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EVALUATING ELEVATOR LANDING DOOR FIRE TESTING SERVICES

The subject of this Thesis has been confirmed by the Departmental Council of the Department of Industrial Management on 4th of September 2013.

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ABSTRACT

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Elevator landing doors are fire tested to measure their fire resistance. The objective of this master's thesis was to create a method to evaluate the fire tests and the organizations that provide these testing services. The main focus area was in creating accurate evaluation criteria and weighting the criteria.

The thesis was formed by first presenting the reader with the literature review of the closest related theories. The theories which were chosen were systematic decision making, supplier selection, and make or buy and outsourcing theories. In the empirical section the created process of evaluating fire testing is presented, with analysis of the current situation of fire testing processes and evaluation methods.

Evaluating fire testing services required two types of criteria to be formed, technical criteria to evaluate the technical requirements, and service criteria to evaluate the organization which was offering the testing service. These criteria formed the core for the evaluation process which consisted of five different phases that were developed based on the literature review. The process was tested to create best practices and to make improvement proposals accordingly.

Systematical process for evaluating fire testing helps to recognize the most important technical and service related aspects. The created criteria can be also used in future to benchmark and monitor the situation of fire testing. The results of the process can be used when deciding whether to outsource the service or to keep it in-house.

TIIVISTELMÄ

Tekijä: Eetu Kulo

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Hakusanat: hissi, tasonovi, palotestaus, arviointi, kriteerit

Hissin tasonovet palo testataan, jotta niiden palonkesto voidaan määritellä. Tämän diplomityön tavoitteena oli luoda arviointimenetelmä palotestaukselle ja palotestausta tarjoaville organisaatioille. Keskeisin tavoite oli luoda arvioitikriteeristö sekä painottaa kehitetyt kriteerit.

Työn alussa esitetään lukijalle kirjallisuuskatsaus lähimmin työn aiheeseen liittyvistä teorioista. Valitut teoriat olivat systemaattinen päätöksenteko, toimittajan valinta sekä teoriat ulkoistamisesta ja tee-tai-osta päätöksestä. Tutkimusosuudessa esitellään kehitetty palotestauksen arviointiprosessi, sekä analyysit palotestauksen prosesseista ja arviointi menetelmien nykytilasta.

Palotestauspalveluiden arvioinnissa tarvittiin kahden tyyppisiä kriteereitä, tekniset-kriteerit, joilla arvioitiin palotestauksen tekniset vaatimukset, sekä palvelu-kriteerit, joilla arvioitiin organisaatiota, jotka tarjosivat testauspalveluita. Nämä kriteerit muodostivat arviointiprosessin ydin alueen. Prosessi koostui viidestä eri kohdasta, jotka kehitettiin kirjallisuuden teorioiden pohjalta. Prosessi testattiin, jotta saatiin selville parhaat toimintatavat sekä voitiin tutkia mahdolliset parannusehdotukset.

Systemaattinen arviointiprosessi palotestaukselle auttaa tunnistamaan tärkeimmät tekniset - ja palveluosa-alueet. Luotuja kriteereitä voidaan myös käyttää palotestauksen arviointiin ja valvontaan. Prosessin tuloksia voidaan myös käyttää, kun mietitään palotestauspalvelun ulkoistamista.

ACKNOWLEDGEMENTS

This thesis has taught me a lot about the technical questions of elevator doors, but also about the relations between different organizations and how matters are handled in business life compared to what I have learned from my studies so far. Choosing the right contact person is critical for a successful relationship, and personal relations affect how easy the relationship is to uphold, even in large organizations.

I would like to thank KONE for giving me this opportunity to write my master's thesis on this interesting subject. Special thanks go to my instructor, Senior Expert Harri Anttila, for his invaluable knowledge on the matters of fire testing, and for his motivation to help me on this thesis. I would also like to thank my examiners, Professor Tuomo Kässi and Associate Professor Kalle Elfvengren, for their academic advices, and also all my colleagues at KONE for providing a positive working atmosphere.

Eetu Kulo

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1 INTRODUCTION

In the world today, there are a lot of possibilities to choose from. It does not matter what you are about to do, you always have to make a choice between different alternatives. Normally people make those decisions based on intuition or desire, and rarely on an objective scale. This does not matter too much if the decision is minor, the risk of wrong decision will be minimal, or the consequences will not be dramatic. Unfortunately, this is almost never the case in business life.

How can one decide then? You must first know your current situation and what the background is, and most importantly evaluate the different alternatives objectively. In evaluation, it all comes down to the criteria which rank the alternatives and ultimately point out the best decision. This way the important decisions in business life are based on many weighted factors of systematic decision making rather than on the intuition of a few people.

1.1 Background

Safety is one of the main elements in elevator industry that has to be controlled and supervised by companies themselves and governmental bodies as well. These safety features are tested and inspected on a regular basis to ensure sufficient quality of products. The central guidelines for safety measures come from general and product specific standards which are put together by many different standards organizations. These standards give guidelines on how to test, measure, and certify elevator products.

When it comes to buildings with several floors fire safety is one critical issue to consider. Buildings are divided into compartments to prevent fire from spreading in case of an accident. This leaves one major flaw in the design of modern buildings – the elevator shaft. In case of fire the shaft functions as a chimney. This means fire could spread into every floor in a building through the shaft if not prevented. Basically the only way to prevent this is with fire rated elevator landing doors which will block fire from entering the shaft in the first place. Elevator landing doors are required with different fire classes based on different standards which are country and site specific. The most commonly used elevator landing door fire safety standards world-wide are EN81-58, BS476, UL10b and IMO MSC61. These standards specify different methods for testing and assessing the results, and they will be explained later in this thesis.

KONE is now reviewing and possibly optimizing its landing door fire testing and certification process. This is due to changes in KONE's current door offering which is undergoing changes. These changes present a good opportunity to review KONE's existing methods of fire testing and to revise its evaluation methods for new fire testing candidates. However, such systematic evaluation or benchmarking methods have not been used which is the key reason behind this thesis. By evaluating the current situation KONE Doors Category Team can spot the problems and benefits of the current model and seek improvements or completely new methods based on the observations.

1.2 Objectives and scope

The main research question of this thesis is: *How to evaluate and choose the conducting method for elevator landing door fire testing services.* This can be divided further into three tasks:

1. Describe and analyze the current way of fire testing elevator doors including criteria to evaluate fire tests.
2. Form criteria to evaluate testing services.
3. Make or buy decision based on criteria of task 2.

In addition, different processes are visualized for new product design and existing products, and how fire testing affects these processes. The newly designed method for conducting fire tests will be also put into practice by creating Excel based evaluation forms and AHP-model. This will be done on a small scale and the focus will be on creating best practices for reaching new candidates and evaluating them, and providing the improvement proposals based on these observations. KONE has its own sourcing policy and strategy which is why this thesis focuses on deciding the criteria, and choosing and using the evaluation tools.

The focus will be on elevator landing door fire testing and certifying processes. The fire resistance of car doors are not taken into account as it is not required to test them in terms of fire safety specified in standards. Also, building doors are not discussed in this thesis as they follow the norm EN 1634-1 which differs from norm EN 1363-1 which is also used in elevators. The landing door fire safety standard in question will be EN81-58.

This study provides figurative evaluation information as to show the principle how the evaluation process functions. Also, make or buy decision and outsourcing suggestions are presented as a guideline to support KONE's own sourcing strategy and processes.

1.3 Methods

The literature section of this thesis is to provide an understanding of systematic decision making and which issues should be considered when making an objective decision. In addition, supplier selection and make or buy decisions are studied as well to seek known methodology and what are the reasons for outsourcing. A study of current norms was made to learn about the issues that affect building safety and how elevators are connected to it, especially in terms of fire safety. Also, how authorities are supervising fire testing and what is the process behind certifying a landing door.

The empirical section is based on interviews of KONE key people in door R&D and the available material on KONE's product data management system. The evaluation criteria were created based on KONE tacit knowledge and literature examples. The technical and service evaluation process was formed based on literature, and the unique aspects of fire testing. The created process was then a combination of analyzed theory frameworks and empirical findings. The process was used to find out the best practices for following the process and to find ways to improve it further.

1.4 Structure of the report

The structure in this thesis follows figure 1 presented below. The image presents the structure by first describing the inputs of each chapter in this paper and then shows what the output is.

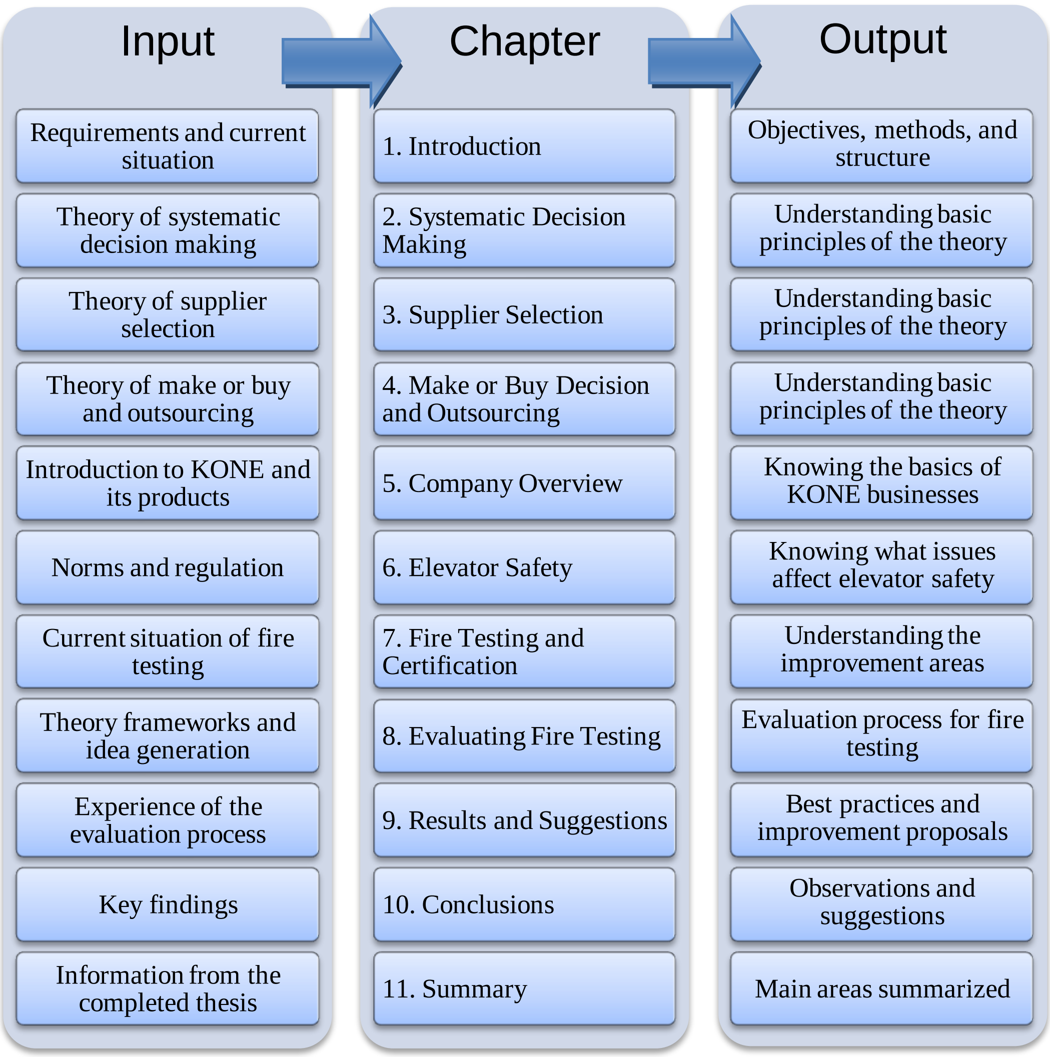

Figure 1. Structure of the report

Chapter one describes the target and scope of the thesis to give a general idea what is included in this thesis. Chapters two to four represent the literature review of this thesis. These chapters are presented next to provide an understanding of the closest related theories, which are later on used as a basis for the findings. Next is the case section of the thesis which starts with the company overview and then followed by the rest of the empirical sections of fire safety and fire testing.

