make the work on the project more efficient and reduce the amount of unsuccessful decisions.

Monitoring the effectiveness of introduced changes would be an additional tool in order to check if the proposed new solutions in risk management brought desired benefits and effects. This evaluation would be done using the questionnaire, Appendix D, sent to the employees participating in the process to gain their opinions and possible suggestions for further improvements. The monitoring can be done after introducing new approaches and after completion of projects.

7.2 Responsibilities for Risk Management in the Design Process in GF Konsult

Division of responsibilities concerning risk management is an important issue in the whole design process. In **Fel! Hittar inte referenskälla.** examples of tasks regarding working with risks for project members in GF Konsult are proposed. According to the table, it is important that each project member becomes involved in working with risks.

Clear tasks and roles that are prescribed to each employee would be helpful in the improvement of the risk management in projects. Additionally, the proposed roles would make the team work more efficient since everybody takes an active part in this process. Each member of the design team should be prepared to work with risks in his/her area and to develop approaches of analyse risks through exchanging information with other colleagues, utilising the experience from previous projects, and consulting the client, if it is possible.

Table 7.1: Division of responsibilities in risk management

Assignment Manager	Team Leader	Team Member
- coordinates work with risks in the project	- coordinates work with risk in a team and motivates team members to skilful utilisation of experience feedback in risk management	- takes an active part in risk identification and analysis in team work from the beginning of the project
- organises meetings with the client and with teams where risk is discussed	- prepares reports to the meetings regarding risks identified by team members	- shares experience and knowledge with other team members in order to identify and analyse risks properly through the whole period of the design process
- informs other project participants (client, project manager, contractor) about risks	- consults other team leaders and the assignment manager concerning analysed risks	- indicates important issues that require reconsideration, changes, or further risk analysis
-coordinates identification and classification of risks in order to ensure the cooperation in this field between the teams of different business areas	- monitors risk management within the team work according to the project progress	
- provides reports and checklists regarding work with risks in the project	- decides about risk transfer to another parts of the project together with the assignment manager	

However, the responsibilities to handle risks are not only limited to the consultant in the project task. Since the project in GF Konsult is realised as a part of a whole building project, responsibilities are also divided among the other project participants such as the client or the contractor and can be transferred according to the needs stated in the contract documents. The consultant company takes responsibility for the prescribed activities and certain risks in the building project and manages them according to the project task definition.

7.3 Need for Education

Since most of the interviewees from GF Konsult perceive risks in projects as something temporary and not so much important for their responsibilities and tasks, the awareness of risks and risks management could be developed by introducing informative meetings or seminars about various types of risks, method of risks analysis and risk management. This kind of activities would help the team member to develop risk knowledge and pay attention to risks in the tasks.

Since risk identification and risk analysis are omitted very often in the decision making process, one of the suggestions would be a presentation of theory and common methods in risk management formulated by risk specialists in connection with practical cases. To achieve this, a good idea would be an organisation of workshops, where working in groups and individually, employees could learn how to use different methods and the advantages of risk management in their everyday work.

When working in teams, the participants of such workshops have a chance to share opinions about risks with other colleagues, and learn how to work with it in the group. It is important that every participant would learn how to identify risks, name the risks and share this information with other team members. Then, a common analysis of the consequences is prepared based on the methods presented on the seminars, such as the ones described in Section 3.4. It is also a good chance to share opinions about the changes in the working system and an opportunity for the manager to check whether the introduced methods turned out to be successful.

7.4 Identification and Classification of Risks in Start Meetings

Since the start meetings can have a decisive impact on the development of risk management in the conceptual design phase of projects realised by GF Konsult and further phases of the building project, an open dialog regarding risks in various parts of the project should start from the beginning.

The consideration of the possible critical events connected with the realisation of new projects does not always have place today during the start meetings in GF Konsult. It is suggested to introduce this as a constant item of the start meetings, which gives an opportunity to analyse the consequences of the decisions made in the conceptual design phase of the project. The identification of possible critical events very early would be useful in the concept development and the process to select a final solution.

