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Swedish University of Agricultural Sciences

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Fuzzy risk assessment for construction projects

- With focus on farm-based grain drying facilities

Anton Eriksson
Marcus Furusköld

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Anton Eriksson
Marcus Furusköld

Supervisor:	Luca Di Corato, Swedish University of Agricultural Sciences, Department of Economics
Examiner:	Karin Hakelius, Swedish University of Agricultural Sciences, Department of Economics

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Anton Eriksson and Marcus Furusköld

Abstract

This study examines the economic risks of building a grain drying facility. Establishment of a grain drying facility is a construction with a high level of customized specific solutions. It hampers the quantification of the risks in the projects, since it makes it hard to gather historical data. The study is conducted in conjunction with Akronmaskiner AB, a Swedish company that manufactures and develops grain drying facilities which have had a strong demand for a study in the area.

In the study a model has been developed to create an assessment of the building process of a turnkey drying facility. Because of the lack of statistical data in this specific subject the study has been conducted with help of fuzzy theories. The fuzzy data is collected through a questionnaire which is set towards companies responsible for the construction of Akron's drying facilities. The respondents have determined how long it takes to assemble the specific components of a drying facility. To test and verify the authentic of the study, the model has been tested against a previously installed drying facility, where the outcome between the model and the reality has been compared.

The study indicates that the model improves the predictability of the costs of building a grain drying facility. Thereby the risks related to the assembly process can be captured and the uncertainties of the projects lowered which by better management of the risks are possible to reduce. The thesis also leaves a smaller analysis of the risks in these projects and how they should be handled and decreased which would be beneficial for all stakeholders in the market. During the study´s survey, the main risks around the building process of a drying facility are quantified and it shows that largest costs in the process are related to the building shell and conveyors.

Sammanfattning

Uppsatsen handlar om de ekonomiska riskerna som uppkommer vid byggnation av torkanläggningar.. Varje byggnationsprojekt är unikt vilket gäller vid byggnationer av torkanläggningar. På grund av bristande statistik kring monteringsprocessen av dessa anläggningar är det svårt att kvantifiera riskerna och att dra lärdomar från tidigare projekt. Tidigare studier inom risk management har visat att det är vikigt att kunna kvatifiera risker för att fatta strategiskt bra beslut. Det har även Akronmaskiner AB upptäckt och därför efterfrågade de den här undersökningen.

Studien har använt sig av så kallad fuzzy theory vilket innebär att kunskaper om riskerna har inhämtats med hjälp av experters bedömningar. I undersökningen har data för simuleringen insamlats med hjälp av en enkät till de bolag som Akron anlitar för att montera anläggningar i det aktuella geografiska området. För att testa den modell som har utvecklats under studiens gång, och på så sätt öka modellens äkthet har en Case-studie genomförts. Caset är baserat på en tidigare monterad torkanläggning som Akron tillsammans med sina underleverantörer har monterat och driftsatt. Under avsnittet analys diskuteras hur och på vilket sätt som den ökade kundskapen inom detta specika område kan användas på bästa vis. Studien analyserar även de marknadseffekter som uppkommer genom en bättre risk estimering av byggnationsprocessen av torkanläggningar.

Modellen ökar möjligheterna att förutsäga kostnaderna och riskerna förknippat med byggnation av torkanläggningar. Genom detta minskar osäkerheten i projekten och vår förhoppning är att den ökade informationen ska ge bättre riskhantering på projektnivå. Modellen innehåller dock fortfarande osäkerhet. Genom att kartlägga tidsåtgången för monteringen av de olika delarna av torkanläggningen samt genom att dela in anläggningen i fler delar så skulle precisionen kunna förbättras. Den nya kunskapen kommer förhoppningsvis att tillåta att projektledningarna kan fatta bättre riskhanteringsbeslut, skriva mer effektiva kontrakt och på lite längre sikt minska riskpremien i marknaden för torkanläggningar.

Dictionary

Construction projects
In this thesis, construction project is the general term used to indicate a building process. Since the focus of the thesis is quite specific, by building process we will always refer to the set-up of a drying facility.

Fuzzy theory
It is a method used to transpose subjective thoughts into numbers and make them countable. This is a method often used when there are gaps in the data sets.

Grain dryer
It is the technical facility formed by a storage silo equipped with air channels blowing hot air through a tunnel system. This enables to dry grain to the desired moisture content level.

Grain moisture equilibrium
It is the water content level allowing for the safe storage of a specific cereal.

Possibility distribution
It is a mathematical operator, used in fuzzy theory, for mapping data into a distribution.

Probability distribution
It is a mathematical operator illustrating the probability of a certain outcome.

Monte Carlo Simulation
It is an instrument used to simulate an outcome based on a mathematical system. It is often used in computerized calculation due to the comprehensive amount of data.

Risk assessment
It is the procedure by which the risk of a specific threat is assessed. This can be done in both a qualitative and quantitative way.

Risk management
It is a concept that includes a company's management method that actively works with analyzing, minimizing and preventing the risks to which a business is exposed.

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1 Introduction

Risk management is becoming increasingly important in a changing world (Power, 2007). This implies that companies need to prepare in order to manage events that may not be fully foreseen. To be able to handle risks, companies need to know which risks they are exposed to and their potential impact on the companies' activities. Increased knowledge about risks, by identifying which factors should be handled with priority, can improve firm performance (Mikes, 2011). Then it is important to manage risk throughout the entire firm's operations. To stress the importance of managing risks in an effective way, Gordon *et al*. (2009), among others, provide a study showing that firms with higher quality of risk management are more profitable.

Knowledge about risks can be achieved using both qualitative and quantitative methods. Most companies combine both methods in order to identify and characterize the risks they may have to face (Baker *et al.,* 1998). Quantifying risks are valuable for comparing risks with each other and, if measured in monetary terms, with other strategic issues (Collier, 2009). Qualitative methods, like SWOT-analysis, are more suitable for detecting causes of risk. The need for calculations differs depending on the specificity of the situation.

Risk management in construction projects requires special measurement tools for quantifying risks (Taroun *et al.,* 2011). The main reason for this is the uniqueness of each construction project; it implies that there are seldom any historical data accessible. This is problematic considering that many standard risk management tools rely on the analysis of data referring to past experience.

Still, risk assessment is an important subject for construction management. This kind of projects is often risky and bad turnouts can have huge impact. Taroun *et al.* (2011) write about a lack of studies estimating a monetary value of the risks associated with construction projects. Monetary values will allow for comparing risks with other costs in the projects, risk optimization and for designing risk-sharing contracts. This may in turn, by contributing to the set-up of more efficient construction projects, allow achieving higher profitability (Öztaş and Ökmen, 2004).

This study will look at the economic risks of construction projects relative to the assembling of grain drying facilities. The facilities are complex plants mounted inside a building and used for grain drying and storage (McLean, 1980). Grain drying construction projects have the typical objectives that one expects in any type of construction project (Thorsson, 2015, pers. comm., and Lock, 2004), that is: i) delivering the building in time, ii) completing it respecting the budget and iii) constructing a building with sufficient quality for the customer (Lock, 2004).

Our study has been developed in collaboration with AB Akronmaskiner (Akron), a Swedish company with a long history in the sector of grain dryers' construction. The company is a family business which has been run in the last 80 years. Akron has annual sales of approximately SEK 80 million and employs nearly 70 people (*www*, Retriever, 2015). The product range has been changing over time and today Akron is mostly selling drying and storage devices for handling grains and axial fans for industrial applications.

1.1 Grain drying facility

The grain dryers currently used were developed during the 1970s and since then there have been many dryers manufactured (Jonsson, 2006). Approximately 80-90% of all the grain produced in Sweden is dried and handled by drying facilities that are located next to the farm where the grain is produced. The main task for the grain dryer is to remove/lower the moisture of the grain until it has reached equilibrium (McLean, 1980). When storing cereals, it is important that they reach moisture equilibrium since this implies that potential damages in terms of crop quality, once stored, are minimized. Many of today's modern drying facilities in Sweden are mounted in a compact building where both storage silos, loading, unloading and drying system are tightly clustered in order to have an efficient utilization of the available space. The most common type of dryer is the High-Temperature dryer which blows hot air through a channel system into a room where the wet grain is exposed. The grain emits water molecules into the warm air, these are then absorbed and the grain is dried.

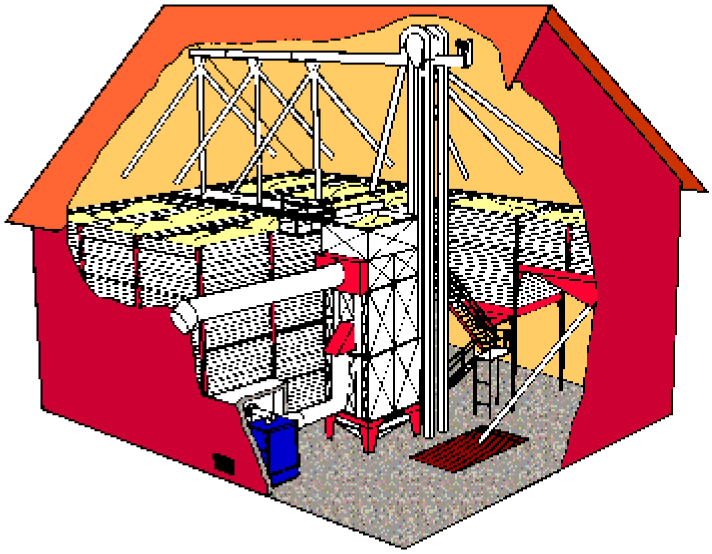

Figure 1, A standard grain drying facility, equipped with the standard components (www, Akron, 2015).

We see in figure 1 the typical construction of a complete grain drying facility commonly mounted in Sweden (Jonsson, 2006). The plant is composed by a number of standard components such as a dumping pit, a drier, storage silos and the bulk loading silos for the unloading part. It is worth stressing that usually the mix of components is customized. During the assembling, the building shell and the inventories for the facility are mounted in the same process. The assembling phase differs significantly between the facilities because of the special design due to specific customer's requests.

Akron's products are sold through different channels depending on the market segment they belong to. In the agricultural segments, the sale channel consists of importers or agents who represent Akron's brand in each market. Sales of Akron's grain drier facilities in Sweden are arranged by their own sales department or by some established dealers. Different sales channels entail different contracting issues which require information about the connected risks.

1.2 The need of a risk assessment

Almost 40% of the total investment needed for a drying facility is represented by the construction process. This includes concrete, ground work and electrification (see figure 2 for an illustration of actual costs). The costs related to the assembling part and the associated uncertainties have always been problematic for practitioners to calculate (Thorsson, 2015, pers. comm.). Since these costs consider an important part of the total investment cost, the relative uncertainty may significantly influence the risk characterizing the entire installation.

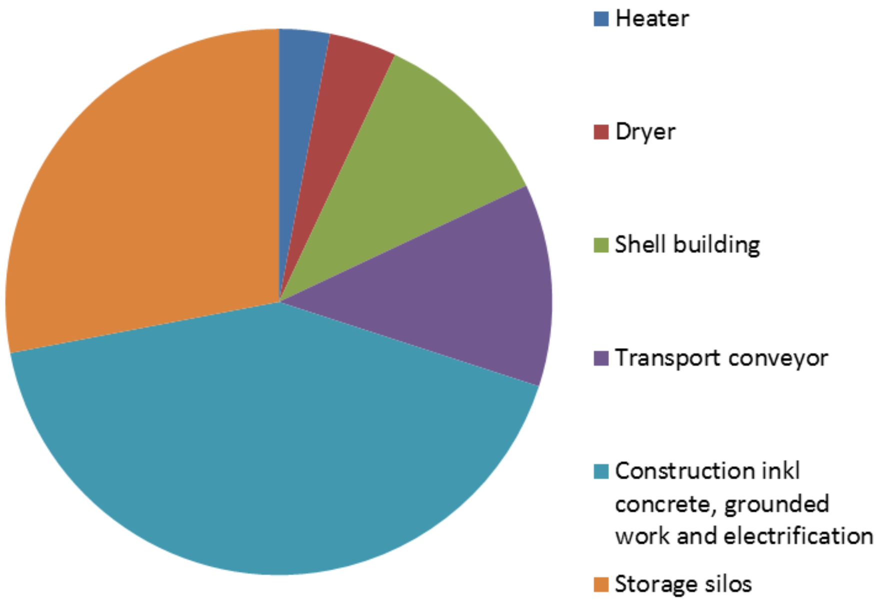

Figure 2, Per-component investment requirements in a drying facility (Own elaboration based on Jonsson, 2006).

In general, it has always been quite difficult to assess the time actually needed for the completion of different construction projects. Therefore, there has always been a demand for investigative studies addressing this issue (Thorsson, 2015, pers. comm.).

A drying facility, for instance, that was built in the southwest part of Sweden in year 2013 was considerably more costly than calculated (*ibid.*). The plant was composed as a normal drying facility with two batch dryers, storage bins, the related transport conveyors and electrical and casting work was also included. The calculations were performed without taking into account any potential variation due to uncertainty. When the construction work was finished, the final cost for the assembling and installation was almost twice the expected cost. The increase was mainly due to the need of spending more time with assembling. If these costs would have been foreseen, losses could have been limited.

The uncertainty and the risks about the assembling are, according to market theory, taken into account through a risk premium to be paid in the market of grain dryers (Pindyck, 2009). The actors involved in the transaction are usually risk averse. This means that they require a higher expected profit if the risks are higher. Under uncertainty, it is also possible that the actors in the markets overstate the potential risks and thereby also require a higher risk premium. Knowledge about risks and improved risk management may then help to reduce actual prices.