The created fire testing process is presented in chapter eight which is followed by results and suggestions. In the final two chapters, conclusion and summary, the key findings of this thesis are presented and the paper is summarized.

2 SYSTEMATIC DECISION MAKING

Stanovich and West (2000) argue that there are two different kinds of decision making types, or as they call them, systems: System 1 decisions are highly personalized or social, intuitive, and context dependent. System 2 decisions are controlled, rational, analytic, and more decontextual and depersonalized. (Stanovich and West, 2000) The most accurate way of making unbiased decisions is through a logical and rational process which provides rationale for the decisions (Saaty, 2008; Baker et al., 2001).

People often think that when making decisions the more we know the better the result is going to be. According to Saaty (2008), who introduced the Analytic Hierarchy Process in 1977 (Saaty, 1977), this is almost completely wrong way of looking at decision making. Too much information is as harmful as too little information. The essentials of systematic decision making is to make sure one knows the problem in question, the purpose of the decision and what are the criteria, and also, who are affected by the decision. (Saaty, 2008) Moreover, a decision making process is important to stay on track and to keep the decision making systematic, clear and transparent to all parties involved (Baker et al., 2001)

2.1 Decision making process

Decisions are a way to achieve goals and requirements which are based on previous understanding and a set of possible alternatives. There are many different approaches to decision-making and many different processes which are often chosen based on the problem at hand due to the fact that different decision theories may provide different results. (Hussien, 2012; Wang and Ruhe, 2007)

Hussien (2012) presents many different approaches from previous theories starting from Bross's theory of 1953. All these approaches have various steps and they have a lot in common even though they are different. These previous decision process frameworks have three main phases: definition or identification, planning or evaluation, and choosing or selection phase. (Hussien, 2012)

One of the latest process models, presented also by Hussien (2012), is the one created by Baker et al. (2001). Baker et al. (2001) divide decision making into an eight-step process that will guide the way to a clear, transparent and understandable decision. A determined process should be followed when a decision has several objectives, multiple decision makers, or can be subject to external factors. (Baker et al., 2001)

The process described by Baker et al. (2001) follows the structure presented in figure 2. The eight steps include definition of the problem and its requirements, establishing goals to solve the problem, identifying alternatives, creating evaluation criteria, selecting a decision tool and further selecting the preferred alternative, and finally evaluating the end result. Before starting this process the decision group must be selected in order to reduce confusion. Moreover, consultants and experts should be used during the process to provide understanding in the different steps and provide validity to the decision. (Baker et al., 2001)

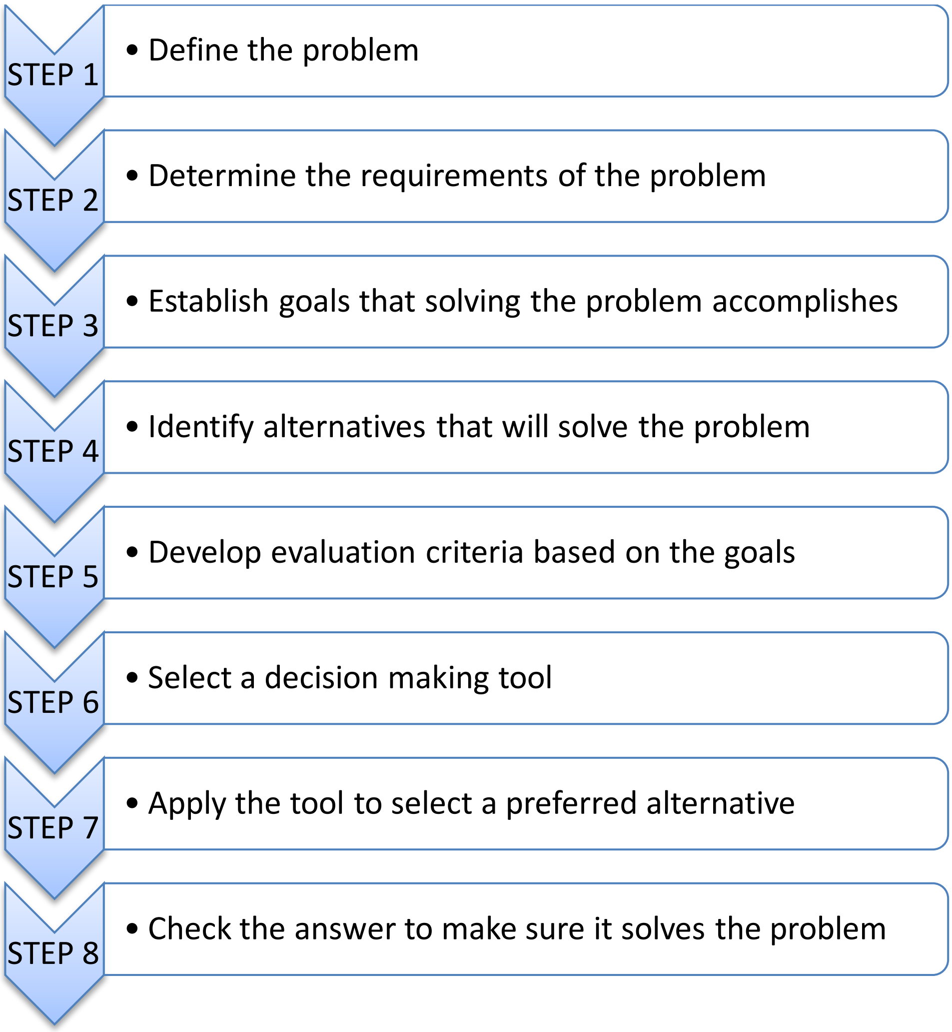

Figure 2. General decision-making process (Baker et al., 2001)

In the definition step, the problem is described in one sentence. The sentence functions as a problem statement which should be as clear as possible. The sentence is formed by questioning the problem in various ways, and all of the questions should be answered. (Baker et al., 2001)

Step 2 means determining the must have criteria of the solution. If solutions are found that have potential but do not fulfill these criteria, they are dropped out. (Baker et al., 2001)

In step 3 goals are formed. Goals go beyond the must have requirements of the solution and they should be described in a positive manner to help evaluating the criteria later on. If the goals are positive it is easier to spot superior alternatives. If the goals are defined properly it can help defining the criteria later on. (Baker et al., 2001)

Step 4 describes the identification of the alternatives. Alternatives are formed by the decision team based on the problem description and formerly set goals and requirements. If an alternative does not meet the set requirements it is normally discarded. The alternatives should differ from each other and provide a solution to the problem. (Baker et al., 2001)

In step 5 the decision criteria are formed based on the set goals and requirements. According to Baker et al. (2001) the criteria should measure something important, differ from each other and only be a few in number. Also, different idea generation methods can be used to determine the criteria such as brainstorming, round robin, reverse direction method, etcetera. (Baker et al., 2001)

Step 6 focuses on selecting the decision making tool which is used to analyze and used as a base to decide the best alternative. There are several options for decision making tools, for example pros and cons analysis, cost benefit analysis (CBA) and analytic hierarchy process (AHP). The methods should be chosen based on the complexity of the problem at hand and the previous experience of the decision making group. (Baker et al., 2001)

In step 7 the tool decided in step 6 is used to evaluate and select the best alternative. Different tools can be used to analyze the result such as sensitivity and uncertainty analysis. Better understanding of the decision method used gives better understanding of the result. (Baker et al., 2001)

The final step 8 is for validating the solution in terms of the problem statement. The final solution should be checked against the goals and requirements that it clearly fulfills them. When the solution is validated the support team of experts and consultants can present it to the decision team with final thoughts, recommendations and conclusions. (Baker et al., 2001)

2.2 Introduction to analytic hierarchy process

Decision making involves many criteria, subcriteria, and also a higher goal. The criteria and subcriteria can be tangible or intangible and have no way of measuring them or evaluating them in specific numbers, for example services. One needs to create priorities for the alternative criteria and subcriteria in order to form a hierarchy between them, but the higher goal must not be forgotten. But how to evaluate and weigh something that cannot be measured? Now comes in to play the relative priorities in decision making. (Saaty, 2008)

Saaty (2008) has created four steps to successfully perform the analytic hierarchy process method:

1. Define the problem and determine what kind of knowledge is to be found.
2. Structure the decision hierarchy with the goal at the top and the criteria and subcriteria forming the next steps, and alternatives usually at the lowest level.
3. Construct pair wise comparison matrices. Each element in an upper level is to compare the elements in the level below with respect to it.
4. Use the priorities obtained from the comparisons to weigh the priorities in the level immediately below for every element. For each element in the level below add its weighed values and obtain its overall priority. Continue until the priorities of the alternatives in the bottom most level are obtained. (Saaty, 2008)

Saaty (2008) has presented an example decision which can be seen in figure 3. There are four alternatives in the bottom level which are being evaluated. The main goal is at the top, which in this case is selecting the best job. The main criteria are in the second level and the subcriteria are at the next lower level. (Saaty, 2008)

In this example of Saaty (2008) there will be 12 pair wise comparison matrices in total. One matrix for the criteria in respect to the goal, two for the subcriteria; one for flexibility, one for opportunity. Nine matrices will be created to compare the four alternatives with respect to all of the covering criteria which are flexibility of location, time and work, entrepreneurial, salary and top level position opportunity, security, reputation and salary. The matrices are presented by Saaty (1994; 2008) and Saaty and Vargas (2012)

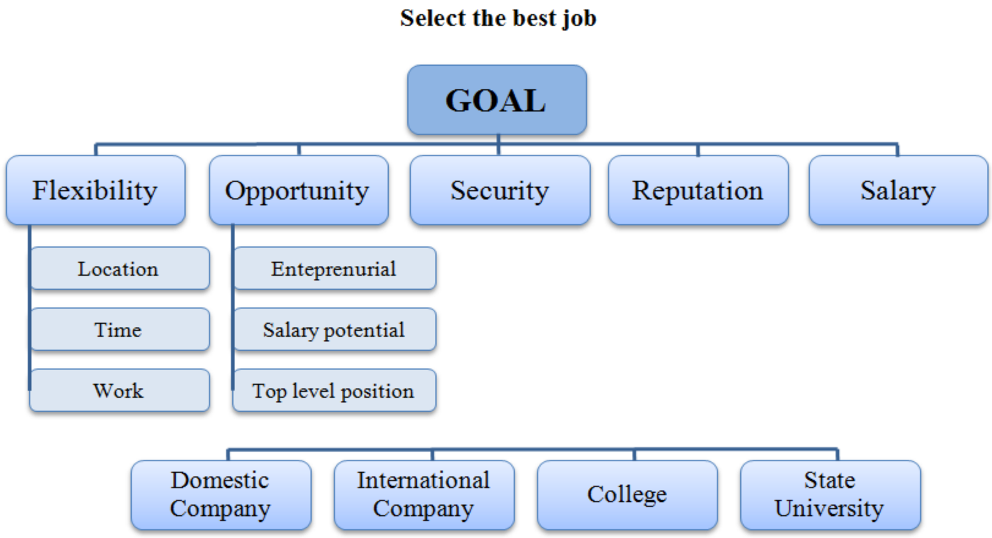

Figure 3. Example of analytic hierarchy process (Saaty, 2008)

Even if the pair wise comparison is a working tool for supporting complex decisions it has some drawbacks as well. Saaty (1990) describes one of the critical flaws as the eigenvalue problem, which is better known as rank reversal (Saaty, 1990; Jan et al., 2011) Rank reversal might occur when adding or removing alternatives from an AHP model (Saaty, 1990; Triantaphyllou, 2001; Jan et al., 2011). This is due to the result of pair wise comparison from 1 to 9. The criteria and subriteria are compared to each other and then to everything else. When there are no measureable units to rank the criteria or the alternatives easily become inconsistent. The more inconsistent the more the rank reversal becomes a problem (Triantaphyllou, 2001; Jan et al., 2011).