The achievement of the desired result depends mainly on the project manager or the assignment manager who prepares the plan for the meetings. The participants should be encouraged to the cooperation and signalisation of doubts and thoughts connected with the risk identification and assessment in the beginning of the project. When more details of the project are known, the searching for solutions and risk management would be developed in order to handle risks properly throughout the whole duration of the project and service life of a building.

7.4.1 Identification of Risk

To start working with risks in projects, the first activity that is suggested is an identification of critical events. This should be done already at the start meetings. It is not an easy task and requires the utilisation of experience feedback and knowledge about risks from the employees. In general, brainstorming would be a good tool in order to achieve the desired result. To simplify this process, it is worth to prepare a set of questions that would determine the way of discussion.

First of all, the questions regarding risks known from pervious projects or experience should be stated. It helps to identify risks that the employees already know and divides them according to the theory presented in Chapter 3. Discussion and common risk identification in team would contribute to reduction of time spent on making decisions and searching solutions. It is important to consider mainly the risks that are related to the current project. The results can be stated as shown in Table 7.2. One column of the table has been completed as an example.

Table 7.2 Identification of risks example

Risks from previous projects related to the current project		Risks not identified in previous projects - current project	
Project name:	Project name: Grand Hotel in Stockholm	Project name:	
Known Risk	Known Unknown Risk	Known Risk	Known Unknown Risk
Subject:	Subject: using of new model of windows	Subject:	Subject:
Source of risk:	Source of risk: The suggested model was new on the market, not so many opinions were available about their functionality and methods of assembly. The designers requires additional consultation in order to decide about the load bearing façade model	Source of risk:	Source of risk:
Consequences:	Consequences: energy saving and costs in service life if the product turns out to be of the quality guaranteed by the producer. Because of complexity in assembly delays can occur and the contractor could need additional equipment and consultation of specialists.	Consequences:	Consequences:
Provided solution:	Provided solution: Meeting with all project participants and the producer was organised. The alternative for the solution was suggested. Simulation of costs due to energy saving was done.	Provided solution:	Provided solution:

At the beginning of a project, there are also many uncertainties. Since all critical events are difficult to identify their consequences can not be known at the beginning of the project. However, it is worth to state these critical events and uncertainties, which the employees know from previous projects, since they are helpful in planning the time schedule and cost estimation in the project.

The unknown risks could be identified in the same way as the known risks in the table. However in a new project it could be difficult to assess this kind of risk at the beginning but knowledge from the previous projects can always give some clues concerning organisation or solutions of the current project if unexpected critical events occur.

7.4.2 Classification and Analysis of Risk

Once a risk is identified, it should be classified in order to obtain clear view of the risk in the project and start the analysis. It is suggested to use a table, which facilitates the activity and is understandable for the project members. The risk could be classified according to categories and connection with other risks. It should be referred to a certain business area where it belongs and should be handled. Furthermore, the influence and connection with other parts of the project in GF Konsult and in the building project should be assessed. Afterwards the probability of this critical event should be estimated. The whole table creates the picture of the risks in the current project.

Table 7.3 Risk classification factors

Risk category	**Level of risk** **Probability of occurrence of critical event**	**Connection with other business areas**	**Connection with other risks**	**Consequence x probability**	**Connection with phase of the building project**
Economical Technical (Design) Construction Organisational Environmental Safety	Expected (often) Occasional (sometimes) Possible (uncommon) Rare Hardly never	Project Management Architecture and Planning Structural Engineering Geotechnical VA-Process Roads and Railway	Name the risks that it is connected with	High Large Low Negligible	Design Phase Construction Phase Closure of the Project Service Life

Table 7.3 can be used by all business areas and teams in GF Konsult individually for each critical event identified in the project. All the documents connected with the risk management process should be updated continuously by the team leader, in cooperation with team members and the assignment manager. It is also important to remember that critical events and their risks may be discovered not only at the beginning of the project, but also during whole project process. Due to this, the monitoring and controlling of risks is suggested to be done regularly by the team leaders and the results should be discussed during the meetings.