We illustrate these considerations using an example of the possible effect of reduced risk premiums in the grain drier market. As shown in figure 3, the supply line has two possible locations, one upper- and one lower position. In the upper-supply-line it is shown that the risk premium is included in the value. Given a certain demand, it follows that we have a lower quantity sold, Q_0, and a higher price, P_0. This illustrates how risks affect the economic system in a negative way, since uncertainty generates higher prices and lower quantities traded in the system.

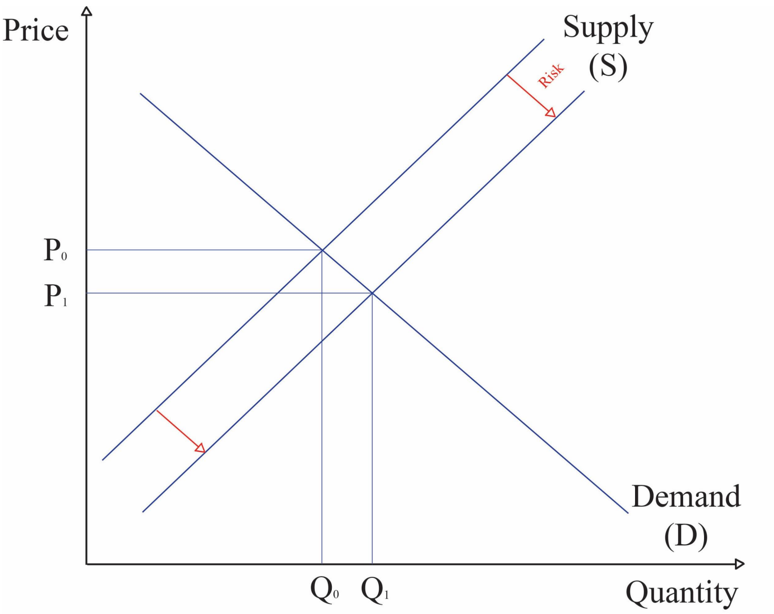

Figure 3, Effect of knowing the risks in construction of drying facilities (Own elaboration based on Pindyck, 2009)

The issue is a risk assessment problem. To solve this firms need information about the risks. Firms that can make a more precise appraisal of the risks are also able to present a better offer to their customers (Nasirzadeh *et al.,* 2014). For the customers and the suppliers of drying facilities, knowledge about risks could be used as an argument in price negotiations and it may enable both parts to agree on a fair price. Assessing uncertainty could potentially lead to better designed risk sharing contracts and enable spreading the risk among parties involved in the projects. Planning the construction projects with respect to risks might help risk handling as well. With a good design of the contracts, risk can be handled in an efficient way.

1.3 Problem

There are several risks involved in the construction of a large facility, such as grain dryers (Lock, 2004). Usually, in these projects a major part of the total investment cost is related to the construction cost (Jonsson, 2006). The construction process includes risks which are hard to assess (Taroun *et al.,* 2011). This may have a negative impact on the value that stakeholders attach to this part of process due to unexpected costs which result in less profitable projects. If the risks associated with the installation could be mapped, the uncertainty surrounding the construction cost could be lowered. This could in turn allow for a more efficient contracting and lead to less costly construction projects. Furthermore it is of great interest for all stakeholders to identify the risks associated with the setup process.

1.3 Aim and research question

The aim of this research is:

i) To set up a model for estimating the economic risks characterizing the construction process of a grain drying facility.

ii) To apply the model for measuring the impact of uncertainty in the cost calculation.

If both the suppliers and the customers have a good understanding of the various risks that arise over the installation of a drying facility, this may support the functioning of a more efficient market with benefits accruing to both parties. Thereby our research questions are the following:

i) which approach should be taken in order to correctly assess the economic risk characterizing the construction of a grain drying facility?

ii) how may fuzzy theory be used in order to evaluate the impact of uncertainty in the assessment of construction costs?

1.4 Delimitations

The study is limited to the use of subjectively calculated data, a limitation that is unavoidable given the lack of objective data. This limitation may, of course, decrease the solidity of our predictions. The use of statistics would surely have increased the solidity of our results (Robson, 2011). The same theoretical framework can be used also with other data assembling methods. Therefore the choice of using subjectively assessed data does not affect the validity of the simulation model and the limitation does not affect the choice of theories used in the study.

The subjective method used in this study is based on the assumption that firms' managers have knowledge about their specific installation times. The fuzziness is believed to be a weak link in the nature of the problem and therefore not possible to exclude (Tokede and Wamuziri, 2012). The uncertainty of the subjective assessment is not treated and measured in the study.

The aggregation method contains a limitation, it does not account for large spreads between the respondents' answers. This limitation is accepted since other aggregation methods are more time consuming. The data are believed to be coherent since all the most likely values are inside the aggregated intervals, thanks to this the effect of this limitation minor.

This research is limited to the examination of the economic risks characterizing the assembling of grain drying facilities. The thesis focuses on the building process since it is believed to be the most uncertain part of the construction project (Thorsson, 2015, pers. comm.). This impression is partly confirmed by Nasirzadeh *et al.* (2014) and other studies. It follows that our study does not address all the risks present in the entire construction project. This limitation implies that our study will not look into risks associated with warranties, delivery times, and constructions' default and contracting. Last, this limitation is also introduced in order to be consistent with the timeframe set for developing a master thesis.

The study is also limited to respondents assembling grain drying facilities delivered by Akron. This seems necessary since other grain dryer producers might have a different organizational structure and then a different approach to the realization of their construction projects (Thorsson, 2015, pers. comm.). This means that the results of our study may not necessarily extend to other companies supplying grain dryers. In contrast, we believe that the framework developed for the assessment of construction risk may be easily adapted to the analysis of other cases.

The study is limited to the analysis of construction projects undertaken in the plainparts of south-western part of Sweden since in these areas the dryer facilities share a similar design (McLean, 1980). The geographical definition is adopted to exclude conditions that differ in different geographical locations. An example of this is that in Great Britain the drying plants usually are built without a covering shell, which is unusual in Sweden (McLean, 1980).

2 Literature review

Chapter 2 provides a literature review of the most relevant academic articles which are in line with the subject of the thesis. The review is divided into three parts depending on the discussed subject, these are; risk management, contracts and construction projects. These literatures are used to pick and combine the theories in the conceptual framework of the thesis. The chapter highlights the importance of quantitative information and the issues of providing such information in planning construction projects.

2.1 Risk management

Risk management is a process in business which aims at detecting and managing risks (Collier, 2009). Managing risks does not necessarily mean reducing risks but it means that managers need to be aware of the risks in order to make strategic choices about how to handle them. By choosing wisely between how to handle different risks, managers can improve the firm performance and use risk management as a comparative advantage (Gordon *et al.,* 2009).

During the second half of the 1900s and onward the researchers have had a growing interest in the risks associated with business (Power, 2007). These are commonly classified as risk and uncertainties where risk is considered to be measurable and possible to calculate while uncertainties are not (Hardaker *et al.,* 2004). The value attached to risks is usually determined as the product of their potential impact and their probability (Hillier, 2010). It follows, that on the basis of the definitions used for characterizing the concepts of risk and uncertainty, risks can be valued whilst uncertainties cannot.

Risks and uncertainties affect companies' profitability. Stakeholders expect companies to be aware of risks and be able to handle unfavorable results (Power, 2007). Catasús *et al.* (2007) shows the importance of measurement for management in organizations. They state that since only what is measured will be managed, organizations tend to focus on the stuff that is measured when they make decisions. It implies that measuring risks are important if managers are to consider those in their decisions. Measurements also enable managers to divide accountability for different questions, it can be a method to reduce risks and improve performance (Catasús *et al.,* 2007). Effective risk management therefore requires quantifying risks.

In Wakolbinger and Cruz (2011), it is stated that knowledge and manageability of risks are important when it comes to writing contracts. It is also shown that being aware of risks can represent a competitive advantage for a firm (*ibid.*). Summing up, we may conclude that measuring risks is extremely important for companies, in particular when they propose and sign contracts.

An overview of risk management in the agricultural sector is written by Hardaker *et al.* (2004). The authors write about the risks that a farmer is exposed to, risks such as weather, production, financial sources, and other business risks. Even though the risks in a construction project may differ from the ones normally faced by a farmer, some of the methods described in their book are also suitable for this study.

Most risk management models are based on standard procedures for detecting and measuring risks based on historical data available to firms (Collier, 2009). The three steps; risk detection, risk evaluation and risk response, are described below. These steps can be regained in the theoretical framework of the study.

2.1.1 Risk detection

The first step in most risk management models is the risk detection (Collier, 2009). This is usually a qualitative process developed through interviews, benchmarking, brainstorming or similar methods. Detecting the risks is important since managers need to know what they are supposed to handle. This process is mainly about finding the risk sources. Grouping risks having similar triggers or impacts can be useful in order to ease the risk evaluation. The definitions of risk sources can be used as a base for further calculations or used for subjective evaluations.

2.1.2 Risk evaluation

The next step in the risk management process is to assess the impact and the probability of the risks (Collier, 2009). This is the same as calculating the value of risks (Hillier, 2010). There are many methods for estimating these values; some of them are Monte Carlo simulations and business continuity planning (Collier, 2009). The choice of method is depending on what kind of information is wanted and on the available input data.

2.1.3 Risk response

According to Collier (2009) managers can choose to handle risks in four different ways:

i) Avoiding it,
ii) Reducing it,
iii) Hedging against it, or
iv) Accepting it.

Avoiding risk means that the firm simply chooses to not consider risky operations. Reduction of the risk means that by some controls the manager may have the opportunity to reduce risk. Another way to avoid or reduce risk is by sharing it with any other actor, for example by outsourcing, hedging or buying an insurance contract. Acceptance is the last method for handling risks. This means that managing the risk is done by accepting the outcome of it and being prepared for bad turnouts. The handling options are a strategic choice of the firm and the right choice differs between firms. The important thing is that the choice is coherent with the company's risk profile.

2.2 Contractual issues

Construction project contracts can be written in different ways (Gordon, 1994). Common agreements are set on the basis of fixed price contracts, design-build, turnkey, build-operate-transfer, material delivery contracts or as a combination of these contractual frames. Different contract types allocate risks differently between the parties (Nasirzadeh *et al.,* 2014). Table 1 illustrates three different contracts normally used by Akron when selling grain dryers. The table also illustrates how the responsibility for risks is split between the parties. As can be seen different contracts are used also for construction projects considering grain dryers.

Table 1, Three typical contracts used in selling process of grain dryers and how they divide responsibility (Own elaboration, based on Thorsson, 2015, pers. comm.)

Construction project contracts for grain driers

Responsible partner	Material delivery	Design	Projecting	Mounting	Groundwork
Turnkey contract	*Contractor*	*Contractor*	*Contractor*	*Contractor*	*Contractor*
Flexible contract	*Contractor*	*Contractor*	*Contractor/client*	*Contractor/client*	*Client*
Material delivery contract	*Contractor*	*Contractor/client*	*Client*	*Client*	*Client*

Nasirzadeh *et al.* (2014) investigate the usability of risk simulations for contracting and risk sharing purposes. The authors conclude that knowing the risks is important in contracting. A fuzzy Monte Carlo simulation can be used for calculating the risks for this purpose in a construction projects. According to Nasirzadeh *et al.* (2014) contracts can be used to divide risks between relevant stakeholders. It is optimal to design the contract such that the party who can better control a specific risk should bear the responsibility for it. Thereby this party is supposed to take initiatives aiming at controlling it. Designing these contracts though require a sufficient knowledge about the risks. Even though this study does not involve a deeper investigation about the design of contracts, assessing correctly risk has very important implications for contracting.

2.3 The uniqueness of construction projects

The projects are usually one-off projects with customized buildings (Taroun *et al.,* 2011). The uniqueness of the projects means that there is a lack of relevant data to use for statistical calculations. This entails that calculating risks in construction projects becomes problematic since probabilities are generated using historical data (Mikes, 2011). Therefore, researchers have tried to find different methods for constructing a probability measure for costs in construction projects. By using fuzzy possibility distributions based on experts opinions we are able to assessing the risks specified in a construction process of a drying facility (Hardaker *et al.,* 2004).

The planning of a construction project is important for its success (Lock, 2004). Planning the time schedule reduces the uncertainty and makes the risks more manageable. The main targets for a successful construction project are i) to deliver in time, ii) to finish in line with the budget and iii) to deliver a building with sufficient quality. These targets are similar in all construction projects. The time spent in the construction phase is usually an important cost and risk source in construction projects. Along with strict deadlines this implies that using time as calculation unit is a logic and common measurement base.

2.4 Risk assessment in construction projects

Carr and Tah (2001) developed a fuzzy simulation model to calculate the riskiness of construction projects. Their model is built on estimating the riskiness of a project through the comparison of the likelihood of a bad turnout with other projects. They then propose, as outcome of the model, a risk index which is used in order to compare the risks. An important concept presented in Carr and Tah (2001) is that a subjectively generated fuzzy density function is often the best estimation possible when there is lack of relevant data. Their model is, however, not able to associate a monetary value to the risk, quite common problem with fuzzy set models for construction projects (Taroun *et al.,* 2011).

In Mohamed and McCowan (2001) a fuzzy monetary evaluation of construction projects is combined with a fuzzy non-monetary evaluation of the projects. Their model is mainly interesting for construction companies that prioritize non-monetary values, such as employing personal and establishing a brand name. The article offers a framework for evaluating these two kinds of factors on a common base. The authors also provide a discussion about the suitability of using fuzzy possibility distributions instead of ordinary probability distributions based on historical data. They conclude that given the circumstances it should be more appropriate using possibility rather than probability distributions.