Even though AHP has some problems due to pair wise comparison which leads to rank reversal, and at first it might seem overly complicated, it is still very popular and frequently used tool amongst managers (Ishizaka and Labib, 2009). The reason behind this according to Ishizaka and Labib (2009) is computer aided support software which provides an easy to use graphical interface, additional analyzes, calculates the inconsistency factor automatically and much more. At least in the case of Expert Choice which is one of the first and most well known software to utilize AHP. (Ishizaka and Labib, 2009)

2.3 Weighted-sum multi-objective evaluation

Multi criteria or multi objective matrices are used to find the most optimal solution to a known problem. There are several methods for weighting the criteria in the matrix but the most commonly known method is linearly weighting the criteria. In this example the weights are used to present the relative importance between the different criteria in question. (Athan and Papalambros, 1996) There are some mathematical issues when this approach is used and the different criteria interact with each other (Giannopoulos et al., 2012). However, this issue will not affect the linear model (Athan and Papalambros, 1996).

Weighted multi criteria optimization does not only find one best solution but it can find multiple semi-optimal solutions. This is usually beneficial when talking about supplier selection because when there are many efficient solutions a decision maker is required. When there is a decision maker involved from the start of the process the acceptance of the results is easier in the top management. In addition, when using multiple methods to evaluate the same problem it gives decision makers more flexibility in their final decision. (Wadhwa and Ravindran, 2007)

3 SUPPLIER SELECTION

Supplier selection and evaluation are more and more seen as a strategic matter in organizations. Nowadays, companies desire long-lasting partnerships that benefit both parties rather than raw purchasing activity. (Araz and Ozkarahan, 2007) When supplier evaluation and selection is done correctly it will increase product development capability and quality, reduce time to market and costs, and in this way increase product marketability. (Chen, 2011)

Supplier selection can be considered as a multi criteria decision-making problem. It follows systematic decision making methodology as one must first assess data, follow sequential decision steps, create evaluation criteria and weight them, and also choose the method of evaluation. (Ertay et al., 2011)

Benyoucef et al. (2003) divide supplier selection into two parts: determining the quantity or number of suppliers and the type of relationship with them, the other aspect is the selection of the supplier amongst the different alternatives. (Benyoucef et al., 2003) Kakouris et al. have a different approach and their phase one recommends to assemble a list of criteria and operations, and second phase urges to evaluate each potential supplier to form a final list of candidates from which the final selection is made. (Kakouris et al., 2011)

3.1 Supplier selection methods

Selecting a supplier is a strategic and important decision for a company. It is also a complex decision with multiple criteria involved. The main goal for a successful supplier selection is to find a suitable candidate that provides the most potential based on the selection criteria. (Kahraman et al., 2003; Kakouris et al., 2011) Kakouris et al. (2011) also state that when the decision to choose a supplier is complex, the anticipated buyer-supplier relationship is usually longer as well (Kakouris et al., 2011).

According to Zala and Bhatt (2011) there are three major reasons why contractor selection may go wrong: the criteria are not suitable for the problem at hand, the criteria are weighted wrongly or an inappropriate method is used to rank and select between the different alternatives. (Zala and Bhatt, 2011) However, Kahraman et al. (2003) state that these criteria are not always easy to assemble as they must be formed based on the company's needs and supply and technology strategy, and be applicable to all the suppliers which are being evaluated. (Kahraman el al., 2003)

The evaluation criteria can be qualitative values which makes comparing them difficult. Also, problems arise when the criteria creation phase overlaps with gathering information of the suppliers. The gathering of information may help in providing insight what types of criteria can be found but this type of approach may overburden the people gathering the information. (Kahraman et al., 2003)

Kakouris et al. (2011) demonstrate a five-step process to guide through the complex decision-making process and focusing on the planning and qualifying phase because they are seen as the most critical parts of the supplier selection decision. (Kakouris et al., 2011) This process can be seen in figure 4.

Figure 4. Supplier decision process (Kakouris et al., 2011)

As seen from the previous chapter this follows closely to the systematic decision making method presented by Baker et al. (2001). Kakouris et al. (2011) describe the steps as the following:

- Initiation phase: Identification of need for a service or a product. Extensive internal communication, feasibility analyses of expected benefits and potential risks, and a management scenario.

- Planning phase: Criteria definition for the supplier. At this phase it is critical to know the needs of service or product from the users. The decision criteria can be tangible and intangible, qualitative and quantitative, but it is also a challenge to balance these factors properly.
- Qualification phase: This phase is as equally important as the planning phase. At this stage a larger list of candidates is compared against the created criteria and a shorter list of final alternatives is created. The alternatives are first roughly eliminated with a few must-have criteria. This is more of a sorting action rather than ranking system, and it can be also described as pre-qualification. After rough evaluation a real ranking process will be done.
- Winning phase: After a candidate has passed previous stages it will be evaluated one last time against the other alternatives. Evaluation is based on the key reasons why the product or service is being outsourced / manufactured in the first place. After evaluation the supplier is selected.
- Monitor and review phase: After selection the company must monitor the relationship with the new supplier. This can lead to a flourishing long-term relationship if handled constructively. New requirements or changes can and will arise which will have to be taken care of. Contracts are necessary part of business relationships but they must not be the key reason for the existence of the relationship. (Kakouris et al., 2011)

3.2 Supplier selection criteria

Normally the selection criteria can be divided into four categories: supplier criteria, product performance criteria, service performance criteria and cost criteria. (Kahraman et al., 2003)

By supply criteria Kahraman et al. (2003) mean how well the suppliers match the company’s technology and supply strategy. Supply criteria can be divided further to six sections which aim to measure the supplier’s financial stability, managerial and technical skill, resources, quality systems and location:

- Financial: A supplier should have a solid financial background. This usually means it has done well in the past and continues to deliver in the future as well.
- Managerial: Management approaches should be similar or compatible with the company and its suppliers. Also, maintaining good relationships require good management skills from both parties. The company should have trust in its supplier's way of managing the company and running its business.
- Technical: A competent technical aspect of the suppliers ensures fluent business in the future for both parties as the product and service quality of the company will not suffer.
- Support resource: A supplier's resources need to be adequate to uphold the required level of collaboration. Suppliers should be evaluated in terms of their facilities, IT systems and training possibilities.
- Quality systems and process: A supplier's quality control is one of the key factors to maintain agreed quality of service of products. Selection criteria may consider the supplier's accreditations to quality standards such as ISO 9001.
- Globalization and localization: Some locations may be more favorable than others for the company. There is also some risk involved in some countries' political decisions, financial status and regulatory changes. (Kahraman et al., 2003)

Product performance criteria examine the functionality and usability of the product or service being acquired. The exact criteria can only be defined based on the product or service itself. However, Kahraman et al. (2003) present some of the common pointers which can be found for example from the following areas:

- End use: Functionality, quality, reliability, compatibility, capacity, speed etc.
- Use in manufacturing: Quality, manufacturability, compatibility, testability.
- Other business considerations: Environmental issues, ergonomics, availability of service, stage in technological life cycle, market trends.

When the service or product is not yet developed the criteria must take into account whether the supplier possesses the technological and managerial know how, and resources to develop the service or product. The evaluating company must make sure the quality standards are the same if the supplier comes from international markets. (Kahraman et al., 2003)

Service performance criteria are something that are nearly always case specific as there are only a few established service standards to follow. However, service criteria should always be included when choosing a supplier as there is always some sort of service included. Especially, when purchasing a very technical solution the service evaluation criteria can be easily forgotten. There are a few areas to consider when evaluating service:

- Customer support: Accessibility, timeliness, responsiveness, dependability.
- Customer satisfiers: value-added.
- Follow-up: To keep customer informed, to verify satisfaction.
- Professionalism: Knowledge, accuracy, attitude, reliability. (Kahraman et al., 2003)

Kahraman et al. (2003) define cost criteria as one of the important factors of any relationship. However, it might be difficult to estimate the cost accurately which is why the costs should be reviewed again in the qualification phase. Typically costs are estimated as purchase price, transportation cost and taxes. Sometimes, even operational expenses can be taken into account, although they require more effort to evaluate. (Kahraman et al., 2003)

Kakouris et al. (2011) emphasize the planning and qualifying phases and provide an in-depth description of both phases. The qualification criteria have changed throughout the years and they are very industry specific. However, there are some universal guidelines to help forming the right criteria. The evaluation areas of Kakouris et al. (2011) differ somewhat from the areas of Kahrama et al. (2003)

but there are lots of similarities as well. These criteria can be seen in figure 5 as well.

Figure 5. Supplier decision criteria of the planning phase (Kakouris et al., 2011)

Kakouris et al. (2011) state that selecting a supplier means a lot more than just reducing costs but, in some cases, even a strategic long-term relationship. To evaluate the candidates properly the company should consider finding as much information of the alternatives from the following six areas. Even if not all the information can be found, the more the better:

- Process and design capabilities: The company has to make sure the information flow capability between the two parties is at a required minimum level. In addition, the capabilities of the candidate have to be evaluated and the candidate must possess previous know-how and experience from the industry in question.

- Management capability: This requirement is difficult to evaluate but it is one of the key factors. Management relations can make or break the relationship between two partners. Good management emphasizes continuous improvement, cooperation and strengthens relationships - a bad one can do just the opposite.
- Financial considerations: A supplier with a weak financial background presents a risk. It may not have enough liquidity to commit in development efforts or have the resources to hire more personnel or acquire new equipment. The supplier may also have or generate a hidden agenda or in the worst case go out of business. These are some of the potential risks that can be avoided with a financial check.
- Planning and control capability: Planning and control capabilities present the systems of the supplier which are used to plan material, equipment, personnel and capacity needs. These IT systems should be checked beforehand to avoid unpleasant surprises in the supply chain.
- Working relationships: A deeper relationship from both parties can lead to a more rewarding partnership where both parties collaborate and cooperate to improve the processes and goals together. This is not an easy task but when succeeded neither party will want to let go of this arrangement and trust between parties is increased. This is also known as the cliché win-win-situation. (Kakouris et al., 2011)

Chen (2011) has collected the most important individual criteria for evaluating suppliers from literature. These criteria are seen in table 1. The table shows the relative importance from various sources that are presented in Chen’s (2011) article.

Table 1. Important criteria for supplier selection (Chen, 2011)

Evaluation criteria	Dickson ranking	Weber importance
Price	6	Very important
Delivery on time	2	Very important
Quality	1	Extremely important
Equipment and capacity	5	Very important
Geographical location	20	Important
Technical capability	7	Very important
Management and organization	13	Important
Industrial reputation	11	Important
Financial situation	8	Very important
Historical performance	3	Very important
Maintenance service	15	Important
Service attitude	16	Important
Packing ability	18	Important
Production control ability	14	Important
Training ability	22	Important
Procedure legality	9	Very important
Employment relations	19	Important
Communication system	10	Very important
Mutual negotiation	23	Important
Previous image	17	Important
Business relations	12	Important
Previous sales	21	Important
Guarantee and compensations	4	Very important

4 MAKE OR BUY DECISION AND OUTSOURCING

The make or buy decision is a frequently tackled issue by managers who wish to exploit the competencies in a supply chain. Make or buy decisions are set in motion when a company wishes to improve its efficiency or increase the quality of products or services to its customers. These decisions arise in many different activities in companies. (Laios and Moschuris, 1999)

The question of outsourcing is a challenge due to internal processes which have often formed to very specific concepts in the mother company. Managers must not only consider the costs of the sourcing analysis and decision but also a number of other factors including the company's engineering, manufacturing and competences. By outsourcing, some of the company's functions may be moved to external suppliers and some kept in-house or it may be preferred to follow all-or-nothing type of approach in favor of a more flexible outsourcing solution. (Piachaud, 2005) Parmigiani (2007) reminds that when some of a company's activities are both outsourced and made by the company itself at the same time the matter becomes more complex to manage and monitor (Parmigiani, 2007).

Also, Bajec and Jakomin (2010) state that make or buy decisions are not made based only on economic considerations but they are rather strategic as a company may lose some of its core competences if the decision is made lightly (Bajec and Jakomin, 2010). Greaver (1999) insists that there are as many reasons to outsource as there are people or companies to ask from (Greaver, 1999, p. 3) Even if there are some risks involved, outsourcing provides companies with a way to focus on their core competencies and key activities (Bajec and Jakomin, 2010).