Not every risk can be analysed by means of numbers and using computer programs. Most of the analysis is based on experience feedback and knowledge of the project members, and carried out by qualitative methods. To make a clear picture of the project risks and alternatives connected with decisions, introducing of Decision tree method is recommended during the team work. However, introduction of the quantitative methods such as the Monte Carlo technique in order to analyse risks that are 'measurable' and can be simulated and visualised, is advisable in GF Konsult. It would give additional information to the risk analysis performed by qualitative methods.

7.4.3 Risk revision

After the building project is finished, the performed risk management should be revised and conclusions drawn in order to learn about the consequences of decisions made with regard to risks in the project. The evaluation can be done during the end meetings of the projects where the general effectiveness of the risk management could be assessed and the need of improvements clarified. The concluding information about risks obtained during the meeting should be stored in a report which will be an additional source for experience feedback as proposed in Section 7.6.

7.5 Experience Feedback in Risk Management

The methods of how to use experience feedback properly were clearly described by Engström and Lierud (2006). The correlation between the risk management in decision making and the experience feedback, as it was described in Chapter 6, has a large impact on the final result of the project task. To be effective in this field, the project participants should be able to utilise these activities together. Due to this, the knowledge about risks gained during seminars or workshops should be naturally matched with the experience feedback and consequently resulted in the decision making. The information from the previous projects and experience should be introduced in risk documentation such as tables and checklists.

One of the issues that are very important in the conceptual design phase of the building project is thinking towards new solutions, but utilising the knowledge from old projects. It is important to understand that using old experience should not mean acting in the schematic way that is closed for innovations or new solutions. The team

members should develop a system of task analysis that working with the risk would be related to the information from the old experience and systematically searching for the consequences of the innovations introduced to the project. Due to this, the team learning and the system thinking development, see Engström and Lierud (2006) see Section 6.1 would be valuable to consider which of the ideas might be used from the old projects (the known known risk identification) and which new ones might be introduced (the known unknown risk or the unknown unknown risk). The brainstorming could be a useful method in this phase that provides to engagement of the employees in the identification and assessment of risks and their consequences.

7.6 The Organisation of Work

Good organisation of work influences not only on the risk management, but also other aspects of the building project like communication, time schedule and project delivery. Considering the information from the interviews, the recommendations in facilitating this field in GF Konsult could be useful in better risk management and experience feedback.

Time schedule is one of the most important tools in order to plan the tasks to deliver projects on time. Due to the suggestions about risk management given above, the time for their realisation should be planned in the project. Also the distribution of responsibilities between the project members, see Section 7.4, requires additional time in the daily work schedule. Taking part in the risk management should become each project member's routine.

It is important to remember that the risks are handled not only within one business area in the company, but may be transferred to other teams in the project task. That is why each team involved in the project could organise brainstorming about risks within its field and prepare the risk documentation together. Then it could be presented at the general meetings and the impact on other fields of the building project discussed by all project participants.

The documentation about the risks managed in old projects is always a matter of discussion and is directly connected with an information exchange and a notification of similarities and differences in the building projects that helps in better risk management and analysis in current and future projects. However, the employees are not always willing to prepare a set of documents about risks and the consequences of decisions made during the whole project's duration. That is why it is suggested to introduce simplified methods of risk identification and analysis such as the tables described in Section 7.4 . Since it is hard to complete all the information about the risks when the project is finished, systematic work with the tables and monitoring the risk management using checklists, see Appendix C, is advised. Systematically prepared documentation, is not only used to facilitate the organisation of work on the current project, but contains also the necessary information for future project realisations. In addition, it helps to collect data about risks in the project from these employees who will be not involved in the new projects, but their knowledge is necessary to identify and analyse the risks for future projects realisation.