In their study fuzzy triangular and trapezoidal density functions are used. This is motivated from the unlikeliness that an expert will be able to answer the questions with a complete density function (*ibid.*). It is likely that they can provide an interval and a most likely value inside the indicated interval.

The use of fuzzy theory in risk analysis in the construction sector is examined also by Tokede and Wamuziri (2012). In their study, practitioners in England and Scotland were asked about their beliefs about the relevance of using fuzzy theories for risk assessment in construction projects. The authors propose a method combining both interviews and a survey for capturing a holistic picture of the subject. The practitioners express that a fuzzy approach is relevant in construction projects and that calculating the risks involve a possibility of detecting risk in operations. Then some risks can be avoided and the projects may become more profitable. For some projects that are highly repetitive it is found that the practitioners believed that it was easier to use simpler mathematical tools for assessing the risks. The practitioners stress that the usage of fuzzy theory must be motivated by the economic gain in the project.

Öztaş and Ökmen (2004) use Monte Carlo simulation in a case study project relative to the construction of a police station in Turkey. They divide the project into phases and then use expert opinions to establish fuzzy possibility density functions for the expenditure of time for each phase. The data assembling used is otherwise only described in fractals in the article. In their study it is found out that the contractor made a complete miscalculation about the costs of the project and therefore made a loss on the contract. This illustrates the importance of this kind of evaluation. As it will become clearer later, the model used by Öztaş and Ökmen (2004) has importantly inspired the analysis presented in our study.

Banaitienė *et al.* (2011) made a qualitative study asking companies in the Lithuanian construction industry about which risks they were aware of. In their literature review they conclude that pure qualitative studies in the field of risk management are unusual since most studies are oriented at quantifying the risks. Qualitative methods usually suits better for risk detection and not for quantifications. In their study the authors do exactly this in order to find out which specific risks affects projects developed in Lithuania. They however conclude that for more practical problems it would be needed to develop a quantitative study.

Baker *et al.* (1998) made a qualitative study in which they described which methods of risk management were most commonly used by practitioners in projects. They found that most companies use a combination of qualitative and quantitative risk assessment.

A deeper literature review about risk management in construction projects is made by Taroun *et al.* (2011). In their review, it is discussed the issue of associating monetary terms to the riskiness of construction projects. This is interesting given that the most part of the literature focus only on risk ranking between projects and do not determine the value of the risks.

3 Theoretical framework

In this chapter the theoretical framework is developed, which are a concept of theories that aims to simplify the theories for the reader. Presenting a theoretical framework is provoked by Robson, (2011). The chapter starts with a summary of the developed framework and continues with a description of the fuzzy and simulation theories. The theoretical framework has also been influenced from the literature review.

3.1 Conceptual theoretical framework

In the subject of risk management, there are a several theories that could be used in order to handle the analysis of risk exposure in construction projects (Collier, 2009). Before the 1960s a limited consideration was given to the risks in construction projects (Taroun, 2014). Many of the standard theories of risk management in construction projects are based on historical data and variations over time. In recent studies, simulation models like Monte Carlo simulations and fuzzy theory have become more common.

In order to explain the links between the theories used in the thesis, an illustration of the conceptual framework is established (Miles and Huberman, 1994). The model helps to understand how the theories that are used interact with each other (see figure 4). In order to evaluate the risk, several steps must be taken. The conceptual framework begins with data collection followed by the simulation and the risk evaluation on which the risk handling decisions can be based on. The risk handling concerns both contracting and risk management strategies.

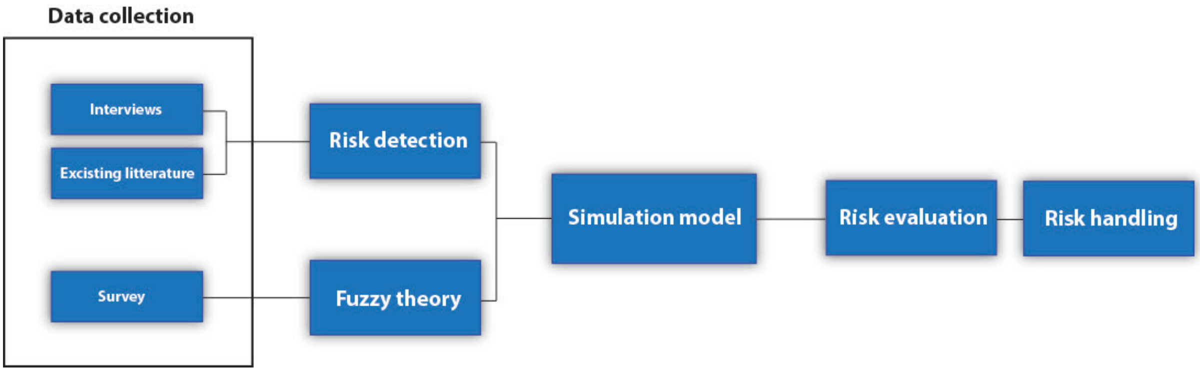

Figure 4, The conceptual theoretical framework that is used in thesis (Own elaboration based on (Miles and Huberman, 1994)).

3.2 Fuzzy theory

The fuzzy logic was developed in the 1960's by Lotfi A. Zadeh (Carr and Tah, 2001). The method is used to quantify subjective thoughts into numbers and make them countable. Usual application areas are medical science, qualitative surveys and intelligent computing (Kuncheva, 2000). Fuzzy theories can also be used for estimating numbers when the recorded data are insufficient or unreliable, as when estimating future events (Jarl, 2003). The fuzzy theory is not a statistical method even if there are similarities (Zadeh, 1965).

A fuzzy theory allows grading how strong a value belongs to a category (*ibid.*). A common example of this is the case of water belonging to the category warm (i.e. hot water) or not, see figure 5. This is an example of a linguistic fuzzy set where a verbal observation is transformed into a number (Kuncheva, 2000).

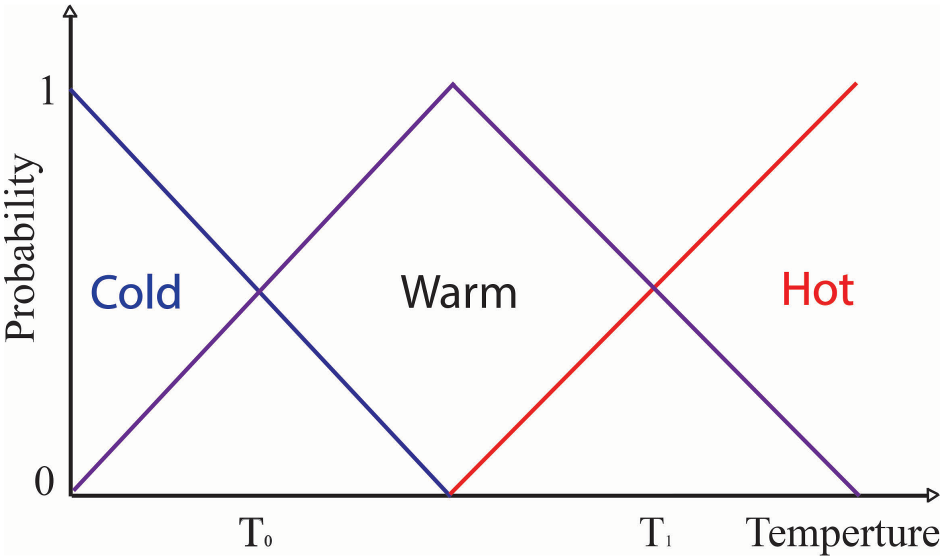

Figure 5, Description of how strong a data belongs to a specific category for the case of water temperature (Own elaboration based on Zadeh (1965)).

This enables the subjective answers to be used in mathematical calculations, such as Monte Carlo simulations, which is the main point about using fuzzy theories (Hardaker *et al.,* 2004). Without fuzzy theories it is not possible to make calculations on subjective information, such that cannot be attained through measures or through statistic databases.

When the fuzzy theory is used it must be considered that it is built upon subjective thoughts that reduce the precision of the information (Kuncheva, 2000). This is why it is called "fuzzy" theory. Thereby the fuzzy numbers have different characteristics than the statistical ones; they are fuzzier (Zadeh, 1965). It is the knowledge or opinions of a human collective that is assembled. For example the joint knowledge from a number of experts in assembling grain dryers.

3.2.1 Fuzzy possibility distributions

Fuzzy intervals are sometimes used in risk management for creating an alternative to probability distribution functions based on experts' subjective evaluations (Hardaker *et al.,* 2004). This is discussed in an article by Mohamed and McCowan (2001) where the authors call it possibility theory, meaning fuzzy theory used for approximation of probability. This method is common in other papers about construction project risk management such as Öztaş and Ökmen (2004) and Carr & Tah (2001). The fuzzy possibility density function is a function which describes the subjective beliefs of the real probability density function of a specific outcome. Shown in a graph the area underneath the line represents the probability of an outcome. The whole area between the line and the X-axis sums to 1, which stands for the cumulated total probability. An example of a possibility density function is shown in figure 6.

There are a number of techniques for assembling the data and for creating possibility distributions out of experts' opinions (Kuncheva, 2000). The choice of which method to use depends on how the derived distributions are going to be used, what is previously known, who is chosen as reference in terms of expertise and the characteristics of the problem. Kuncheva (2000, p. 111) names 5 different methods for creating fuzzy intervals, that are: i) Polling which means picking a statistical sample of a population to see how they will vote in certain question to later generalize it to the whole population, ii) Direct estimation, imply asking direct questions to the respondents to answer with a number, iii) Reverse estimation, means that the respondents identify things that belong to a set from given examples, iv) Interval estimation, where the respondents set an interval as answer to a question, v) Pairwise comparison, where the respondents are asked to compare two things against each other.

In our study, we use the interval estimation. This method is believed to capture the characteristics of the problem. It also allows for creating intervals of the answers from a limited number of experts (Hardaker *et al.,* 2004). Furthermore there are different methods to establish possibility distributions from intervals surveys. Two common methods are the visual impact method and the method via a fuzzy triangular density function.

3.2.2 Fuzzy visual impact method

The visual impact method is based on asking the expert to express the believed probability of different outcomes (Hardaker *et al.,* 2004). It is done through placing points representing the likelihood of an outcome. This method can define an accurate distribution function with many measuring points. This technique, though, risks ending up with complex surveys which are not answered by the respondents. One way of making the surveys less complex is to provide the intervals in the survey and only ask for the density functions. This is not suited for this study since the intervals are also unknown. Another way to reduce the complexity of the survey is to limit the number measuring points in the interval. However this implies that some information may be lost.

3.2.3 Fuzzy triangular density function

One common way to make an easier measurement of the distribution is to use the triangular density function (Hardaker *et al.,* 2004). This is a fuzzy density function that is established from only three measurement points, which are: i) maximum, ii) minimum and iii) most likely. The density function is created by drawing a triangle with the corners in the minimum and maximum values and a top at the most likely value (see figure 6). The triangles height is given such that the area of the triangle becomes 1, i.e. represents all possible outcomes.

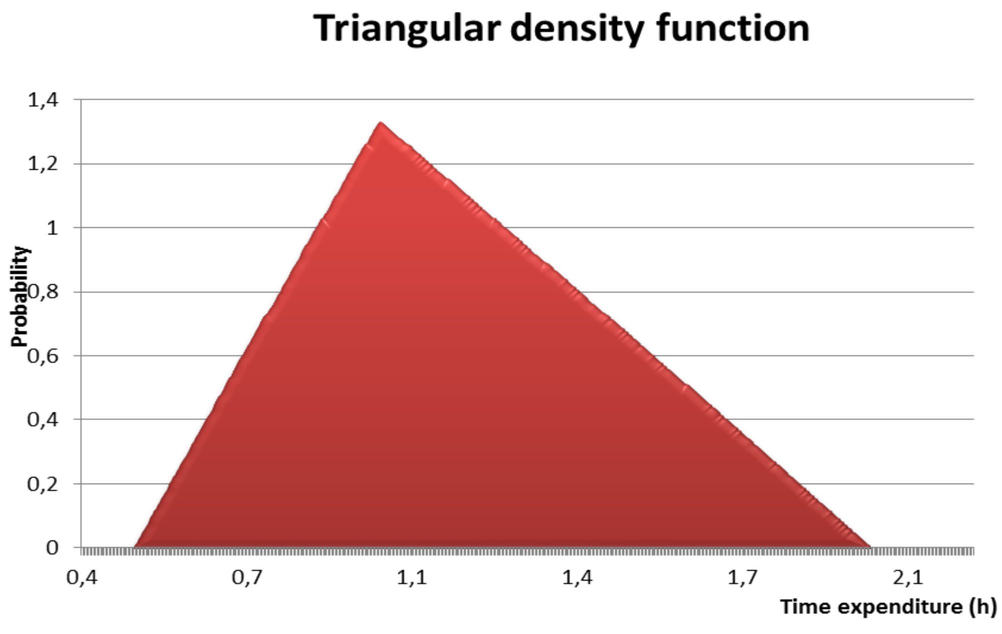

Figure 6, Example of a fuzzy triangular density function made in @risk (Own elaboration)

The fuzzy triangular density function allow for less complex surveys even when there is no earlier information about the data (*ibid.*). The fuzzy triangular density function is an approximation of the probability density function, it provides an image of the skew, the median value and the interval limits. It is commonly used in fuzzy studies thanks to the easy creation of it (Macdonald, 2002).