4.1 Reasons for outsourcing

Greaver (1999) mentions that there are fundamentally two types of outsourcing, tactical and strategic outsourcing. Tactical outsourcing focuses on short-term outsourcing decisions and strategic outsourcing answers to the need of the company's long-term needs and follows the company's strategy and vision. (Greaver, 1999) From these two approach points Wadhwa and Ravindran (2007) state that strategic outsourcing is focused in finding the company's core competences and outsourcing activities that are not part of them (Wadhwa and Ravindran, 2007).

Reasons for outsourcing can also be divided further into six categories that take into account most of the common reasons behind outsourcing decisions. These categories are organizationally driven, improvement driven, financially driven, revenue driven, cost driven and employee drive decisions. (Greaver, 1999) Vagadia (2012), however, divides outsourcing motives into three types which are financial, strategic and other. These motives are seen in figure 6 as well. (Vagadia, 2012)

Organizationally driven means improving efficiency by focusing on the key activities and what the company does best. To increase flexibility in a changing business environment, meet changing demand or changing technology. (Greaver, 1999) Also, by focusing on the company's core processes and activities the firm can have better leverage from its core competences. (Vagadia, 2012)

Improvement driven reasons include improving operating performance, improving best practices, acquiring expertise, skills and technologies that are not possessed by the company, to improve management and control, and to enhance risk management abilities (Greaver, 1999; Vagadia, 2012). Also, to acquire innovation and to improve credibility and image by associating with superior providers are improvement driven reasons (Greaver, 1999).

Financially driven motives aim to reduce investments in assets and freeing them to other purposes, and to generate cash by transferring assets to a provider. Cost driven differs a little from financial driven motives as these goals are to reduce costs through suppliers lower cost structure and better performance. One reason might also include turning fixed costs into variable costs. (Greaver, 1999) Vagadia

(2012) states that reducing company head count reduces training and recruitment costs. Moreover, companies can benefit from their service provider's economies of scale where the cost savings are eventually passed on to the outsourcer. Also by outsourcing, companies can simply get rid of unwanted or complex processes and functions by making them someone else's problem. (Vagadia, 2012)

Revenue driven intentions include gaining market access and business opportunities by using the provider's established network, and to accelerate expansion through the provider's capacity and processes. In addition, expanding sales and production capacity when it would not normally be possible, or exploiting an existing provider's skills would be considered revenue driven motives. Employees can also be reason for outsourcing. In these cases the aim is to provide employees opportunities on their career path or increase their commitment and energy in non-core areas. (Greaver, 1999)

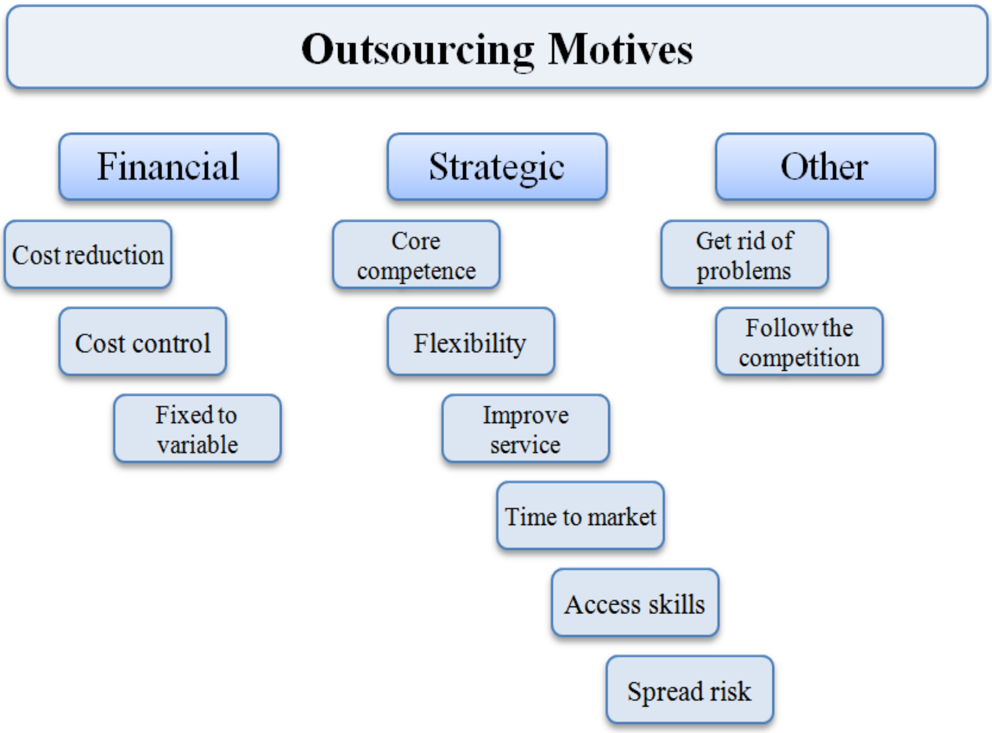

Figure 6. Outsourcing drivers (Vagadia, 2012)

Usually the main motives can be divided into seeking efficiency, effectiveness, or flexibility. While all these are valid motives the outsourcing company must choose its vendors based mainly on one of these motives. Vendors are usually not able to accommodate the outsourcing organization if all of the three motives are asked from them. In addition, key people in change of the outsourcing process are likely to be confused about the motive to outsource. However, without a clear motive the outsourcing is very likely to fail. (Vagadia, 2012)

4.2 Outsourcing risks

The chances of successful outsourcing are normally slim especially if the problem is tackled lightly. Conventionally firms outsource in strict legal terms and contracts, or form a more strategic partnership. (Vagadia, 2012) The risks of outsourcing take various forms and the most common risks are described next.

Loss of core competences, skills and innovation capability can happen when such activities are outsourced that should not be outsourced, or transferring key employees to the outsourcing service. By losing core competences and in this way key people, the company ultimately compromises its ability to innovate. Furthermore, if the competence is transferred to the vendor it might drive the outsourcing company to a hold-up situation where it is in a dependent relationship with the vendor. Even though the company could leave the relationship it has no longer the required competence to find and evaluate new partners. (Vagadia, 2012)

Costs may escalate rapidly in the course of the relationship. At first, the contract looks promising but after some time has passed the inevitable changes could increase the costs of outsourcing considerably. Also, loss of managerial control of the outsourced activities creates a dependency to the vendor. The loss of control might happen as the activity is now handled by someone else and there is no longer direct ownership of the activity. (Vagadia, 2012)

Selection of the supplier presents its own problems as well. If the evaluation and selection phase of the new vendor fails the company may select a wrong or incompatible vendor. Poor legal knowledge can also lead to a poor contract between the parties and confidential information may leak into the wrong hands. Communication may be sometimes difficult and can result in poor organizational communication, cross functional political problems between the parties, or unclear expectations. (Vagadia, 2012)

4.3 Other sourcing models

There are also other types of sourcing than outsourcing. Vagadia (2012) presents the usual four modes of sourcing which are captives, joint ventures, pure outsourcing, and local partnerships. These sourcing models are also presented in table 2. The third and fourth models are more risky than the first two models as they rely purely on a written contract. The most typical model of the four types is the third one, especially in medium and small enterprises. (Vagadia, 2012)

Captives and joint ventures are typically formed by multinational corporations who have enough resources in terms of lawyers and consultants. In this way it is possible to identify, evaluate and minimize most of the risks involved. By sticking with local partnerships firms can simplify legal and managerial relationships as both are working within the same jurisdiction. Vagadia, 2012)

Table 2. Sourcing models (Vagadia, 2012)

Captives	Direct Captive – a firm using its own resources to create, own, manage and control an organization within an offshore destination, often known as captive centers – i.e. offshoring but not outsourcing
Joint Ventures	Joint Venture – a local firm may partner with an offshore entity for shared control of the offshore operation – again offshoring but not necessarily outsourcing
Pure outsourcing	Direct Third Party – firms outsource to a third party service provider located offshore. Control of the working arrangement is governed strictly by the contract terms agreed with the third party service provider – i.e. offshore outsourcing
Local partnerships	Indirect Third Party – an organization may enter into a contract with a domestic outsourcing service provider, who then subcontracts out all, or a part of the work, to an offshore company – essentially the indirect third party may bear some of the risks for a given payment consideration. The outsourcing arrangement, whose objective is to offshore, may be agreed with an onshore outsourcing intermediary

4.4 Outsourcing methodology

Outsourced products and services require different types of assessment in terms of make or buy. For this reason it is difficult to create universal make or buy typologies. (Laios and Moschuris, 1999) However, to assist in this complex decision Bajec and Jakomin (2010) suggest the following four stages should be followed to make a successful make or buy decision:

1. Building incentive for outsourcing. The planning stage.
2. Exploring strategic implications. The evaluation stage.
3. Analyzing costs/performance. The analyzing stage.
4. Selecting providers. The selecting stage. (Bajec and Jakomin, 2010)

However, there are still three more steps to consider after selection: Planning negotiations, planning transition and managing relationship (Bajec and Jakomin, 2010). These seven steps are also very close to the steps that Greaver (1999) suggests:

1. Planning initiatives
2. Exploring strategic implications
3. Analyzing costs/performance
4. Selecting providers
5. Negotiating terms
6. Transitioning resources
7. Managing relationships (Greaver, 1999, p. 17)

Greaver (1999) also states that these steps should be individualized to suit the target organization and situation properly. Moreover, even though these guidelines are described as steps they should run somewhat parallel to each other as:

- The steps can be followed both ways as there will be constant learning, testing and adjustment. If followed as one way gates some of the new information would be lost.
- If the previous steps are not monitored continuously the goal of the project might drift to wrong tracks.
- A parallel approach reduces the lead time of a project as one can move from one step to the next with fewer requirements and come back if necessary. (Greaver, 1999, p. 17)

5 COMPANY OVERVIEW

KONE is one of the global market leaders in elevator and escalator industry. It is providing new elevators, escalators and automatic building door doors as well as solutions for modernization and maintenance. KONE has over 1,000 offices around the world and maintains over 850,000 elevators and escalators globally. Key customers are builders, building owners, facility managers, and developers. (KONE, 2013)

KONE started off as a 10-man machine shop in Finland over 100 years ago in 1908. The name KONE was incorporated in 1910 when Gottfrid Strömberg bought the company. During the first years KONE mainly produced equipment for World War 1, and it was struggling on elevator sales due to stalled construction business. By 1924, KONE was recovering with the economy and selling 100 elevators annually. However, KONE’s parent company, Strömberg, was facing bankruptcy and it was forced to sell KONE to a businessman, Harald Herlin. Almost eighty years later, KONE is still owned by the Herlin-family and the company has grown to a global multi-billion organization with almost 40,000 employees. (KONE, 2013)

Since 2005, KONE’s vision has been: “- to deliver the best people flow experience by developing and delivering solutions that enable people to move smoothly, safely, comfortably and without waiting in buildings in an increasingly urbanizing environment.” (KONE, 2013) KONE has set four strategic targets to achieve and measure its success: customer loyalty, great place to work, profitable growth and best people flow experience. KONE focuses strongly on its customers and emphasizes on its customer processes and striving for better understanding on customer needs. (KONE, 2013)

Currently KONE is present in over 50 countries, has eight production units in main market locations and seven global R&D centers. The corporate office is located in the KONE Building in Espoo and the Head Office is located in the Manor House in Helsinki. KONE global operations can be seen in figure 7.