When the project is finished, the documentation containing information about the risks should be stored in an accessible way such that it can be found whether it is necessary in the future. Taking the example from the Volvo Cars Corporation system of work, it is suggested to create a database, see Figure 7.1., in the local intranet that would contain the information about risks from different projects prepared by business units and divided according to the categories of risks and project types.

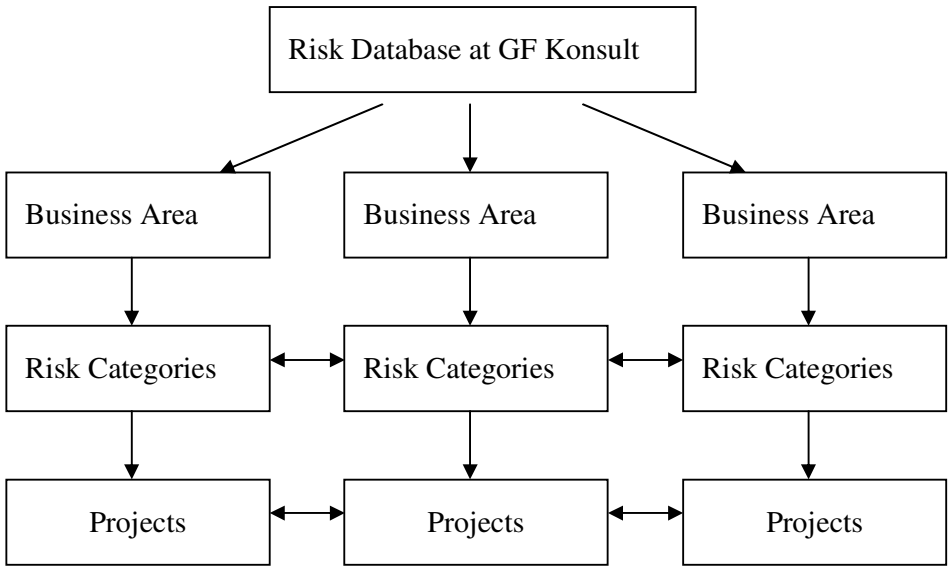

Figure 7.1 Simplified Risk Database Scheme

The risk documentation prepared by individual teams within a business area is collected and stored in files according to risk categories that are the same for each business areas. Each risk category is divided according to the projects realised by GF Konsult. If in one project, one category of risk is considered by different business units, information about it is visible to the user and there is a possibility to link to other business units respectively. If the same risk is considered in different projects it is also possible to check the documentations about it. That is why the risk categories and projects from different units are related to each other. It is suggested to implement the browser option that after typing in the password, all the risks or projects connected with the searched phase would appear, so the searching of information would be simplified.

This kind of database created in the intranet of GF Konsult could be useful in identification and assessment of risks in new projects and the time for these activities would be reduced. However, it should be updated continuously in order to assure the best quality of information searched in the browser.

7.7 Conclusions

The described solutions and recommendation are suggested to support the whole conceptual design phase of projects in GF Konsult. All of the methods are related to each other and give successful results if implemented together. Since there are many

ways of risk management, the presented ideas of improvements are not the only ones that exist.

In the author's opinion, the given suggestions of improvement can be divided into two groups: the values and activities that come from the design team members and the ones that are the results of these activities see Figure 7.2. However, all of these issues are influenced by each other, both within the group and outside. For example the results obtained in the risk analysis could not bring the desired effect without engagement of people and their experience feedback and knowledge. Also obtaining of desired results in analyses would not be possible without communication, clear vision and goals, strategy and methods implemented at work on the project in GF Konsult.