3.3 Monte Carlo simulation

No theory is perfect for estimating the risk of a certain project but Monte Carlo simulation is recognized as a good tool which enables simulating many different uncertainties at the same time (Taroun, 2014). Scenario analysis, which is another popular quantitative risk management method, only enables changing one variable at the time (Collier, 2009). In contrast, Monte Carlo simulation sums up different distribution inputs and generates a joint distribution function as the output. Usually the output is the answer to some sort of problem (Hardaker *et al.,* 2004). The name of the theory comes from the famous casino in Monaco, where the game roulette can get many results which can be described by a Monte Carlo simulation.

To understand the Monte Carlo simulation it is important to understand the cumulative distribution functions (CDF). The CDF is another way to represent the probability (Hardaker *et al.,* 2004). Compared with the probability density function the CDF represents the integral of the probability density. This mean that for a normally distributed probability the cumulative probability function is S-shaped.

The CDF provides for each possible number the probability of an outcome equal or lower to that value (*ibid.*). On the Y-axis the CDFs have a scale from 0 to 1 which represents the probability. In figure 7 the CDF corresponding to figure 6 is shown.

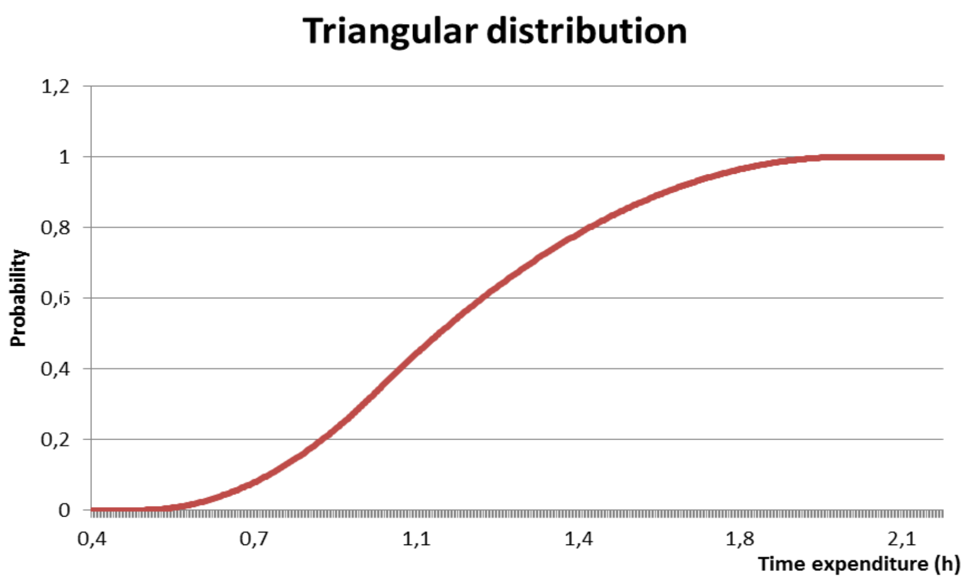

Figure 7, The CDF corresponding to the fuzzy possibility density function in figure 6 (Own elaboration)

The Monte Carlo simulation slumps a number between 0.0 and 1.0 (Hardaker *et al.,* 2004). The number is then connected to its outcome through the CDF. Through this process the

Monte Carlo simulation enables simulating a lot of outcomes from different distribution functions. By doing this slumping repeatedly and registering the outcomes, the Monte Carlo simulation can recreate the probability distribution function.

In a model with more than one variable that is uncertain, a Monte Carlo simulation can simulate each variable and sum them up through the model and give an output distribution which is based on the defined inputs (Hardaker *et al.,* 2004). Summing up different uncertainties make it possible to capture the net impacts of the inputs and get an overview of the problem.

The usage of Monte Carlo simulation should reveal the whole nature of the risk (Hardaker *et al.,* 2004). On the other hand Monte Carlo simulation is a complex tool which does not provide complete final conclusions. It provides, however, additional information to the decision maker. Sometimes the use of Monte Carlo simulation might only make a problem more complex. Using Monte Carlo simulation is a good method to view the risk in a decision.

3.3.1 Latin hypercube sampling

Latin hypercube sampling is a more precise version of probability simulation; it is an improved simulation method similar to the Monte Carlo simulation (Hardaker *et al.,* 2004). In Latin hypercube sampling the probability scale are divided into equally intervals and then the simulation is done with the same amount of samples from each interval. This leads to a better representation of the probability distribution with fewer samples and increased precision. Using Latin hypercube sampling should therefore be used when it is available because of the increased reliability.

3.3.2 Simulation programs

After setting the theoretical framework a model for simulating the risk in the assembling of grain drier facilities is constructed. The model uses assembling times for different components of the facility as calculation units for estimating the risks of the construction process. The model is built in Microsoft Excel® and the add-in @risk® from Palisade® is used for the simulations. Other programs could be used but this was accessible and provides a solid base of functions which is good enough for the simulations needed in the study. In the empirical background the simulation model used in this study is explained.

4 Method

This chapter describes the methodologies used in the study, which aims to give the reader a clear view how the study has been conducted. The method chapter explains the data assembling approaches, and evaluates the impacts on reliability, validity and ethical considerations.

4.1 Open interviews

In order to collect technical information about the construction of a drying plant, two open interviews with the area sales manager Martin Thorsson at Akron were performed. Martin is responsible for the sales organization of Akron's agricultural division and is therefore responsible towards Akron to provide successfully projects. Mr. Thorsson has explained how important it is for his organization to have a good handle on the calculation of the assembly process of a drying plant. The open interviews with Mr. Thorsson took place at Akron's head office in the 22nd of January 2015 and the 9th of March, 2015.

Participating in conversations is an effective way to gain an understanding of the construction process and of the theories on which the simulation model is based upon (Kvale, 2014). The main purpose of the interview was to give the researchers a better understanding of the construction process and thereby bring the study closer to reality. The interview also enabled the creation of the questionnaire-survey to fit into our model and to look familiar to the respondents. The foundation of the questionnaire was formed on the basis of the dialogue. Akron's influence on the survey increased confidence for the survey and avoided misunderstandings among the respondents, since their vocabulary was used.

An example that proves the value of the interviews is a problem that was raised during the establishment of the questionnaire. The problem was about which unit of a component that should be used in the response formula. The literature and the practitioners used different units. It is important to design the questionnaire such that the answer is easy for the respondent to indicate (Ejlertsson, 2014). Therefore we have designed the questionnaire using the same vocabulary as the respondents are accustomed to working with. Thanks to the interview these considerations could be caught before sending the questionnaire to the chosen experts

The interviews were conducted in an open way in which the meeting was controlled by an open agenda. During the interviews, notes were taken and to verify and increase the validity of the interviews, the notes have afterwards been verified by the respondent (Robson, 2011). Another option could have been to record the interviews, but this may have influenced the atmosphere during the meetings and thereby lowered the quality of the conversation.

4.2 Survey

A survey was made in the study to receive assembling times for different components of the grain drying facility. This was considered as the only option for gathering data to the study. The questionnaire is divided into three categories were each expert answers in his specific area. The used questionnaires are included in appendix 1-3. To avoid confusion, in particular when handling specific technical terms, the survey is written in Swedish.

4.2.1 Sampling

The respondents were companies with many years of experience in the business and a solid expertise in the area. All these companies have been collaborating with Akron for a long time. The respondents were chosen with a purposive sampling technique with consideration to a long documented experience in assembling drying facilities and from a geographic point of view. All respondents are active in the south-western part of Sweden. Installation of drying plants is a fairly small industry with highly seasonal workloads and it is important that the projects are carried out properly to secure the functioning of the facility. Therefore the companies in the business are few, specialized and experienced in the task.

Normally the drying facilities sold by Akron are mounted by different companies that are specialized in different parts of the process. Therefore the respondents are only expected to be able to determine the assembling times concerning their respective parts. This implied that the survey was split into three categories. This makes it easier for the respective respondent to answer their specific part. The three categories of firms are as follows:

i) ground and concrete companies,
ii) electrician companies and
iii) assembling companies.

To the ground and concrete companies the survey parts concerning the bottom plate was sent. They provided the working times for the excavation and the assembling of the bottom plate. The electrician companies answered about the installation work for all the machineries. The assembling companies answered about the construction times of the inventories and the time needed for sky lifts and cranes.

In total six firms were surveyed, two firms for each category. This covers a significant part of the actors operating in the business. According to Akron there are only a few assembling firms in Sweden that they use for mounting grain drying facilities (Thorsson, pers. com. 2015). Information about which firms have constructed each component was collected in the interview. For this study it is important to keep the sample limited to the construction companies specialized in the construction of grain drying facilities. According to this, samples of two firms from each category were picked from the small population. A bigger sample would have lowered the relevance of the experts and is therefore not desirable.

The survey was sent to all respondents by email during the first week of April 2015 and all the respondents had answered the survey and responded by email by the 7th of May 2015. The high response rate is believed to be accomplished thanks to the business relationship between Akron and the respondents. All the respondents were contacted by an initial phone call in which they were asked to answer the survey. During the phone call the project was presented as a study made for reducing the uncertainty in assembling grain dryers and performed in cooperation with the authors and Akron.

The reference to Akron was made to increase the legitimacy of the survey and to make it more interesting for the respondents to answer. For all respondents Akron is an important customer and there is obviously an incentive to have a good relationship. A high commitment from the respondents is desirable in all surveys since it increases the reliability of the answers (Ejlertsson, 2014).

After the phone call the respondents got the survey sent by email and were asked to answer the survey. Emailing was chosen since it was believed to be an easier way for the respondents to answer and to avoid the administration of using ordinary posts. The distribution should be chosen with consideration to the respondents, to make sure that the commitment is maintained (*ibid.*).

4.2.2 Questionnaire design

The questionnaire is designed based on the components that consist in a drying facility as described by McLean (1980). The respondents are asked to answer with the time needed to complete the different activities performed during the construction work for each component. To increase the quality of the answers the questions are not designed as cross questions where the respondents can easily answer (Ejlertsson, 2014). This pushes the respondents to consider their answers before leaving them. This is something that may affect the response rate negatively. However, we consider this as a significant small problem as the respondents have incentives to respond at the survey because of their position with respect to Akron. The questionnaire is formed as a self-completion survey which implies less risk that the interviewer influences the results.

The answers provide a fuzzy possibility density function for each resource and the specific component. To make this possible without having unnecessary complicated answer sheet fuzzy triangular density functions are used (Hardaker *et al.,* 2004). The respondents answered each questions with three values, minimum, maximum and most likely. The survey is formed as a table which easily can be overlooked by the respondent. This is to avoid a heavy impression from the template which could risk the confidence of the respondent (Ejlertsson, 2014).

4.2.3 Survey: description

The questionnaire had a front page in which the study and the problem were introduced. Furthermore there was a short description of the logic of the survey. Presentation of the survey was also made during the introducing phone call. For each section in the questionnaire there is an explanatory text which had the task to get the respondent to be familiar with the prevailing conditions, such as the tools assumed to be included. Except for explaining the text filled a purpose of inducing an interest in the subject of the investigation to make the respondent engaged in answering the questions (Ejlertsson, 2014).

Long questionnaire formulations may induce the respondents to both sloppy respond or refrain from participating (Robson, 2011). Therefore, we have chosen to use short and consistent questions and technical terms which the respondents are accustomed to. This is to facilitate the task for the respondent and avoid that misunderstandings occur (Ejlertsson, 2014). It is important that the model is defined in a proper manner and that the questions do not leave room for interpretations. Furthermore, the survey is written in Swedish to avoid linguistic difficulties that easily can arise when translating technical terms (Robson, 2011).

Since the questionnaire has parts of highly technical nature, we offered the opportunity to call the researchers for clarifications. This opportunity was utilized twice, once for checking which type of grain dryers that was used and the other for checking the question about loading point base. The fact that the respondents cared to call and ask questions about the questionnaire is taken as a proof of the commitment to provide high quality answers.

4.2.4 Pilot study

Before sending it, the questionnaire was tested using, as pilot, a group of students at the Swedish University of Agricultural Science (SLU). It was difficult to perform a solid pilot study since the questionnaire is so technical in certain parts that only no students knew all terms. But the target group for the survey is expected to be familiar with the terms and for them it would be more annoying with simplified terms. Therefore our decision was to keep the technical terms.

Having the pilot study done with the practitioners would have reduced the pool of accessible respondents even more and therefore this option was not considered. Instead the technical terms were explained to the students who then understood what they were supposed to answer. To complement on and ensure compliance with the comprehension of the survey the phone call opportunity were offered. Sending out the survey without having cleared all the misunderstandings in the pilot study is risky but there were no alternatives for this study. Thanks to the interview the respondents understanding of the technical terms was known even if there was no good pilot study.

4.2.5 Aggregating the survey answers

The two surveys from each type of company are aggregated through the weighted averaging technique, which is described by Chang and Hung (2004). Mohamed & McCowan (2001) uses the method for combining their monetary and non-monetary values. The weighted average method is described by equation 1 where r_i is the aggregated fuzzy number, P_{ij} is the values that the experts have reported and W_j is the weight of each value.

(Eq. 1)

$$r_i = \frac{\sum_{j=1}^{J} Wj * Pij}{\sum_{j=1}^{J} Wj}, i = 1 \ldots\ldots, I$$

(Based on Mohamed & McCowan, 2001)

This method lowers the effects of extreme values which results in smaller intervals than if a union interval would have been used. Therefore it can cause a lowering of the risk image for the problem, if for example the intervals are separated, it will not be represented by a larger risk in the model. This is a problem with using this method in a risk basement study but alternative methods are far more complicated. This limitation has been accepted in this study. Figure 8 is an example of how the density functions are aggregated illustrated graphically. The solid line represents the aggregated density function and the two other lines represent the two respondents' answers. The weighted average method is used for both aggregating resource consumption times and for aggregating price data.