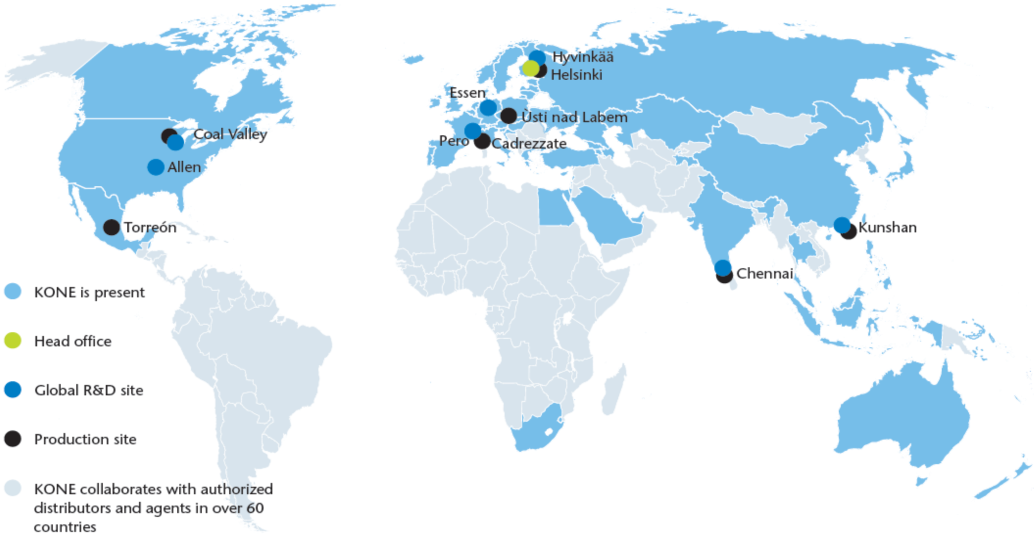

Figure 7. KONE worldwide (KONE, 2013)

KONE is a financially solid company with revenue of 6.3 billion Euros (KONE, 2013). The key financial figures of 2012 can be found in table 3. As seen below, KONE has done grown noticeably although the situation especially in European markets has been tough. The growth is mostly due to the strong economic growth in Asian markets and especially in China as the net sales in China was close to 25 % of total. (KONE, 2013)

Table 3. KONE key financial figures (KONE, 2013)

	Business year 2012 [MEUR]	**Increase/decrease compared to 2011 [%]**
Revenue	6,277	20.1
Operating income	784	8.1
Total assets	5,109	8.1
Share value (6.2.13/OMXH)	62.5 €	45.3

Today, the KONE offers mainly elevator and escalator solutions as new elevator products or service products. Service solutions, SEB (Service Equipment Business), consist of maintenance and modernization. In 2012, new equipment business (NEB) accounted for 50 % of total sales while service was the other half with maintenance 34 % and modernization 16 %. (KONE, 2013)

KONE has a variety of elevator offerings ranging from high commercial buildings to low residential buildings. Most of them are powered by a KONE EcoDisc solution which is the hoisting machine, marked green in Figure 8. It is located in a machine room above or below the elevator, such as in tall buildings, or it can be located in the elevator shaft as in the figure below in a KONE Monospace elevator. KONE has been one of the leading innovators in the elevator business with its EcoDisc hoisting machine, its award winning visual solutions, and the new UltraRope technology.

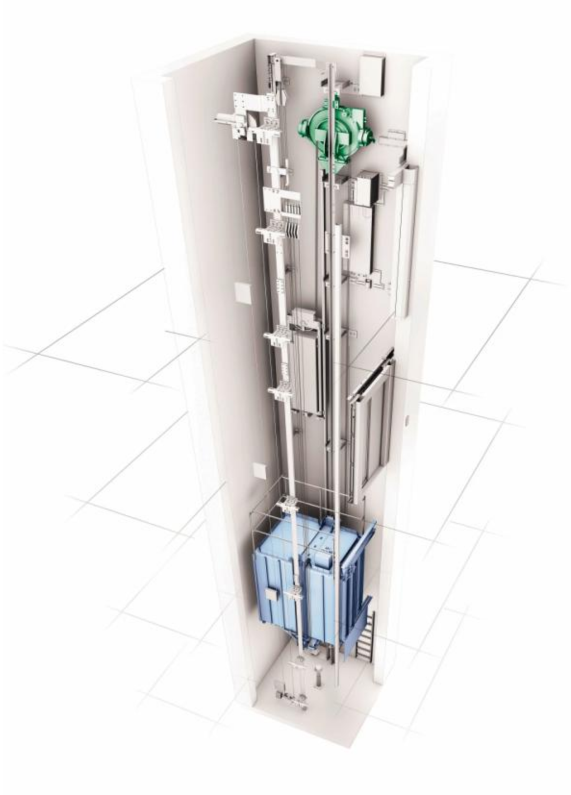

Figure 8. KONE Monospace elevator (KONE, 2013)

All KONE elevators can be divided into 13 different modules. The main modules are hoisting machinery, electrical parts, shaft mechanics, elevator car, and doors. Doors are divided to car doors and landing doors. Basically all the visible parts to end users are landing doors on every landing, the inside of a car, and signalization devices which are used to call the elevator. Doors are the volume products used in elevators, especially landing doors. KONE manufactures its own landing doors as well as uses third party doors in its elevators.

KONE offers new landing door solutions in four different product lines which are all called KES, KONE Entrance System. These product lines are diversified to match different needs of customers in terms of annual duty cycles per elevator. For example, the KES 201 product line offers doors that are suited for 200,000 cycles annually and KES 800, a heavy duty door, is designed to handle 800,000 cycles annually. KONE door product lines for NEB business are KES 100, 201, 600 and 800. Normally the high duty doors are used in hospitals, hotels and other commercial buildings. The lower duty doors are commonly found in small residential buildings that do not have such an intensive usage ratio.

The structure of a KONE elevator landing entrance can be divided into four parts: the frame of the door, door panels, door sill and railing or top track which holds and moves the door panels. These landing door panels are merely hanging from the railing and there is no motor or electricity to monitor or move the door panels. However, simple door contacts are used in the railing to send a signal indicating whether the door is closed or still open. The signal is read by the lift controller which reads the landing door contact and door signal. The system is called a safety chain where all landing entrances and car doors are connected. Elevators may not move if any contact or door is open. This lift controller is located in the machine room, the elevator shaft, or on one of the landings. The landing doors are moved by the car mounted door operator which opens and closes the landing door whenever it stops on a landing, or is required to perform such an action by user pushing a button or by some other means. A typical centre opening landing door is shown in figure 9. The landing door is seen from the shaft side in the image.

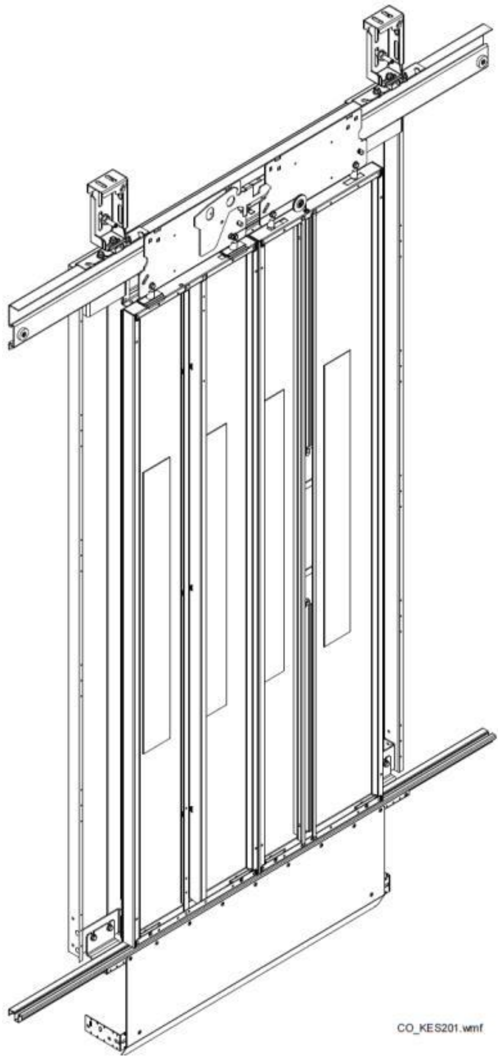

Figure 9. KONE landing door (KONE, 2013)

KONE elevator doors are normally manufactured from steel, stainless steel or glass, or a combination of the above, plus smaller parts are made from various materials. The frame, railing and panel structure are normally made of sheet metal which is bent and welded or glued together. These sheet materials make it easy to implement design changes and are highly customizable. In addition, they provide decent robustness, nice visuals and high resistance to fire.

A normal-sized non-insulated landing door can withstand fire for only a short period of time before its integrity is lost completely and it starts leaking hot gases. This integrity is normally the deciding factor whether a door passes a fire test or not, but there are several other factors to consider as well. If a landing door is insulated and a so called fire-door, then fire wool is placed on the panels to prevent heat radiation entering the shaft side. In addition, special fire labyrinths are used in fire-doors to ensure that hot gases cannot penetrate the structure and enter the shaft side. The construction of landing doors and the purpose of different components is described better in the next chapter.

6 ELEVATOR SAFETY

Elevators are a part of our everyday lives but we seldom think about the ride in terms of safety. Most elevators are built in buildings which have at least three floors which would mean a ten meter drop from top floor to bottom if something went terribly wrong. Some of the highest elevator shafts are several hundred meters long and safety becomes an even more important issue. Moreover, the new UltraRope can further increase the maximum shaft height even to one kilometer.

6.1 Building safety

Building safety in Finland is described by Finnish Ministry of the Environment (2013) in The National Building Code of Finland. It is divided in seven sections which include a general section, structural strength, insulation, emergency management, fire safety, building planning and housing planning, and building. This code contains technical regulations and instructions. The regulations are binding and concern the construction of new buildings, and are also applicable to renovation and alteration works. The instructions are not binding but are stated as acceptable solutions. (Ministry of the Environment, 2013)

Building fire safety, or structural fire safety, is further divided to seven separate parts which consist of regulations and guidelines. Regulations are presented in “E1 Structural fire safety in buildings”, the rest of the fire safety parts are guidelines. E1 defines the fire classifications of building elements and building materials, surfaces of internal walls, ceilings and floors and doors and shutters. It has taken effect on 1 July 2002. (E1 The National Building Code of Finland, 2002)

According to The National Building Code of Finland (2002) “The fire safety requirement is deemed to be satisfied if the building is designed and executed by applying the fire classes and numerical criteria provided by these regulations and guidelines.” (E1 The National Building Code of Finland, 2002) In addition, fire safety can be deemed satisfied if the building elements have been checked with fire scenarios. These scenarios should be in accordance with the testing standards EN (European) and ISO (International), but also national interpretations of these standards may be used if they are enforced by other member states of European Economic Community. The building documentation should then include the description of the fire safety systems and the testing methodology. (E1 The National Building Code of Finland, 2002)

Building elements are required to use pre-described symbols to illustrate their fire resistance. These symbols for elements which are load-bearing or fire-separating are divided to three parts: R for load-bearing capacity, E for integrity and I for insulation. Fire resistance is then expressed in minutes after the letter, for example EI60 type element would hold its integrity and conceal the thermal radiation as well, for 60 minutes. (E1 The National Building Code of Finland, 2002)

6.2 Elevator safety

An elevator consists of many safety devices such as emergency brakes, over speed governor, emergency drive modes and many more but in this thesis the focus is on landing doors. An elevator has two types of doors, landing doors and car doors. A car door is attached to the elevator car and there is usually only one of them required per elevator. Landing doors are located at every floor of the building the elevator stops. The most important feature of a landing door is to prevent people from falling into the elevator shaft. Landing doors are tested with standardized punching and force tests to ensure the safety of the door by demonstrating a person pushing or punching the door from the landing side. Landing doors are tested according the standard EN81-1.

EN81-1 standard “…specifies the safety rules for the construction and installation of permanently installed new electric lifts…” (EN81-1, 1998). The elevators included are traction elevators designed for passenger and goods transportation between defined landing levels. These elevators are also suspended by ropes or chains and they are moving between vertical guide rails. (EN81-1, 1998)

6.3 Elevator fire safety

Most are aware of the basic visible fire suppression methods including sprinklers, fire extinguishers etc. and why they are used. However, not many people remember the passive fire protection that actually keeps the fire in place. Passive fire protection, if correctly maintained, is always at work and can save lives, assets and even the building itself. (Aker, 2008)

Another especially important safety issue for landing doors is their fire resistance. Landing door fire resistance is based on the scenario where fire is burning on a landing and attempting to enter the elevator shaft. This is also how EN81-58 and other fire testing standards describe the testing procedure. Landing doors are not fire tested from the shaft side but only on the landing side. The usual fire tests include integrity and radiation tests. Integrity means that the door must not leak hot gases or CO_2 more that the limits allow and the radiation factor test how much infra-red radiation is emitted from the door entrance as a whole. These fire ratings are mostly the same as in the building safety of fire-separating elements.