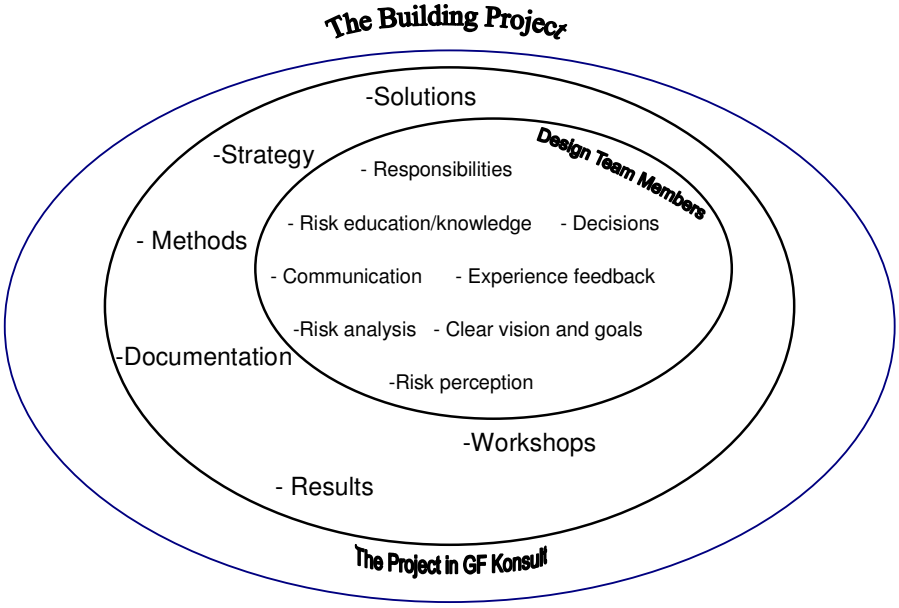

Figure 7.2 How the suggested activities are related to each other in a building project

The projects realised by GF Konsult are parts of the building projects that bring the results of the risk management to the conceptual design or the whole design phase of the building project, depending on the form of contract. However, the risk management integrates all the phases of the building project and could be perceived as the internal matter of the consultant company during the project task and as the common case of all project participants in the building project. That is why the communication between the project participants is essential in order to achieve the desired results in risk management.

Taking into consideration the work with risk within the GF Konsult area, one of the main roles plays the organisation of work where the team work routines could be enriched with new activities and responsibilities in order to assess the risk properly for the project that is every time unique, even if very similar to the previous ones. It depends on the managers how the suggested methodology would be developed and adapted to the needs of the team and project work and how the division of

responsibilities would be introduced to the project teams. The rest belongs to the team members that should find the work with risk valuable and helpful for other activities that are performed in scope of the project task and the building project in general.

The improvements suggested above, are based on literature study, project observations and the results of interviews with the employees presented in previous chapters of this thesis. Additional successful solutions gained from the experience of the reader would be a large complement to the advice and given suggestions.

8 Conclusions

A conceptual design phase and risk management in building projects are the issues that require knowledge and engagement of all project participants in order to identify and handle all critical events and their risks in projects. According to the theory and observations it is important to define and understand the problem of risks, their sources and consequences, before the project team starts to work with them in a new project. Also skilful utilisation of time in conceptual design phase in order to identify critical events and their probabilities is necessary for successful risk management in the project. However, the importance of a conceptual design phase is trivialised by project participants very often. As a result the potential of a conceptual design phase as a key for good risk management in other phases of a building project is not fully developed and utilised by project teams. Due to this, there is a need of a consequent improvement of risk management in consultant companies and evaluation of a system that would facilitate outgoing methods of concept development in building projects.

Since the suggestions presented in this Master's project are based on literature study and the observations of only two building projects, they are not the only ones solutions that are needed to achieve a perfect system of risk management in a consultant company. However, recommendations such as new documentation work, common risk identification, database and meetings that consider the critical events and risk in a conceptual design phase, would be a good start point to a better concept evaluation regarding risk in future projects.

Since risk definition has a very large spectrum to consider not only in the building industry but also in other business units, this Master's project is only a part of deliberation about the risk in building projects. Due to this, further research of the phenomenon is needed in order to answer the questions that could rise during consideration of risk not only in the building sector but also in other business areas that work with risk everyday. Below possible subjects regarding risks that could be helpful for future Master's projects development in Department of Civil and Environmental Engineering or other divisions are presented.