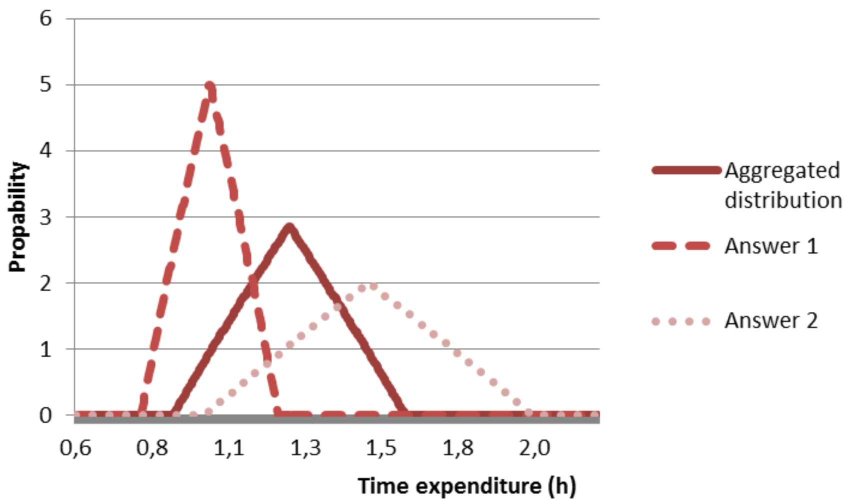

Figure 8, The aggregation of the respondents answers (Own elaboration)

4.3 Price data

Because of the specific subject, the necessary statistical price data is strictly limited by the public authorities. Therefore this data is provided by Akron and to verify their reliability and get a price interval, a minor investigation has been carried out by calling a number of suppliers of this type of equipment active in the region. These companies were sampled through a list of suppliers supported by Akron. Out of this list a purposive sample was done by choosing the companies in the investigated geographical area. For each input price at least two companies have been called. All the cost figures given by Akron are within the defined intervals, but it was believed more relevant to use the fuzzy numbers provided during the phone calls.

The phone calls were made with an instruction manual to ensure that the interviewer did not affect the answers. The manual started with a presentation of the study and its background. Here it was stressed that the investigation was made in cooperation between SLU and Akron. This was done in order to increase legitimacy of the survey. It is important for getting trustworthy answers (Ejlertsson, 2014). Then it was stressed that it was important that we got actual prices which would be paid by an assembling firm. They usually have discount levels on gross prices (Thorsson, pers. com. 2015).

When this introduction was done, the companies were asked about an interval of the prices for the input to the construction projects which they provide. To visualize the risk in the price of these input services and because there is no sufficient long data series available it is chosen to make fuzzy triangular density functions for these prices. The respondents were therefore asked to provide the three numbers to establish such interval.

When the costs were provided the interviewer thanked for the call, promised that the firm names would not be published and finished the conversation. Being polite and respecting firms' wishes of not publishing specific data is important for continued cooperation between academy and companies (Kvale, 2014).

Having a small sample may weaken the robustness of the results of the study. Hence, running a simulation where these prices may vary may potentially capture the impact of their volatility. When projecting a construction project in reality these input-prices can normally be fixed from contracts and therefore not interesting to simulate for practitioners. However, the simulations are also run with fixed cost prices on inputs to determine the effect of having fixed prices.

4.4 Case study

To verify the theory and our fuzzy simulation model a case study based on a previously mounted drying facility is used. This is done to increase the validity of the study and of the model that has been developed. It is one of the usage areas that Yin (2003) proposes as suitable for case studies. As well as using an experiment a case study can be used to confirm a theory. This is the main reason for setting up the case study. As part of the testing of the theory, the case study is also a suitable tool for showing the principles of the simulation model. The case project is based on an earlier facility built by Akron. This type of verification of a risk assessment model is also used by Öztaş & Ökmen (2004).

The use of a case is for ensuring that the model works, is able to illustrate it in the thesis and to test if the model gives relevant answers to a practical problem. The case is used as an experiment test and to prove the theory the test should be repeated many times (Yin, 2003). This is something for future research to continue with and outside the scope of this thesis.

4.5 Literature review

A literature review is presented in order to provide an overview of earlier research undertaken in the area (Robson, 2011). The literature search was made using highly respected academic resources. The search process includes extensive searches in SLU primo and Google Scholar where a few recent and relevant peer-reviewed articles were found. By using several databases, we believe that we may account for differences between the databases.

The relevant literature is organized and saved in a Zotero library. This is done in order to make the process transparent and facilitate the correct use the academic references. It should be acknowledged that all relevant literature can never be entirely examined (*ibid.*). To cover up for this fact the searches have been continued until no more findings in the searched area appeared. Then it is believed that the most important and current research in the area has been found.

A further technique that is used is adding the keyword "literature review" to the searches. This enables finding earlier literature that provides an overview of the research about the subject (Robson, 2011).

A considerable amount of literature about risk management was found in the searches. It is a broad area and a few interesting articles which provide a wider picture of the research area are selected and reviewed in detail. For the applied area of construction projects the earlier literature is thinner but closer to the problem area. A couple of reputable articles are reviewed in the section relative to construction projects.

4.6 Qualitative study with a fixed design

In this study a qualitative research method combined in a fixed design is used (Robson, 2011). The fixed design is a simulation model established from the theoretical framework, earlier literature and interviews with Akron. The fixed design approach is chosen to ensure that the result of the study is in the form of a fuzzy possibility density function which can be used in practice to assess a price of the risk. With a flexible design the data assembling could be expanded into something problematic to structure into a quantifiable problem.

The fixed design is limited to look for processes that involve risks which are covered by the model (*ibid.*). This means that there can be risks that are out of the range in the simulation model but would be detected with a flexible design. To decrease this risk, the model is design according to reflections from the interviews with Akron.

4.7 Validity

Certitude that a study measures what is stated to be measuring is described by its validity. In this study the validity is if the fuzzy possibility density function reflects the cost outcomes of the construction projects. There is an obvious threat against the validity of the study, that is, the use of fuzzy theory. When subjective data is used it always includes an uncertainty about the predictive validity of the study, it is depending on both the knowledge of the respondents and the questions ability to ask for the right things in the survey (Ejlertsson, 2014). Compared with using historical data this implies that the validity of the study is lowered (Robson, 2011).

A result based on statistical data must be evaluated for the likelihood of the history to recur and the robustness of the measurement. A fuzzy data on the other hand must evaluate the respondents and the communication between the interviewer and the respondent (Kuncheva, 2000). An illustration of a risk with this is for instance when the assembling firms are asked for the time to completion for assembling a bucket elevator. Then they might feel that it is a boring job and therefore perceives that it takes more time than it does. It is possible that this type of biases is included in the data used in this study, and it is not certain that the possibility interval reflects the actual probability interval (Ejlertsson, 2014). It is therefore important to keep this in mind and be careful when drawing conclusions from the fuzzy possibility.

The case study will serve at illustrating that the simulation model works (Robson, 2011). This is since it is based on a real construction project were the actual outcome is known. The case is based on a recent project performed by Akron. Through the case study the simulation model can be tested and compared with the actual outcome of a real project. Testing the model on several case studies is believed to be possible if there would be access to more data (*ibid.*).

4.8 Reliability

The reliability of the study is considered to be high, all the information has been collected through carefully selected sources and our respondents in the survey have highly relevant experience in their area (Ejlertsson, 2014). There is also full response rate in the survey which means that there is no problem surrounding why companies did not answer. This is believed to be important for the reliability (Robson, 2011). Having a high reliability of the study does not ensure validity. It is still a subjective evaluation that is measured in this study.

In order to maintain a high level of reliability in the study, all the respondents had access to the same questionnaire as well as the same amount of background knowledge. These operations are made to make sure that the respondents perceive the same questions (*ibid.*). The respondents are believed to have a high commitment when answering the study and it is therefore likely that they have answered with their best knowledge. As long as that knowledge is not changed, it is believed that a repeated survey would get similar answers (Ejlertsson, 2014). All data that is collected in the survey are given by two different companies independent of each other. Due to limited time of the study a reliability testing survey is not performed.

4.9 Ethical considerations

When designing a research it is important to take the ethical aspect in consideration in all parts of the process (Oliver, 2010). This is especially vital when data are collected from individuals and it is important to have an objective view of which answers that are grounded in people´s individual experience and opinions. This study uses as known a self-completion questionnaire made by respondents which answer with subjective assessments. This type of data collection does not raise any specific ethical concern. The survey that is used in the thesis cannot be compared to a traditional survey where a greater amount of respondents is asked. Once the survey is worked through in this way it is important to inform respondents about why the survey is conducted and how it is structured. Material in the form of technical drawings and other documents by Akron considered as not for official use has been treated with the utmost confidentiality.

An essential part of the work is the business ethics in the relation with Akron. It is important for continued cooperation between academies and companies that none of the parties is negatively affected by the cooperation. In this case treating internal documents with respect and not exposing information that can be strategically important have been an important issue. Meanwhile it is important for Akron to share its information to make the risk assessment as good as possible.

5 Background for the empirical study

Following chapter present the simulation model and the empirical information about the case study. Out of the theory, a fuzzy Monte Carlo simulation model is constructed for estimating the risk in construction of drying facilities. The simulation model is described in detail and this chapter explains how the results of the study were achieved.

5.1 The Case plant

To clarify and validate the thesis a case study has been carried out in addition to the rest of the research. Case studies are a useful method for testing and validating theory (Yin, 2003). It is also believed to be suitable for explaining the logic of the study to the readers of the thesis.

The case study is based on a construction project of an earlier built grain drying facility from Akron. All the information about the installation of the facility is documented by Akron and their supplier. The specific information about this plant, such as number of storage bins and elevators, is inserted in the simulation model. Along with the established fuzzy intervals from the survey the model simulate an outcome of the current facility.

The actual facility that is set as our case plant is placed in the south-western part of Sweden and can be seen as a normal farm-based drying facility (Thorsson, 2015, pers. comm.). It is as earlier described customized and designed with its main components clustered tightly together inside a shell building. The outcome of this case should not be seen as an attempt to generalize the cost of assembling grain dryers, instead the technique used in the case could be copied for projection of new dryer facilities.

The case facility consists of 15 transport conveyors, five trusses, 636 m² of walls, one dumping pit, one dryer type 4, three bulk loading silos, three storage bins, stairs and electronic installations for running the facility. Out of the transporters there are twelve conveyors for moving the grain horizontally in the facility and three elevators for lifting the grain to the top of the plant. Two of the conveyors connect the new facility to an old storage facility.

This plant provides a total capacity of drying 12.1 tons of 18% moisture grain to 14% moisture per hour and has a storage capacity of 270 tons. Keeping into account the connected old storage facility, the total storage capacity is above 1600 tons of dried grain. The grain facility also has a loading silo capacity of 150 tones for fast loading of trucks.

The farm where the plant is built is a company which operates on 300 hectares and a normal harvest in the area is about 6830 kg/ha (*www,* SCB, 2015) which means that the storage facility is well adapted to the farming company. This is a normal size for a farm in this area. Normally a farming company of this size has access to a minor set of standard farming equipment such as tractors that can be accessed during the assembling (Thorsson, 2015, pers. comm.). During the assembling of this facility a wheel loader from the farmer´s own equipment was utilized for the assembling. Since this is common for other installations to, we assume that some machines always will be borrowed from the farming company and that this is included in the intervals given in the model.

In practice adding and withdrawing components from the list will probably be needed as a part of the adjustments for different customizations. The importance of using a standardized and structured tool of calculation is though important to manage to get an overview of the problem and this is possible with the model developed in the study even if it is not adjusted for all situations yet (Lu & Tzeng, 2000).

The case facility is located in the south-western part of Sweden, the area is one of the plain areas of Sweden and the facility is used for drying grain both for selling to bakeries and for usage as feed in animal breeding in the farm. It is quite usual that the dryers are customized to provide a flexible solution that fits the specific needs of the farming company (Jonsson, 2006). The total material cost of the facility where approximately 2 100 000 SEK. This mean that according to Jonsson (2006) the assembling cost should be approximately 2/3 of that which is 1 400 000 SEK. The actual turnout of the assembling cost is provided later in the results part. But this approximation does at least show that it is a construction project of sufficient size for motivating our calculations.

5.2 Simulation model

The simulation model is built based on theory, earlier articles and the interviews made with Akron. The layout of the model is inspired by Öztaş & Ökmen (2004) and is developed to fit the construction process of a grain drying facility. The most important economic risk sources found were the cost attached to time to be completion for different tasks. This was found through the interviews with Akron and similar risk sources used in earlier studies (Öztaş & Ökmen, 2004). The use of many resources is done to be able to set the output in monetary terms instead of time.

Earlier literature usually divides the projects into many parts, while the practitioners that Akron usually work with divide the project in wider parts (*ibid.*). Therefore the model is constructed to divide the projects into components with usually used units that are familiar in the branch.

Earlier studies have used different bases for dividing the projects in their specific simulations, for instance Carr & Tah (2001) use risk source, such as weather as their component. Another way to create it could be like in Öztaş & Ökmen (2004) which use scheduled phases for dividing the project. A problem that could arise with many ways of dividing is that it becomes hard to quantify the risks in monetary terms. This is part of the aim in this study and are requested from companies in the business, Taroun (2014) even talks about the lack of studies with this profile. Using components as calculation base makes the model easy to adjust to a new project and in the same way makes it possible to analyze in monetary terms.

5.1.1 Calculation units

The assembling cost for each component are defined as consumption of different input resources in the building plot, such as assembling personal time, crane time, excavator time etc. As a final step in the calculation, resources are priced and turned into costs.