Different countries have different safety standards for building fire safety and what requirements elevator landing doors need to fulfill in terms of fire safety. Based on the requirements specified in these standards all new landing door models need to be tested and certified to comply with the terms. There are a few different types of standards for testing landing doors and certifying them which are specified in the country specific fire safety regulations. For example, Finnish building fire safety regulations E1 (2011) specify elevator landing doors to be tested according to standard EN 81-58. Other countries specify these testing methods based on different standards. Here are a few examples of the typical landing door fire testing standards and where they are typically used:

- EN81-58; Standard used in most countries in the area of Europe.
- BS476: part 22; Standard used in Great Britain and its former colonies.
- UL 10B; Standard used in North America.
- IMO MSC 61: part 3; Standard for marine elevators.

6.4 Description of EN81-58

In this thesis the main focus will be on EN81-58 as it is the most common standard in Europe and KONE is now looking for additional service providers for this specific standard. In short, EN81-58 fire standard specifies the testing method for determining the fire resistance of elevator landing doors which may be exposed to a fire from the landing side (EN81-58, 2003).

The EN81-58 norm specifies the testing principle, equipment, conditions and specimen details. Also, how the test should be monitored, what are the testing instruments, what is the testing procedure, and by which criteria the test specimen is ranked and reported. (EN81-58, 2003)

6.5 Critical parts in safety for landing doors

Here are presented the functions of the critical landing door parts that affect elevator safety and also fire safety. The main components are sill, frame, railing, and door panels.

The sill is the base support element of the landing door. The door entrance is fixed to a floor or shaft wall with sill fixing brackets and sill structure. During the elevator lifetime the sill is constantly under dynamic and static forces due to elevator loading and unloading which is why it is important that the sill keeps its rigidity. Between landing door panels and sill there is a running clearance which is allowed to be a maximum of 6 mm with new installations, and after wearing the clearance may be 10 mm. This door bottom running clearance is a potential leakage source during a fire accident, or fire test. The sill itself has no remarkable role in fire testing as it is behind the concrete floor and only a short portion of it faces direct heat. However, solid aluminum sill profiles might melt during two-hour fire tests. The sill structure with attached toe-guard is shown in figure 10. The toe-guard is the metal sheet that prevents the elevator from cutting a passenger's toes off in case of elevator door control failure and the car arrives to floor with its doors open. (Interviews)

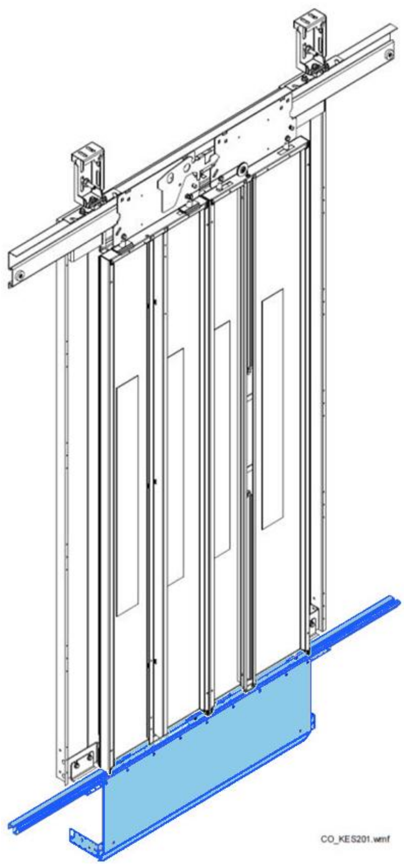

Figure 10. Landing door sill and toe-guard

The frame is the piece that supports the whole entrance. It has the interface to the building wall, which can be concrete, dry line wall, or steel shaft, and with base duty doors it includes signalization which is the device that calls the elevator and shows on which floor it currently is. The frame is the part between door panels and entrance wall and typically it carries the railing mechanism. The frame includes insulation if needed but typically it is non-insulated. It includes two vertical uprights and one horizontal lintel part. All of the frame parts are important in terms of fire integrity. Rigid connection to the wall and to the railing mechanism during fire accident, or testing is essential. The frame assembly can be seen in figure 11 below. (Interviews)

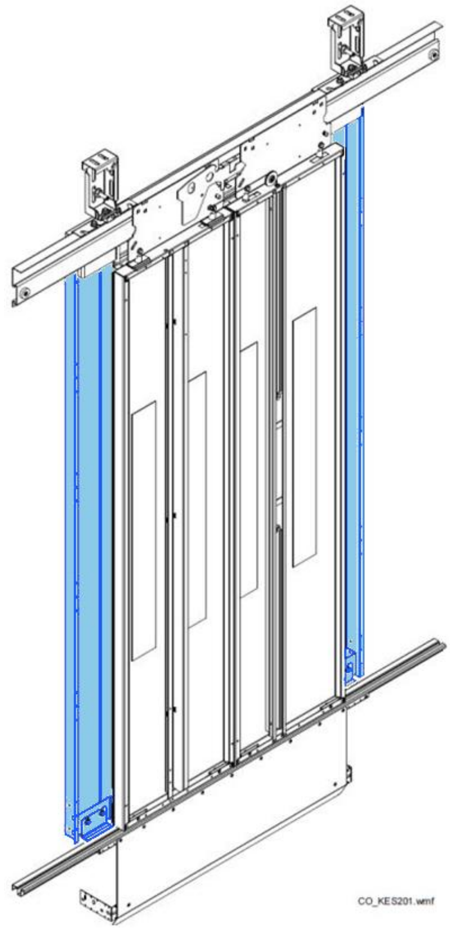

Figure 11. Landing door frame

The railing is the heart of the landing entrance. It includes the locking device which prevents unwanted door opening. If the doors were not locked in case of fire, fire integrity would be lost immediately. This is the reason why all landing doors must be locked when an elevator is not in operation, and the reason why the railing mechanism's main operation is to keep door panels locked, and during operation to allow doors to open and close. Hanger plates are the contact points for door panels and they include running wheels which make opening and closing the doors possible. The landing door railing is shown in figure 12 with brackets on top. Brackets are used to fix the railing to different types of wall in the same way as the sill and frame assemblies. (Interviews)

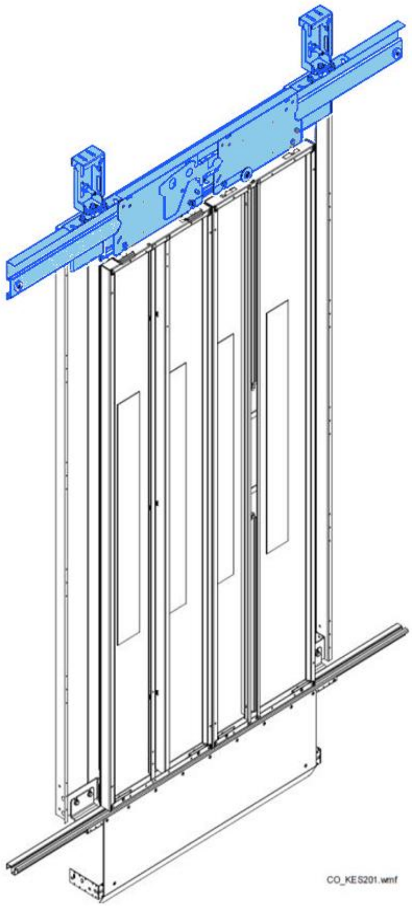

Figure 12. Landing door railing mechanism

Panels are the most essential part of the landing door in terms of fire safety and fire integrity. The more panels are used in one entrance system the more challenging task fire integrity becomes. In figure 13 are presented the door panels of a landing door, and in this case there are two panels. For instance, a landing door assembly with only one panel opening to the side is the best type in terms of fire integrity, but on the other hand a six-panel centre-opening door is the most difficult case to handle. (Interviews)

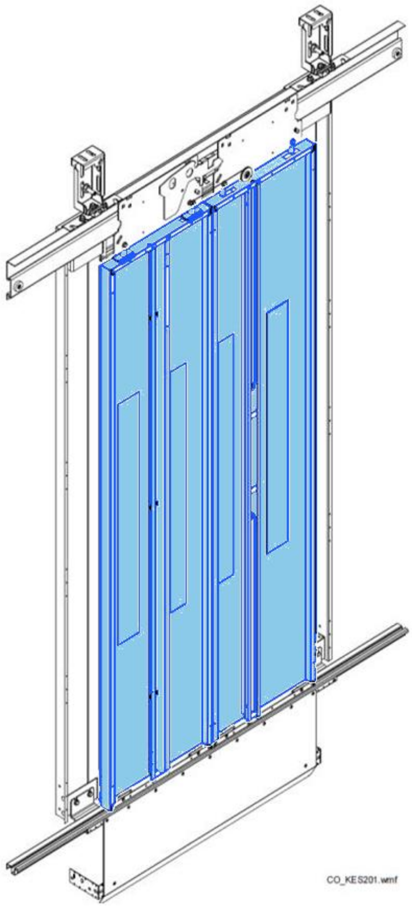

Figure 13. Landing door panels

Between the door panels and between panels and frame there needs to be a fire integrity blocker. This blocker, or limiter, can consist of just a simple steel labyrinth which makes panels, or panel and frame, overlap each other thus preventing gases from leaking from one side to another. If labyrinths are not used, another solution is to use intumescent material, normally heat expanding tape, which is used especially in building doors. Panels may be non-insulated or insulated depending on the fire classification needs. Insulation is typically added to the shaft side of the door construction. (Interviews)

7 FIRE TESTING AND CERTIFICATION

As stated before, elevators possess potential safety hazards if not designed, built, and tested properly. Fire hazards are one of the matters that are almost always supervised by a state's fire inspector or a governmental body. Unfortunately, more often than not, these supervising bodies do not possess the product know-how, or have the authority to vouch for the product's safety. Therefore products are tested and certified by trusted parties to ensure safety requirements are fulfilled and supervising bodies are able to check their function from commonly known markings.

KONE fire tests roughly 5-10 landing doors annually. These numbers illustrate the full scale fire tests that are tested by an accredited notified body, and if passed, can be certified accordingly. KONE also tests using smaller scale fire tests solely for testing purposes and also pure material tests. Small scale tests are mostly done to ensure the design of the door is good enough to pass a full scale test, or to check new designs for unseen faults. The total cost of a full scale fire test is approximately 20,000 Euros, a smaller test is much cheaper. The price includes all personnel and material costs from KONE and also certification, assessment and personnel costs of the testing party. (Interviews)

7.1 Fire testing scenarios

Fire tests are normally made to existing door types when there have been changes to the design or the certificate is expiring. Fire tests are done to new door designs too during their development. (Interviews) To better understand how fire testing affects time to market in terms of delays and extra work, the new product development process is shown in the figure below.