- This Master's project includes considerations about the working with risk mainly in consultant companies. Since project participants are also a client and a contractor, it would be interesting to analyse how risk management is provided in their companies. This analysis would be a complement in order to compare work with risk of all project participants at the same projects.

- Since the risk may be analysed deeply in many sectors of the building projects, it would be interesting to consider more in detail risk in different fields like safety risk, risk of investments, environmental risk, economical risk, risk of failure in different kinds of structures *et cetera*.

- Also deeper consideration and comparison of effectiveness and application of different quantitative methods of risk analysis would be a great interest for the companies not only in building industry but in other sectors that would like to implement new solutions and improve the risk assessment and management in their work.

- Due to the time limitation it was not possible to provide the detail analysis of risk management through whole project life cycle. However, it would be interesting to follow the project from the beginning to the end and monitor how the assessed risk was handled and managed in individual phases and how effective the risk analysis turned out to be during the whole project realisation.

- The other possible subject for further research would be to study how the risk management has been developed by companies in other countries in different regions of world. Which kinds of risk aspects are taken into consideration during the realisation of the projects and how they differ form each other depending on the environmental conditions and organisation of work.

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Interviewees:

Borglin Elisabeth	GF Konsult
Brazee Nils	GF Konsult
Erlandsson Anders	GF Konsult
Gabrielii Per	GF Konsult
Heijmans Herman	GF Konsult
Thunberg Åke	GF Konsult
Westerbo Tore	Norconsult
Hoell Schildknecht Georg	Norconsult
Hammarström Lars	Volvo Cars Corporation
Margitin Anna	Volvo Cars Corporation

Appendix A: Interview Questions to the Structural Engineers and Architects

Task and responsibilities

1. How many years do you work as Structural Engineer? What kind of projects have you been working with?

2. How do you start working on the new project task? If you are involved in conceptual design phase, do you have any special method to start the new project with in conceptual design stage?

3. Are your tasks and responsibilities the similar or different when working on different project?

4. How are responsibilities divided between the engineers in your team during conceptual design? How do you share information and experience with colleagues?

5. What is your risk responsibility as engineer when working on the project in conceptual design phase?

6. Do you use some kind of routines when working on similar tasks in different projects?

7. Do you participate in meetings when the concept of the project is evaluated?

If yes:

- Is the need analysis, objectives of the project and vision clearly presented to all participants of the project?
- Is there a risk probability and scope discussed on such meetings?

If not:

- Why not?
- Are there any other methods to inform participants about the new project and risk associated to it?

Choosing solution

8. How is the final alternative selected? How the key parameters and weight criteria are chosen?

9. What are the risk factors in alternative solution process?

Meeting the client and contractor

10. How often the client is met by structural engineers in your company? Do you participate in these kinds of meetings?

11. Do you discuss risk evaluation with the client?

12. How is the client informed about progress of the project, any uncertainties and new risk?

13. Do you have a good relation with contractor of the project? How often do you discuss the risk with contractor?

14. Does your company work with so called "Partnering contracts", where contractor is involved in the project from the very beginning?

If not:

- Do you think it is a good idea to introduce this kind of contract that allows better cooperation between participants, and minimizes the risk of misunderstanding?

If yes:

- What kind of advantages and disadvantages you find in this kind of contract?

15. Do you normally compare the design solutions with contractor's work on site?

Risk assessment and analysis

16. Do you use some kind of sequence or routine in each new project when analysing risk? Especially in conceptual design phase? How is a risk analysis done in your Structural Engineering division? How is the information about risk probability and consequences collected?

17. Allan Mann in his article (2003) describes theory of risk as simple equation risk=probability x consequences. Do you agree with this statement?

18. Does your company have any routines about risk identification in conceptual design stage?

19. How is the risk allocated to different parts of the project? Is there a special system which allows transferring the risk from one part of the project to another?