Since each component is mounted separately in the project it is believed that the correlation between different inputs in the model is zero (Kuncheva, 2000). It could be argued from a logical reasoning that there are correlations between some of the fuzzy time expenditure distributions. This could not be investigated in the study because of the limitations in the data assembling method. Therefore zero correlation is assumed. It is believed that the error from assuming zero correlations is limited in comparison to the uncertainty involved in the rest of the model. All input parameters are therefore assumed to have zero correlations.

5.1.2 Components

The components (indexed *i*) in the facilities are selected from earlier projects undertaken by Akron. This choice was also discussed during the interviews with Akron. The resources (*r*) used in by the project is assembling crew time, excavator time, crane time and electrician time. The model also considers costs of sky-lifts (Sk) and portable cabins (P), these costs are though calculated from the time consumption of assembling time. For each part the respondents are asked to determine an interval of time consumption of each resource. These answers are used to set triangular fuzzy possibility functions as inputs for the Monte Carlo simulation (see equation 2).

(Eq. 2)

$$F(r_i) = \begin{cases} \dfrac{2(r_i - min\, r_i)}{(max\ r_i - min\, r_i)(mostlikely\ r_i - min\, r_i)}, x \leq mostlikely\ r_i \\ \dfrac{2(\max r_i - r_i)}{(max\ r_i - min\, r_i)(max\ r_i - mostlikely\ r_i)}, x \geq mostlikely\ r_i \end{cases}$$

(O*wn elaboration based on Hardaker et al., 2004*)

5.1.3 Resources

For each component there are fuzzy assembling time expenditure, a fuzzy electrician time expenditure, a fuzzy excavator time expenditure and a fuzzy crane time expenditure. For some of the components all the services are not needed and therefore these intervals are assumed to be zero. To see which components that are assumed not need different resources, see the questionnaires in the appendixes. Summarizing the service columns an estimation of the total need of resources can be determined. These cells are defined output cells in @risk® to gain fuzzy distribution values as results. The function used to determine these outputs is equation 3.

(Eq. 3)

$$Resource\ consumption\ times = \sum_{1}^{i} F(r_i)$$

(Own elaboration)

The sky-lifts are needed during assembling time (A) of different components of the facility, and then they are assumed to be rented at the building plot on a per day basis. Therefore the costs of renting the sky lifts are depending on the time consumption of assembling the components needing a sky-lift (equation 4). The data relative to the sky-lift were collected in the survey (see appendix 1). In Excel® the condition of needing a sky lift or not is modeled with a "true or false function" which makes the sky lift equation zero if the lift is not needed.

(Eq. 4) $$Sk_i(Ai) = \frac{\frac{Ai * WF}{N_{sk}}}{8}$$

(Own elaboration)

The function assumes that the number of workers (WF) and skylights (Nsk) are known. It is also assumed that 8 hours' workday is used. The use of portable cabins is calculated referring to the assembling times, the number of workers and the number of portable cabins (Npo) in equation 5. The equations 4 and 5 make the rent costs to be zero if the numbers of sky lifts respectively portable cabins are nil since N then equals zero.

(Eq. 5)

$$Po_i(Ai) = \frac{\frac{Ai * WF}{N_{Po}}}{8}$$

(Own elaboration)

The model assumes known number of workers, sky lifts and portable cabins. Uncertainty characterizing these aspects is not considered in the model. These factors are considered depending on decisions made by the assembling firms, and not on randomness. Therefore it is not considered as a risk even though it increases the variance of the cost (Hardaker *et al.,* 2004). The impact of changing these factors could be explored with the model and used for improving decisions.

5.1.4 Costs

For calculating each of the parts assembling costs equation 7 is used. In equation 7 the term costs for input resources (*F(rC)*) is found. The indexed r for the sum stands for summary for the different resources. The cost of each resource can be filled in at the top left corner of the model. If these are unknown, the model also accepts simulation of these numbers based on the fuzzy intervals collected from Akron. The function for these fuzzy triangular density functions is in equation 6, where the term rC mean the fuzzy number of the resource cost.

(Eq. 6)

$$F(rC) = \begin{matrix} \frac{2(rC - \min rC)}{(\max rC - \min rC)(mostlikely\ rC - \min rC)}, x \leq mostlikely\ rC \\ \frac{2(\max r_i - r_i)}{(\max rC - \min rC)(\max rC_i - mostlikely\ rC)}, x \geq mostlikely\ rC \end{matrix}$$

(O*wn elaboration, based on Hardaker et al., 2004*)

(Eq. 7)

$$Assembling\ cost\ for\ part\ i = \sum_{1}^{r} \mathrm{F}(rC) * F(r_i)$$

(Own elaboration)

5.1.5 Outputs

Summarizing the column of assembling costs generates the fuzzy total assembling cost which is the last output defined in @risk®. The sum is given by equation 8.

(Eq. 8)

$$Sum\ of\ assembling\ costs\ i = \sum_{1}^{i}\sum_{1}^{r} \mathrm{F}(rC) * F(r_i)$$

(Own elaboration)

This means that model consists of 94 input values and 12 output values; the actual amount of inputs used in a simulation is though depending on the facility to which the calculations refer. When quantities of components are set to nil the number of inputs is reduced. The simulation was performed with Latin hypercube sampling and 10 000 drawings.

The model estimates the assembling time for constructing a grain drier facility based on expert's estimations about assembling times for components of the facility. The model is also able to convert the times into a monetary value and answer the question about which assembling costs have the biggest impact on the total project. All the numbers are though subjectively generated; therefore the models predictions are dependent on the expert's evaluations.

The model is a practical and suitable tool for structuring and calculating the assembling of drier facility. It allows for basing the data on experts opinions or data from earlier projects. With the case study the prediction ability of the model and the theory is tested (Yin, 2003). The hypothesis of the case study is that real outcome of the real project should be inside the likely interval predicted by the model. Because of the uniqueness of each project using more case studies would only repeat the first experiment and not add certainty to the first fuzzy possibility distribution (Yin, 2003).

6 Results

In this chapter, we present the results relating to the research questions. Other information that can be received from the model is also disclosed along with viability tests for some of the assumptions made. The outcome from the model can be compared against the actual cost of the facility which is disclosed at the end of this chapter.

6.1 Possibility distribution for the total assembling cost

In Figure 9, we plot, using the simulation data, the graph of the fuzzy possibility density function of the total construction cost for the case. From the graph, we can grab important information such as median value which, in this case, is really close to the expected cost and the range in which the maximum and the minimum value can be inferred. In addition, looking at Figure 9, the reader could get a sense of the range of values where the most part of the fuzzy possibility is cumulated.

Figure 9, The total cost of construction fuzzy possibility density function. (Own elaboration)

6.1.1 Shape

The fuzzy possibility density function of the total building cost is, as can be easily seen in Figure 9, almost shaped as a normal distribution. We note in fact that the skewness is close to zero. This in turn implies that the mean, the mode for most likely value and the median, are very close. The fuzzy density function have a standard deviation of 132 000 SEK, which is about 7 % per cent of the total construction cost. This is a useful measure since it can be used to illustrate the risk in the project (Hardaker *et al.,* 2004).

6.1.2 Maximum and minimum-values

The interval considered is strictly limited by the minimum and maximum values that were drawn in the simulation. The corresponding values are 1 416 000 SEK and 2 373 000 SEK, respectively. It should be highlighted that at the tails of the fuzzy density function the possibility for an outcome to occur is very low. In other words, a draw at the tail should be considered as unlikely according to the model, but the interval is interesting for contracting.

6.2 The inputs with the highest impact

Using @risk it is possible to identify the input variable with the highest impact in the simulation. This is interesting information especially when the simulation is used for risk assessment (Collier, 2009). The correlation coefficient of the assembling cost illustrates the impact of changing the standard deviation for variables by one unit. This means that the variation in one of the input variables will lead to a change in the total cost expressed by the product correlation factor times the standard deviation of the total cost. Thereby the correlation factors can be used for identifying the highest risk factors. Figure 10 shows the coefficient factors for the inputs with the highest impact in the case project. As shown in the figure 10, assembling of conveyors, walls and trusses have the highest risk impact on the total building cost. Sky lift rent and assembling cost per day are the costs with the highest risks that was found by the model.

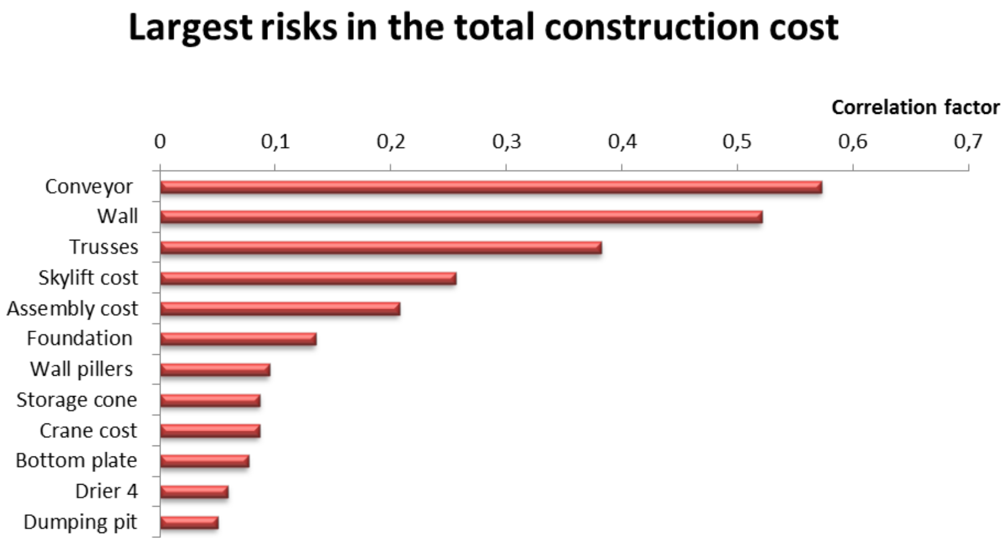

Figure 10, Illustrates the coefficients of the different inputs (Own elaboration)

Assembling time of the conveyors appears as the most important source of variations, no matter if the input prices are varied or not. It shows a 0.55 correlation factor with the standard deviation of the total cost. This is a high correlation factor and decreasing the volatility in time expenditure for assembling the conveyors could make the total project less risky.

6.3 Other outputs

The model does not only provide information about the total construction work and the cost related to it but it also provides information about the consumption of different input services during the building process. This is illustrated in figure 11 which shows the fuzzy range in which the time (specified in terms of hours) for assembling work varies. During the planning phase of the project this is valuable information for the management team. This knowledge enables contracting suppliers in advance, setting a starting date, making sure that the project is finished before deadline and deciding how many inputs that will be needed in the project.

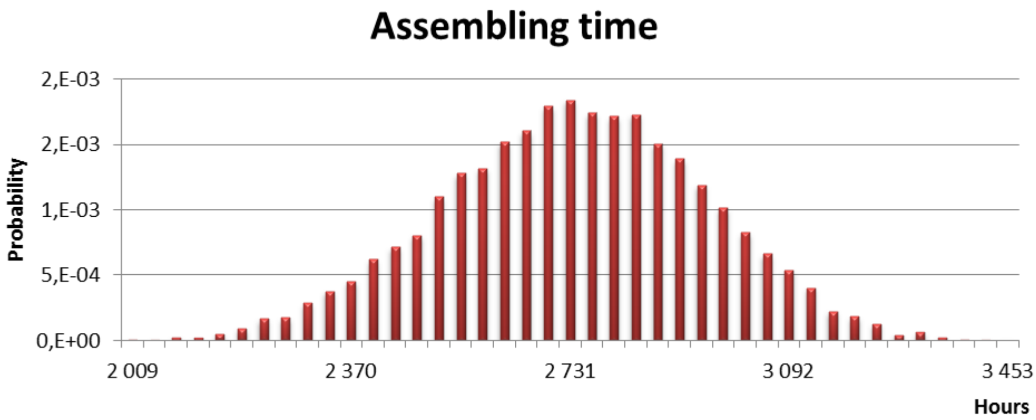

Figure 11, The possibility density function of assembling time (Own elaboration)

A risk evaluation can be performed by studying the parts of the assembly which constitutes the major part of the variation of the outcome. This is illustrated in figure 12 which shows that the largest impact on assembling time is due to the assembling of concrete, trusses, walls and the conveyors. From the graph it possible to determine how much the different components risk affecting the time needed. It enables for instance concluding that when the conveyers are set we know that the project will finish in time. This can be valuable for making strategic decisions during the project.

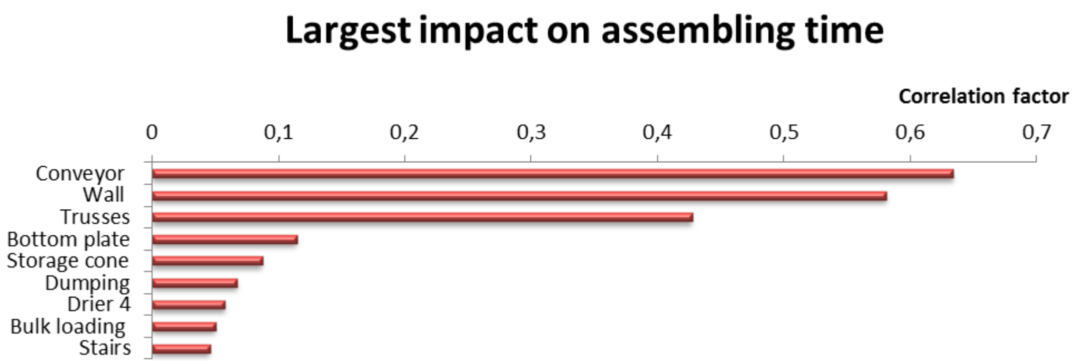

Figure 12, An illustration of the impact of specific activities on the overall assembling time (Own elaboration)

6.4 Cost drivers

By using our model, we may also identify which component that mostly affects the total construction cost. This information is provided in figure 13. The information may be of great interest where the reader gets a sense of which activities that affect the total construction cost at most.