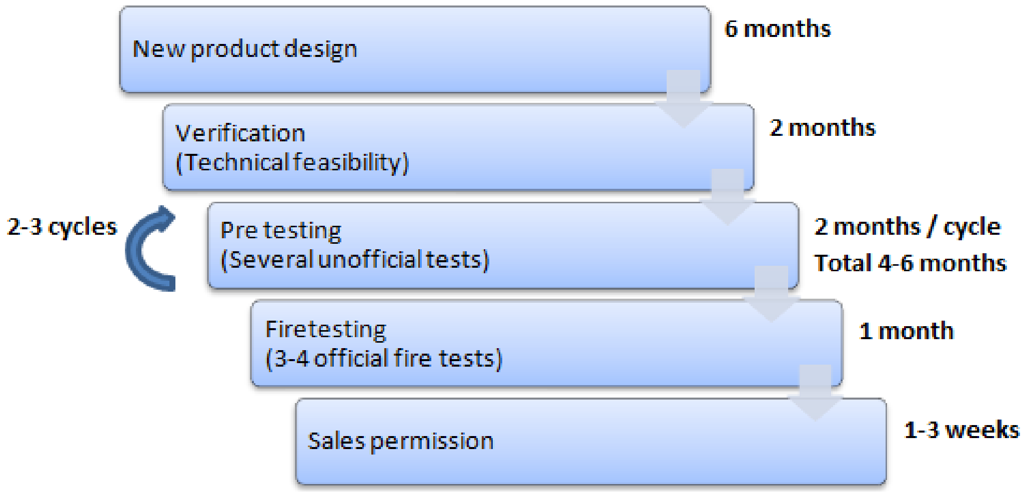

Figure 14. Product development cycle

In this example, in the development process of a new landing door product the design phase takes roughly six months to complete. In the end of the design phase pilot designs are manufactured and then testing can begin. The verification phase lasts approximately two months. During this time, regular safety tests are conducted as well as other tests such as endurance tests. These measures are done to ensure the product's technical feasibility and to highlight any design flaws. These safety tests are done according to the standard EN81-1. (Interviews)

The third major phase in door development is pre-testing. These tests are unofficial fire tests which are less costly than the official full scale fire tests, roughly 1/10th of the price of a full scale test. The reason behind these tests is to make sure the door is up to the testing standards, in this case EN81-58. By testing small scale first, a lot of costs can be avoided if the design will not pass the test straight away and further modifications are required. This phase normally takes two to three testing-modification cycles to perfect the design and to make sure the official full scale fire test is passed on the first try. The length of this phase is normally four to six months. (Interviews)

After the small scale tests have been done and the door concept has passed the pre testing phase, several full scale tests are done. Usually one product line requires four full scale tests to make sure that all the different product variations are included in the certificate. This means different height, width and materials, and if the product offers different types of frame types such as narrow frame, or a full size front. The different product combinations often have tens of different variations and it is the job of the testing body to select a few combinations that present the weakest links of any combination possibilities. This phase usually takes one month to complete and is the most expensive of the testing phases. (Interviews)

When the fire tests have successfully passed, all of them or partially, the notified body who performed the tests grants sales permission for the approved door combinations. The sales permission is usually given in a few weeks without much extra costs. (Interviews) After the successful fire test have been conducted the door can be certified based on the assessment report given by the testing body. This process is described in the next few chapters.

As seen from the figure 14 the most time consuming process is pre testing and the most pricy is official fire testing phase. If these phases face delays or the process between both parties is not clear time to market is likely to be delayed. Also, the preparation of the door design in pre testing is critical to reduce costs in the official tests. The testing body has to present sufficient elevator know-how to be able to recognize the different combinations from the door offering without having to fire test all the different variations.

After fire testing the product it has to be certified so that it can be presented to officials who supervise the safety of buildings. When a new building is constructed it will be inspected for safety issues including fire safety. Certification is described in more detail in the following chapters.

7.2 What is certified

KONE offers four different types of landing door platforms. They are KES 100, KES 201, KES 600 and KES 800 series. KES comes from KONE Entrance System and the number means how many duty cycles, opening and closing, they are designed to handle annually.

KES 100 and KES 800 door families are more customizable for the customer and their volumes are low, for KES 100, and medium, for KES 800. These doors can be seen in figure 15. KES 201 and KES 600 families are more of volume products and they do not offer as much tailoring for the customer to choose from. KES 201 is the main volume door for KONE and KES 600 has an average sales volume.

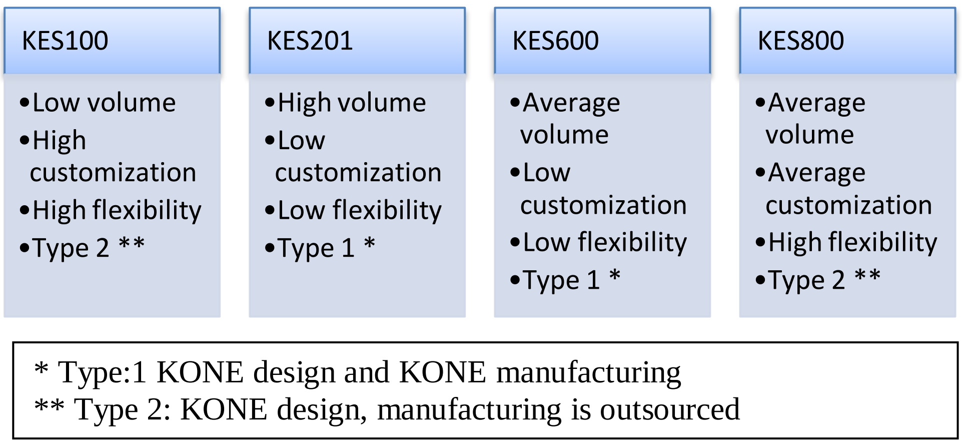

Figure 15. KONE door offering and key aspects

In terms of certifying these products, all the door families could benefit from different types of certification approach as they offer different amounts of variation and sell with varying volumes. Also, new door designs and existing designs might benefit from different certification processes. Currently, all door families follow the same certification process at KONE. This means all door families tested by the standard EN81-58 are tested and certified in the same place. There are certain benefits that come from centralizing all testing and certification activities, and this current model will be evaluated in next chapter. However, it might be beneficial to create four completely different processes for certifying these product families as the product lines require different kinds of treatment from each other. Unfortunately, this might create confusion, process maintenance issues and additional costs.

7.3 Current testing and certification process

At the moment, the normal testing procedure at KONE goes as follows: First, a few test specimens are selected from the door offering. The selection is done by the testing body and it is their responsibility to select the worst case scenarios from the offering. Usually, two test pieces are required per one combination, one is installed and tested, and the other is examined. After the test door is selected, KONE employees install the door to the test frame of the testing oven. After that the specimen is checked by the notified body that it matches the manufacturing drawings and production line quality. This protocol may vary between different laboratories but it represents the general procedure. (Interviews)

The typical certification and testing process can be seen in figure 16. First, the requirement for product change comes from customer specifications, cost savings, design innovation, supplier change or when a new design is developed. Next, the changes are evaluated in terms of fire safety by a notified body that is in charge of the certification. If the changes have weakened the doors fire safety, or it cannot be certain, then the door must be fire tested. If it can be certain that the new product changes do not affect fire resistance negatively the changes can be written in the existing certificate without further testing.

Fire testing is performed by a notified body with an accreditation of ISO 17025 and the accreditation of the required door fire standard, for example EN81-58. Once the test has been completed, usually the testing body gives a written assessment report on the performance of the door. The certificate is then based on the assessment report and it can be granted by a notified body with an accreditation of EN 45011. All these steps can be done by the same notified body or they can be divided amongst separate service providers.

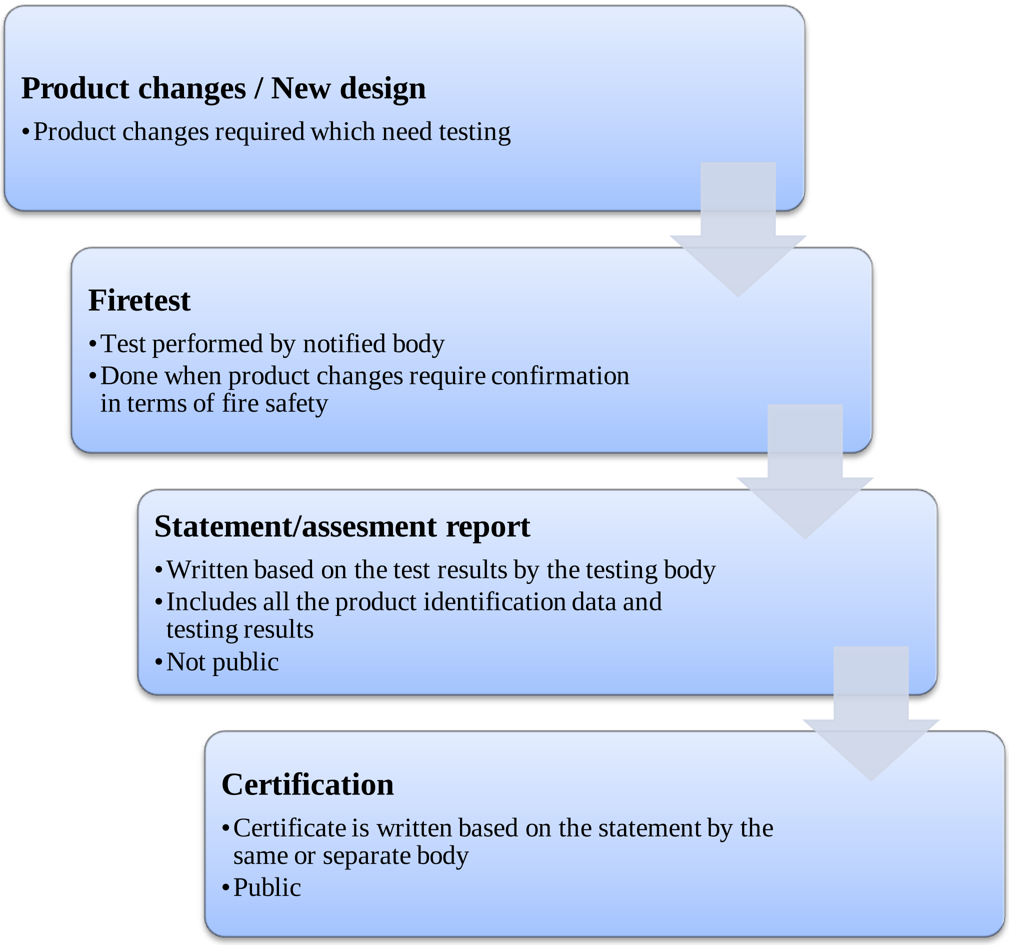

Figure 16. Testing and certifying process of door fire safety

As seen from the figure above the statement or assessment report is vast and covers all the important aspects of the product offering, what combinations were tested, and how well the specimen performed. This document is not found in public archives as it contains manufacturing drawings and other product specific information. The certificate is a public document that is based on the assessment report. It has fewer pages than the assessment report and it does not contain manufacturing drawings. However, some notified bodies require that the certificate has drawings of the door design and some do not. There might be other differences between different certifying bodies. The purpose of a certificate is to show that this product has been tested and certified by a notified body and the product variants stated in the certificate fulfill requirements specified in standards. In addition, there is a fire label on every certified KONE elevator door that specifies what requirements and standards they fulfill which is required by the EN81-58 standard. This label includes the number of the certificate, name of testing standard, and fire classes.

The process stated in the figure above describes the current situation at KONE. At the moment, KONE is planning to review its fire testing and certifying procedure and methods. Negotiations are underway and the structure of this process is likely to change. Therefore, it will analyze the current certifying process for future reference with a simple SWOT-analysis that shows the Strengths, Weaknesses, Opportunities and Threats of the current model. This SWOT-analysis can be seen from table 4 below.

Table 4. Current certifying process

Strengths	**Weaknesses**
• Flexibility in process • Only one notified body • Short certificate	• One process for all product lines • Only one notified body
Opportunities	**Threats**
• Product training is easy for only one party • Product know-how increases from previous tests	• All eggs in one basket

The main strengths of the current certifying process are flexibility in the process itself, the fact that there is only one service provider for all the steps of the process and the shortness of the certificate. Process flexibility means that changes to the process can be implemented rather quickly by mutual agreement, schedules can be changed, and excessive bureaucracy can be eliminated. In addition, when there is only one service provider the company must only associate with them which means fewer meetings, less confusion, same agreed terms and routines for all products, contacts are possibly more frequent and relationship is possibly better when there is only one contractor. Possibly the most important issue currently is the shortness of the certificate document itself. It requires less maintenance and less hassle, and not many certifying organizations are enthusiastic towards such a solution.