20. How often do you consult colleagues regarding problems with risk? Do you have routine meetings when you can discuss doubts and problems together?

21. How often do you participate in different methods regarding risk analysis and identification? What is the method to control the assessed risk in your company (division)? Do you use any check lists, interviews *et cetera*?

22. Is the risk probability calculated by using some methods in conceptual design phase?

23. How do you store information about the risk from experience and previous projects?

24. How does your team utilize the experience feedback during working on risk assessment?

25. What is your opinion about awareness of risk among project participants in your company? Is it on high or rather low level? Are there any improvements needed?

26. Do you have any ideas how to improve effectiveness in risk assessment and risk management in new project?

27. Do you agree with the statement that the risk management should be naturalized towards project management?

28. Time reduction in the project of Teknikhuset was a requirement given by the client. Did you identify any risk in execution of this task? What was your idea for working on such a milestone? How was the work organised to fulfil this requirement?

29. What kind of risk have you found as a team during working on the project? How have you handled them? Did you have any special system of risk management?

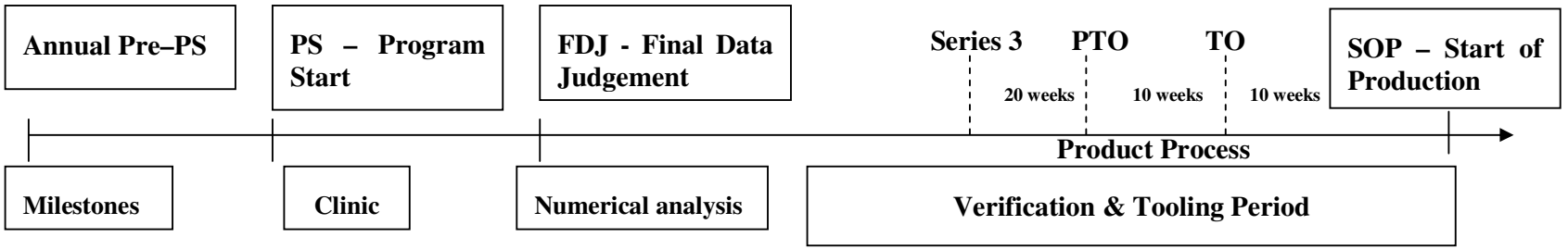
30. Where there any special kinds of risk in the design phase that you paid attention to? How did you identify them?

31. Was there any risk transferred to further stages of project? How information about this transfer was stored?

32. Where there any situation that you found difficult to solve from risk point of view and what where the reasons of them?

33. How do you store information about the risk? Which critical values where taken from experience?

Appendix B: Volvo Car Design Process



Appendix C: Example of Checklist

PROJECT NAME:				Date:	GF KONSULT AB Box 8774, 402 76 Göteborg Tel 031-50 70 00 Fax 031-50 70 13
BUSINESS AREA:					
SUBJECT:				Revised by:	
ACTIVITY:					
Date of application:		Advanced according to the schedule [%]:			
Date of completion:					
Preliminary date of completion:					
Decision/Solution	**Benefits**	**Possible negative consequences**	**Probability of occurence**	**Influence on other phases of the project**	**Special Considerations**
COMMENTS:					

Appendix D: Questionnaire to Evaluate the Efficiency of Risk Management Improvements

Date:	Business Area:	GF KONSULT AB Box 8774, 402 76 Göteborg Tel 031-50 70 00 Fax 031-50 70 13

- How much the effectiveness of decisions made in the project work in your team has improved after the changes made in the risk management in your Business Area?
- Do you have any problems to use new system of documentation or methods in working with risk in the project task?
- Did you develop your knowledge about the risk in building projects after the seminars and workshops organised by GF Konsult?
- How often do you use the methods newly introduced to the risk management?
- Do you think that the work with risk in the project was improved by the changes in the risk management?
- Do you have any suggestions what should be developed more or facilitated in the risk management of the projects that you work with?