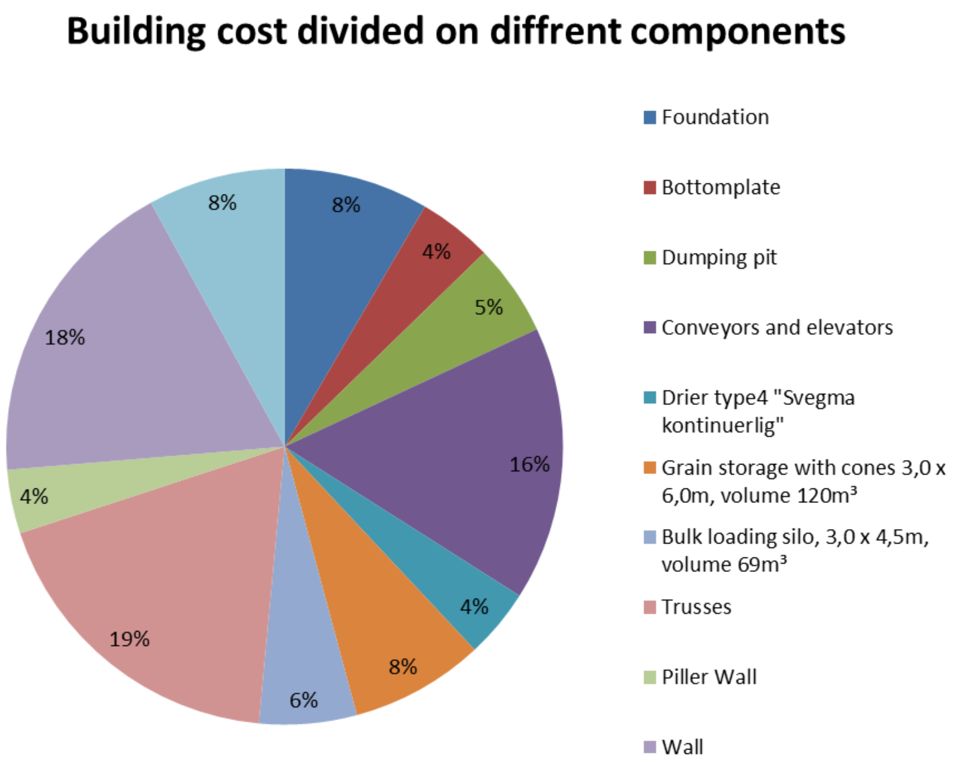

Figure 13, Illustrates which components that affect the total fuzzy construction cost at most (Own elaboration)

According to the figure 13 almost 40% of the assembling costs are originated from the assembling of the walls and the roof (trusses), this is also about 20% of the cost for the whole project. It can clearly be seen that it is costly to mount the shell house.

6.5 Impact of assumptions

Figure 14 presents four different plots. Two of them, lines 1 and 3, illustrate the result of using fixed or varied input prices in the simulation model and the other two, lines 2 and 4, show the outcome if the correlation assumptions are changed.

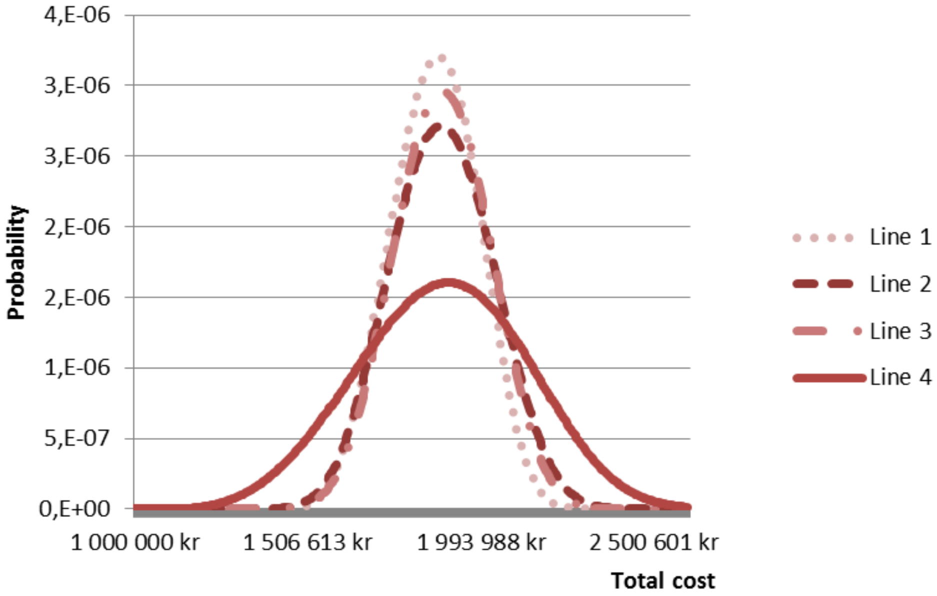

Figure 14, The cost possibility distribution with fixed and simulated input prices, correlation in input prices and correlation in timing (Own elaboration)

The line number 1 shows the impact of having fixed input costs, such as hourly rates for employee and crane hire. This can be compared with the ordinary outcome (line 2). The variance of the fuzzy density function is the highest impact on the outcome from introducing fixed and known prices. With fixed input prices the variance is 120 000 SEK. This shows that the project is more risky with unknown input prices; however, it must be said that, as shown in Figure 14, the difference is relatively small.

In Figure 14, we also plot two fuzzy graphs illustrating the results of running the simulation with correlation in the different inputs, costs and time expenditures. In line 3 it is assumed to be correlations between the input prices and in line 4 it is assumed to be correlations between the times required. In both cases, a correlation equal to 0.5 is assumed. Both tests increases the standard deviation more for the case of correlated prices the standard deviation is 143 000 SEK and for the case with correlated time required the standard deviation is 240 000 SEK.

It is shown that in the presence of correlation, risk increases. This makes, of course, sense since the effect of risk diversification is lowered (Hardaker *et al.,* 2004). In the tests the correlation was set equal to 0.5 between all the inputs tested. If this correlation is true in reality for time required the model underestimates the standard deviation with about 100%.

Correlating the time consumption variables would mean that the model reflects that the projects might be an easy to mount project or a difficult to mount project. This means that if there are problems with mounting one component the rest of the components are expected to be more problematic to mount as well.

Furthermore the correlation between the input prices would imply that the prices shifts between the different projects and if there are high costs of one resource then the other prices are likely to be high. This could be caused by local differences in supply and demand for different services. As an example there might be higher salaries in areas close to big cities. The impact on the fuzzy total assembling cost from assuming correlated input prices are though limited and thereby not as interesting to explore as the correlation between time consumptions.

6.6 Outcome in reality

In order to verify the reliability of the model proposed in the study, we should compare our results with the evidence relative to the actual finalization of the construction project that we have chosen as reference. The previous installations of Akron´s drying plants have not been documented in a specified level which makes it more difficult to compare the cost drivers per category. We are instead forced to compare on the overall level which give us an indication of the model´s solidity.

The figure about the project that could be gathered from Akron's database is basically the total final assembling cost (not including the concrete work) which was equal to 950 000 SEK. This means that the assembling time for the facility were about 2 700 hours. Our model indicates a fuzzy expected total assembling cost of about 821 000 SEK which in turn would correspond to about 2 220 hours of assembling time.

Other components were not sold by Akron and it was therefore not possible to receive data about these costs. But in addition we chose to control the other outputs in the model for the case plant with the sale manager of Akron and we noted that the actual outcome for the model was in the right interval (Thorsson, pers. comm. 2015).

7 Analysis and discussion

This chapter contains the analysis part of the study which discuss the results obtained once run the simulation model. In the following, we discuss our results in the light of the research questions.

7.1 Outcome for the case

We have shown that construction projects for grain drying facilities are none standardized operations because of the great level of customization. This implies that the costs for assembling are difficult to estimate and the uncertainties in the projects are big. Making better calculations can though be costly. An alternative where the supplier is not able to customize the buildings would probably not be a good idea due to the complexity of farming operations. This because each farm has its specific requirements for the equipment and installations, such as connection to existing facilities, number of serials possible to handle and lot more. Thus, standardization is impossible to implement even if it would bring great simplifications regarding estimation of construction time.

One possible solution for the calculation problem is to divide the project into smaller units that can be standardized and thereby possible to use as calculation unit in a model. The assembling time for these can then be assessed and the uncertainty reduced. The model used in this thesis is based on time required for installing each component.

By comparing the actual and the estimated outcome from our model we can analyze the validity and precision of the method. The simulated fuzzy total assembling cost for the grain drying facility has an expected value of 1 889 000 SEK compared with the actual outcome of 2 000 000 SEK. This means that the case study experiment strengthens the validity of the simulation model. However, this is only compared against one previously installation which of course cause some uncertainty.

If the model could predict the outcome of more cases with a similar precision it could be assumed that the model can predict the cost outcome of a grain drying project. If that is the case it would imply that both the outline of the model and the fuzzy data reflects the real costs as intended. This would mean that the fuzzy data provided by the experts would be close to the real numbers, but to conclude the relevance of the fuzzy data more case studies are needed. It is still possible that there are some errors in the experts' estimations. Trough performing more case studies it might be possible to detect these errors.

7.1.1 Cost analysis

Good measures and control of costs can in the long run improve efficiency, it enables allocating unnecessary cost. This is only possible with our information thanks the used monetary values in the calculations. The usage of monetary values also enables comparing the costs with risks and with other strategic issues. It might be more profitable to use a more expensive building solution due if it contains less risk and thereby reduces the cost of the risk. The elements of the construction process which indicates high deviations such as installation of conveyor, walls and roof represent the major risk elements in the case construction project.

Since the model calculates the installation cost of the construction project specified on each component it is suitable for analyzing which parts that are most costly to install and which costs that contain biggest variation. For practitioners this knowledge about facility can be good for making cost effective plants. The model can be a helping tool for learning the nature of a project's costs.

7.1.2 Quantifying risks

It is possible to quantify the risk in grain drying construction projects by studying the deviations from the mean in the resulting costs. It should though be remembered that the results are fuzzy when the decisions are made and it will increase the uncertainty of the decision.

The level of risk in a given project affects the price that the supplier chooses to present. With a low-risk project the supplier can choose to select a less surcharge on the deal because of the known cost structure. However, if there is risky the supplier choose a higher surcharge to secure for unexpected expenses which could cause a loss.

For sales decisions other measures of risks then the standard deviation are usually relevant. Especially the risk of making a loss or the chance of making a certain level of profit is used in these kinds of decisions. With the fuzzy possibility distribution it is for example possible to ask for a price which means that there is only a 20 % risk that the company will make a loss on the project. This pricing strategy would be hedging against making losses in projects.

For the usefulness of the simulation model it is important that the standard deviation and the distribution can be generated. Examining the fuzzy possibility distribution gives an idea of the riskiness of a project. In order to manage the risks in an efficient way it is important to obtain information about them, this is confirmed by Power (2007).

7.2 Risk evaluation

This study was requested by Akron and their controllers. This means that there may be some practical areas application for our model. For this study it is believed that the calculation model is the most interesting part for practitioners. The results are depending on subjective data and might therefore be better set for each individual project (Öztaş & Ökmen, 2004).

7.4.1 Risk Sources

Detecting the risk sources are important for management, for knowing what to handle. Managing all the risk in a project is though usually hard, especially in complicated projects like construction projects. Focusing the effort to the risks with the highest impact is therefore usually preferable. According to the result in figure 10 it is shown that there are a few risk sources in the case project that basically influence the variance of the total construction cost. Therefore it could be a good idea to focus on managing these risks with priority.

7.2.1 Risk analysis

Important information about the model is the capture of the risks in the costs; this is done through the Monte Carlo simulation. The fuzzy density graphs illustrates how much from the expected value the different outcomes are, this can be used for the firm's risk management teams as information in their decision making (Mikes, 2011). Out of this information the management team can decide for each risk how they should handle it.

For construction projects of drying facilities several different methods to handle the risks connected to the project could be use, they are; i) avoid, which simply means not taking a risky contract ii) avoiding it, implies changing something in the project which implies that the risk is lowered or avoided. iii) hedging for the risk, which could mean contracting the risk to another partner or asking a such a high price that one is covered even if the bad risk falls out iv) Accepting the risk would mean that the firm did not do anything else then keeping supervision of the risk and being prepared to take an eventual bad outcome.

When deciding the strategy it is important to remember that increased risks bearing usually increase the profitability. Contracting risk away often becomes costly with judicial expenses as result. Therefore it is important to make assessment about the risk and how this impacts the profitability, this to be able to regulate a firm's risk exposure.

Mikes (2011) provide interesting examples of how the total risk exposure for a firm can be assessed to see the total impact of a risk falling out. The methods that are used by the case firms in Mikes (2011) are scenario analysis and Monte Carlo simulations. These methods could be used also for evaluating the risks in construction projects for deciding if a company should carry a risk or not and can be examined through the model.

As previously mentioned it is shown that there are three components that are equipped with the highest risk, conveyors, walls and the building's roof. There are obviously a number of different methods to handle the risk of the construction work and which way that the best is still unclear. Most likely it is a combination of them that is the most effective.

The construction type of drying plants differs between different regions in the world, however, the construction type in the Nordic countries follow the same appearance. To give an example, in the UK a typical drying facility is equipped with the same components as the type that is used in the Nordics. But in UK the plants are delivered without the outer shell, i.e. without walls and roof, why this type of building solution not is feasible in Sweden is for the authors not clear. But it may be of great advantage to avoid a great part of the risk in the construction while it in the same way fills almost the same function.

7.2.2 Contracting

Except for risk management the model is believed to have its biggest application area in contracting. Nasirzadeh et al (2014) clearly points at the importance of knowing the risks for writing good contacts. An uncertainty that cannot be measured are hard to specify in a contractual form and therefore increases the risk for the parties in the contract. Before this study the risks characters in building a grain drying facilities were not quantified. The results of this study will contribute by informing about them and enable a better allocation of risk responsibilities. An example of this is that from the knowledge of how much of the risk that is depending on the electrician's it should be possible to contract the responsibility for these risks to the electrical firm. Thereby their initiative to reduce the impact of the risk will increase. In other words the information enables for a bigger accountability for the electrician company. This is a well-known phenomenon in literature (Catasús *et al.,* 2007). Splitting the turnkey contracts like this might help reducing the costs of constructing grain drying facilities and reduce the risk premiums in the market.

7.3 Market for grain drying facilities

As the study earlier has shown there are large variations in the cost structure related to construction process of a drying facility. The study aims to determine the degree of economic risk and the importance of the activities that affect the overall risk. The result present which activities that can vary greatly. This information is good to know both for the supplier and the customer of drying facilities. To give an example, it may be easier for the local framer to bear the risk of groundwork than that the supplier is responsible for this. If all the stakeholders are aware of which risk that is associated with the construction work we think that the grain dryer market will work in a better way. This is because each actor which in the best way is able to handle the risk will do so. This lead to a reduction of prices on drying facilities when exclude that any actor will take a good economic space for the uncertainty as a turnkey facility installation generates.

7.4 Improvements of the model

Even if the most interesting information that the model provides is the fuzzy possibility density function of the total construction cost, the model will also provide other useful information. This information can be valuable for managers of the construction projects. The interesting information can of course differ depending on the circumstances characterizing different projects. The model is though adoptable to a large extent for providing lots of information.

One thing that was requested from the practitioners was an efficiency factor for taking into account that assembling personnel sometimes are less experienced and that different assembling teams therefore need different amount of times for assembling. This type of function would be quiet easy to introduce in the model but it is not used in the study since this parameter is not examined. It could be something to improve the model with later.

7.4.1 Calendar connection

Another way by which one may improve the model is by linking it to a Gantt schedule in which the different phases can be visualized. With this kind of improvement, it could be easier for the management team to conclude when the different resources are actually needed over time. This extension is unfortunately out of the scope of the study. It should however not be too complex for managers to calculate it using the information given in the model.

It can be approximated through divide the assembling time needed with the hours done on a working day and then compared with the working days in a calendar. This requires that it is assumed to assembling time is assumed to be the tight sector for proceeding the project. This can be argued to be a good approximation since assembling times is the activity that has the largest time consumption and is involved in almost every moment of the building.

7.4.2 Application to other projects

As previously stated the theories are picked form earlier research about other types of construction projects. This implies that the theoretical framework is not unique for construction of grain drying facilities. Furthermore it is believed that a similar approach could be used for calculations on other similar types of construction projects. It has not been tested in this study, but the approach can possibly be used also for other types of construction projects if the information needed could be gathered.

The immediate application area that we consider is other types of farm buildings such as cow stables, machine halls, stables and barns. We have not concluded that the problem of unique projects consider also these projects, but then a similar approach to is needed. If it is the case, these building projects could also be divided into components and the simulation model could be used for calculating the likely cost of assembling. However there would be a need of a new data assembling.

7.5 Future research

The fuzzy possibility density function for the construction cost indicates that the building of a grain drying facility is a risky business. The fuzzy standard deviation is not remarkably high but the results are uncertain and the correlations are not known. This means that knowledge about the actual amounts of times required is lacking. To increase the reliability of the data, we suggest a study to measure the time expenditures in the building process to create a probability interval instead of the fuzzy possibility interval. If many construction projects are examined the correlations could also be examined to reduce the uncertainty.

As usual with drying facilities, the most part of what one may observe is plant-specific. It follows that it become hard to gather information about the different cost of the facility. The relevance of this issue has been stressed in our previous discussions. This is of course making the investigation harder to perform but it also points out how necessary it is having an investigation in the area. This thesis might not solve the whole problem by providing the proper tool for calculating the risks of building a grain drying facility but it may provide an instrument that if used may improve the management and planning of these specific construction projects.

8 Conclusions

The chapter conclusions intend to explain and answer on the basis of the following research questions, i) which approach should be taken in order to correctly assess the economic risk characterizing the construction of a grain drying facility, ii) how may fuzzy theory be used in order to evaluate the impact of uncertainty in the assessment of construction costs?

The study has resulted in a calculation model for fuzzy possibility density functions which can be used to assess the economic risks related to construction process of grain drying facilities. The fuzzy possibility density function is calculated through a Monte Carlo simulation where the model is based on earlier literature and adapted to the practical case of grain drying facilities.

The model assumes dividing the project into different components and identifies the different cost drivers in the assembling of each component. As a result of the lack of historical data from previous installations the model are based on expert opinions received through fuzzy theory. It is found to be a suitable technique to gather information about construction projects that can be used in calculations. Furthermore the model is believed to compile the information available and create an assessing tool for designers of the facilities.

The reliability relating the model´s risk assessment is still uncertain as they are based on subjective answers by the respondent’s interviews. As an example the impact of an error in assuming none correlations between the input resources could imply an increase in the risk by 100%. However the model provides a solid base for further calculations and we believe it will play an important role as computation tool for future construction processes.

Writing efficient contracts between shareholders in construction projects can improve risk sharing. Though all actors have good knowledge of where the major risks are concentrated; these risks can be handled in a better way and improve the efficiency of both individual projects and for the whole market of grain drying facilities. In order to increase the model´s reliability measurements and data collection for time consumption on a component level are suggested. Perhaps this could be carried out in future research.

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Personal messages

Martin Thorsson
Marketing manager of Akron
Personal meeting, 2015-01-22, 2015-03-09

Appendix 1: Questionnaire for assembling firm

Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Intuitionen för ekonomi

2015-04-01

Enkät med monteringstider för torkanläggningar

Enkäten är utformad för att undersöka montagetider vid byggnation av torkanläggningar. Formuläret utgör den huvudsakliga datainsamlingen i vår masteruppsats, vilken syftar till att redogöra för de ekonomiska riskerna med monteringen av en torkanläggning.

Vänligen komplettera de bifogade formulären med den tid Ni uppskattar är korrekt för respektive aktivitet. Minimum- och maximumvärdet ska definieras som det intervall inom vilket ni finner det troligt att en aktivitet tar i antalet timmar. ”Mest troligt” är den tid som ni tror att aktiviteten tar i anspråk de flest gånger den utförs, dvs. ”median värdet”.

Tack för ert deltagande!

Med vänliga hälsningar.

Marcus Furusköld & Anton Eriksson

Studenter på Ekonomiagronomprogrammet

Montertingstider

I den här delen ska monteringstider i antalet timmar fyllas i för varje aktivitet. Svaren för respektive aktivitet består av tre tider, minimum, mest troligt och maximum. Respondenten ombeds även avgöra om en skylift är nödvändig för montaget eller inte. Antag i övrigt att montören har full tillgång till alla nödvändiga verktyg.

		Monteringstider (h)			Behövs skylift?
Aktivitet	**Enhet**	**Minimum**	**Mest troligt**	**Maximum**	**Yes**
Inventarier					
Trasportörer och elevatorer	st				
Tork typ 1 ”Akron Satstork"	st				
Tork typ 2 ”Akron Satstork"	st				
Tork typ 3 "Svegma Satstork"	st				
Tork typ 4 "Svegma kontinuerlig"	st				
Spannmålfickor med konbotten 3,0 x 6,0m, volym 120m³	st				
Utlastningsficka, 3,0 x 4,5m, volym 69m³	st				
Luftningsficka/golvsveperplåt	st				
Tippgrop 3,0 x 4,0m, 18m³	st				
Trappor	st				
Byggnadsskal					
Takstolar	per anläggning				
Väggplåt	m²				
Väggpelare	per anläggning				

Tid för kranbil

I den här delen ska tider för kranarbete i antalet timmar fyllas i för varje aktivitet. Svaren för respektive aktivitet består av tre tider, minimum, mest troligt och maximum. Antag i övrigt att kranchauffören har full tillgång till allt nödvändigt material.

Aktivitet	Enhet	Krantider (h)		
		Minimum	Mest troligt	Maximum
Inventarier				
Trasportörer och elevatorer	st			
Tork typ 1 ”Akron Satstork"	st			
Tork typ 2 ”Akron Satstork"	st			
Tork typ 3 "Svegma Satstork"	st			
Tork typ 4 "Svegma kontinuerlig"	st			
Spannmålfickor med konbotten 3,0 x 6,0m, volym 120m³	st			
Utlastningsficka, 3,0 x 4,5m, volym 69m³	st			
Luftningsficka/golvsveperplåt	st			
Tippgrop 3,0 x 4,0m, 18m³	st			
Trappor	st			
Byggnadsskal				
Takstolar	per anläggning			
Väggplåt	m²			
Väggpelare	per anläggning			

Appendix 2: Questionnaire for electrical firm

Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Intuitionen för ekonomi

2015-04-01

Enkät med monteringstider för torkanläggningar

Enkäten är utformad för att undersöka montagetider vid byggnation av torkanläggningar. Formuläret utgör den huvudsakliga datainsamlingen i vår masteruppsats, vilken syftar till att redogöra för de ekonomiska riskerna med monteringen av en torkanläggning.

Vänligen komplettera de bifogade formulären med den tid Ni uppskattar är korrekt för respektive aktivitet. Minimum- och maximumvärdet ska definieras som det intervall inom vilket ni finner det troligt att en aktivitet tar i antalet timmar. ”Mest troligt” är den tid som ni tror att aktiviteten tar i anspråk de flest gånger den utförs, dvs. ”median värdet”.

Tack för ert deltagande!

Med vänliga hälsningar.

Marcus Furusköld & Anton Eriksson

Studenter på Ekonomiagronomprogrammet

SLU, Box 7070, SE-750 07 Uppsala, Sweden
Org.nr 202100-2817
www.slu.se
tel: +46 (0)18-67 10 00
info@slu.se

Tider för elektriker

I den här delen ska tider för elektrikerarbete i antalet timmar fyllas i för varje aktivitet. Svaren för respektive aktivitet består av tre tider, minimum, mest troligt och maximum. Anta i övrigt att hantverkaren har full tillgång till alla nödvändiga verktyg. Exkludera energikälla till torkanläggningen (panna).

		Elektrikertider (h)		
Aktivitet	**Enhet**	**Minimum**	**Mest troligt**	**Maximum**
Inventarier				
Transportörer och elevatorer	st			
Tork typ 1 ”Akron Satstork"	st			
Tork typ 2 ”Akron kontinuerlig"	st			
Tork typ 3 "Svegma Satstork"	st			
Tork typ 4 "Svegma kontinuerlig"	st			
Spannmålfickor med konbotten 3,0 x 6,0m, volym 120m³	st			
Utlastningsficka, 3,0 x 4,5m, volym 69m³	st			
Luftningsficka/golvsveperplåt	st			
Tippgrop 3,0 x 4,0m, 18m³	st			
Trappor	st			
Lysen och övrig elinstallation	per anläggning			

Appendix 3: Questionnaire for concrete firm

Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Intuitionen för ekonomi

2015-04-01

Enkät med monteringstider för torkanläggningar

Enkäten är utformad för att undersöka montagetider vid byggnation av torkanläggningar. Formuläret utgör den huvudsakliga datainsamlingen i vår masteruppsats, vilken syftar till att redogöra för de ekonomiska riskerna med monteringen av en torkanläggning.

Vänligen komplettera de bifogade formulären med den tid Ni uppskattar är korrekt för respektive aktivitet. Minimum- och maximumvärdet ska definieras som det intervall inom vilket ni finner det troligt att en aktivitet tar i antalet timmar. ”Mest troligt” är den tid som ni tror att aktiviteten tar i anspråk de flest gånger den utförs, dvs. ”median värdet”.

Tack för ert deltagande!

Med vänliga hälsningar.

Marcus Furusköld & Anton Eriksson

Studenter på Ekonomiagronomprogrammet

SLU, Box 7070, SE-750 07 Uppsala, Sweden
Org.nr 202100-2817
www.slu.se
tel: +46 (0)18-67 10 00
info@slu.se

Tider för gjutning & grundarbete

I den här delen ska tider för gjutning och grundarbete i antalet timmar fyllas i för varje aktivitet. Svaren för respektive aktivitet består av tre tider, minimum, mest troligt och maximum. Anta i övrigt att hantverkaren har full tillgång till alla nödvändiga verktyg och utrusning. Med bottenplatta enkel menas en standardiserad körbar betongplatta utan specifika element för en torkanläggning.

		Monteringstider (h)			Grävmaskinstider (h)		
Aktivitet	**Enhet**	**Minimum**	**Mest troligt**	**Maximum**	**Minimum**	**Mest troligt**	**Maximum**
Bottenplatta							
Markarbete	m^2						
Bottenplatta (Enkel)	m^3 betong						
Tippgrop	per st						
Belastningspunkter	per st						