Weaknesses of the current status are the fact that there is only one process for all different product families and that KONE associates with only one notified body. As it is good to have one mutual process for all products there is also some issues that come with it: this one process can never be as optimized for all the different door types as it could be with multiple service providers. In case of just one provider the methodology behind the other processes is always in the background and blocking the way for possible process differentiation. Also, the fact that there is only one service provider ultimately means that KONE receives only their know-how in the matter and learning is hindered, and potential innovations are missed as fewer people are working on the process.

The possible opportunities concentrate on training and know-how. As there is only one service partner the training costs are reduced and effectiveness is increased. In addition, product know-how increases as all the fire tests are made in the same laboratory and not divided amongst multiple service providers.

Threats are focused mainly on one major flaw in this model, the fact that there is only one service provider. In case of changes in the testing or certifying organization, the effects are felt instantly at KONE. The smallest threats consist of sick leaves, delays, and other minor issues that could affect KONE in the short term. The biggest issues are possible organizational or strategic changes in the testing organization which often require new meetings, agreements, and contracts to be made between the different parties. The worst case scenario would be the service partner ending its business and leaving huge confusion behind.

7.4 Evaluation of fire testing

KONE needs fire testing for various reasons as previously described in this chapter. To conduct approved fire tests several things are needed, for example: a testing facility with installation equipment and waste disposal, proper testing equipment, educated testing crew, approved evaluating crew, recording devices and accreditation for used testing methods. To evaluate the current status of fire testing these requirements are used to create evaluation criteria.

The fire test evaluation criteria are based on the technical aspects of fire testing rather that evaluating the service or partner itself. These technical criteria point out the core area of focus when it comes to evaluation of fire testing of elevator doors. These technical evaluation criteria are then used to map the possible testing facilities. The current evaluation criteria at KONE are not systematic, which is the main reason why such criteria are created. Most of the technical requirements for fire testing are described in the testing standards such as EN81-58 but it can be beneficial to evaluate other aspects as well.

Technical criteria are not the only ones to consider as, in the end, evaluating the testing service is the key to a functioning and beneficial business relationship. These service criteria are not systematically evaluated at the moment and they are described in the next chapter when the complete fire testing evaluation process is presented.

8 EVALUATING FIRE TESTING

Initially, the process of candidate evaluation begins with defining the key aspects of what is needed. The essential is that KONE needs new options for fire testing elevator landing doors. The second point is certifying these products. To find these service providers, first the criteria for the testing is created and evaluated, then the process for certifying will be thought through. When the criteria and methods are clear to fire testing and certification the focus will be shifted towards evaluating the service itself. Finally, when the criteria for service evaluation are done it is time for the make or buy decision.

The process presented here follows closely the systematic decision making framework and supplier selection theory presented in the literature review. The aim is to make the process suit the purpose properly, which is to guide the way for KONE to choose the best way to evaluate and choose the method to conduct landing door fire testing. The process of evaluating and choosing a fire testing service provider is presented in figure 17.

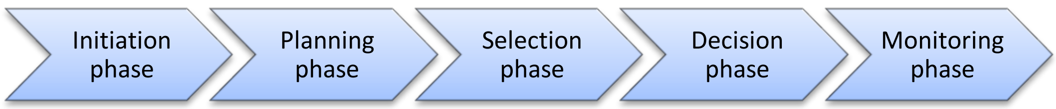

Figure 17. Decision making process for evaluating fire testing methods

After these five phases it will be discussed whether it is reasonable for KONE to make the decision of buying or outsourcing this newly defined alternative way or is it practical to own the testing activity altogether. This discussion relies on the theories presented in this thesis, the current competences and strategies at KONE, and whether a suitable candidate can even be found in the first place.

8.1 Initiation phase

The process of developing evaluation criteria and choosing the method of fire testing begins with a definition of the current situation and the need for a new way of testing. In the initiation phase it is important to also choose the project team that will connect the different people and parties during this complex process. The key aspects of this phase are found in figure 18.

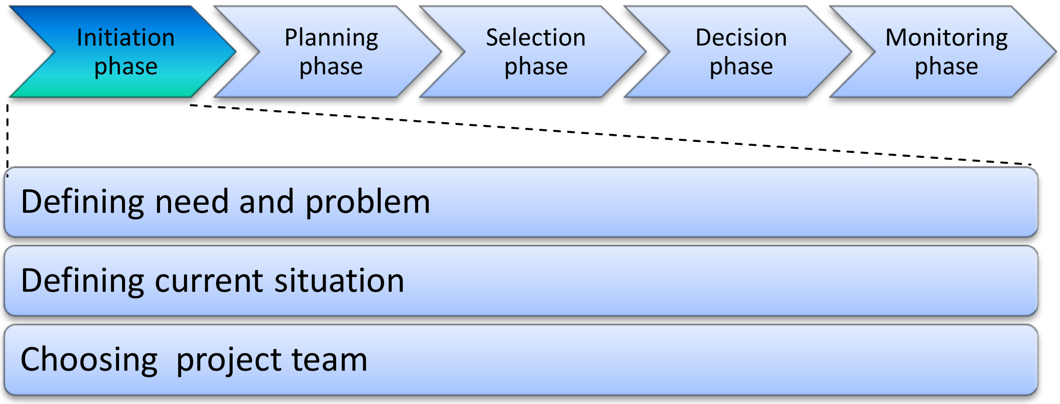

Figure 18. Key areas of initiation phase

KONE needs new candidates for fire testing laboratories that could provide fire testing according to the standard EN81-58. The need for new fire testing locations can be based on several factors. KONE is finding new alternative testing laboratories to re-evaluate its current methods. In addition, new testing facilities are mapped to possibly optimize the current way of testing and certifying landing doors.

KONE was lacking a systematic way of evaluating the fire testing technology and service being used. This means that evaluation criteria would have to be created to objectively rank KONE's current fire testing and certifying method versus possible other providers. Furthermore, the service would have to be ranked as well, with newly found criteria which will be presented during this thesis.

When the evaluation criteria are chosen they can be used further on to systematically benchmark KONE's fire testing facilities and testing services.

Systematic benchmarking criteria did not exist during the making of this thesis and the criteria would help KONE’s door managers to better keep track and monitor fire testing status.

The project management or decision team will consist of KONE door R&D managers who will make the final decision on the key matters. Door R&D experts, who were also interviewed during this thesis, will provide insight to the problem and assist the management team mainly in technical questions, but in other questions as well such as candidate suggestions and previous relationships with different candidates. The whole project team then forms a specific problem statement, which in this case, would be *How to define criteria to evaluate elevator door fire testing, and testing service?* In addition to *What is the best way to conduct fire testing and certification?*

In this thesis it is a dual-process as two types of criteria must be created: one type of criteria to evaluate the method of fire testing in terms of technology and service, the other to evaluate certification aspects. Fire testing and certification are closely connected which is why a supplier often provides both services. However, when creating the criteria the certification is kept as a separate operation because testing and certification service could be provided by different parties, one provider for testing and one provider for certification. In this way the both parties are individual and can be evaluated separately. Even if one supplier ends up winning both evaluations it can be beneficial to keep the operations separate to keep neutrality. This means the testing company may not create a business case for itself by deliberately refusing to certify the product without an official fire test due to minor details.

8.2 Planning phase

The planning phase is formed around the creation of the technical criteria and the service criteria. These criteria are based on previous experience in fire testing technology and methodology, future needs of the fire testing and certification processes, and future requirements towards testing services. These criteria are used in the next phase to evaluate the different alternatives. The focus areas of planning phase are presented in figure 19.

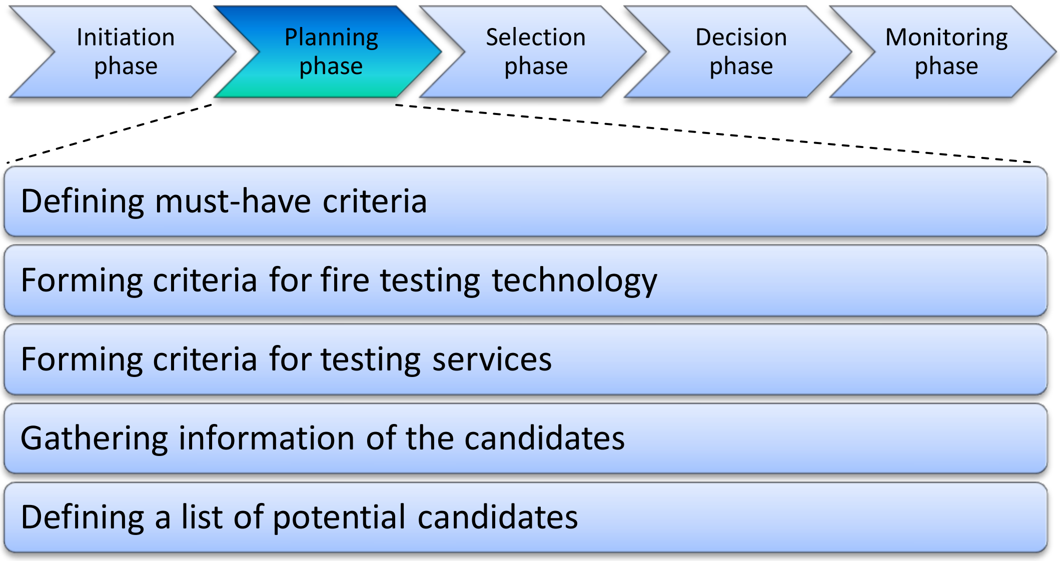

Figure 19. Key areas of planning phase

Criteria can be created before the list of alternatives has been assembled but it can be also formed on the basis of the information found about the candidates. Either way, the list should be formed during this phase to be ready for the evaluation itself in the next phase.

8.2.1 Must-have criteria

The must-have criteria are the roughest criteria and they are only a few in number. These criteria are used when the list of candidates is composed and only a little is known of the candidates. If a candidate does not fulfill these specific criteria it is dropped from the potential alternative list. The purpose of these criteria is to form a suitable list of candidates that is not too long or too short. Also, these candidates will then posses the most essential features required from them and these factors will not affect the evaluation itself.

For elevator landing doors fire testing laboratories the most essential aspect to consider is the accreditation for testing, which is the ISO 17025 standard. Without this accreditation the results of a fire test cannot be used for certification purposes as they are not official (Interviews). This accreditation also gives a heads-up of the experience level that the fire testing parties have, as they have probably done several tests before if they have the accreditation to ISO 17025. In addition, the location of the testing facility should be relatively close to Northern/Mid-Europe (Interviews). This keeps the logistical costs at an appropriate level and provides quick access to the facility for KONE employees when meetings or tests are arranged. These criteria can be also seen from table 5.

8.2.2 Technical criteria

Technical criteria consist of requirements allocated for the testing facility itself. These criteria do not yet consider the service level of the candidate but rather focus on the critical factors required in fire testing landing doors. These criteria are later used in the rough-evaluation of the candidates in the next phase of the process. After the rough-evaluation is done the results are then included in the final evaluation phase. If some candidate provides insufficient requirements for the technical requirements by a large margin it can be eliminated from the list of potential alternatives.

The criteria for technical evaluation of the facilities are capacity, age, size of testing oven, and suitability for elevator doors. Also, depending on the decision of the management team the accreditation to fire testing standard EN81-58, or some other standard, can be one of the technical evaluation criteria. The reason behind this is due to the technical requirements described in these standards. For example, EN81-58 requires specific measuring equipment to be implemented and describes the burning procedure of the testing oven. Capacity should be sufficient at an annual level and it is measured in tests per year. Age and modernization date of the facility can be a concern as well. An aging facility requires more maintenance than a new one and is more likely to cause delays or faulty test results. A larger size testing oven provides possibilities to test larger door specimens, and the suitability means there is a convenient way to attach elevator doors to the oven in the first place. An overview of these criteria can be found in table 5.

8.2.3 Service criteria

Service criteria are the main evaluation criteria in finding the suitable fire testing service provider. The service criteria are used to evaluate the testing service in total after they are ranked and weighted. These criteria contain many factors including the costs, lead time, competences and know-how, previous experience with fire testing and the reputation of the supplier. The purpose of this step is to rank the candidates and pick a few of the best candidates for final evaluation and negotiations. After the initial ranking the same criteria are then used to determine a more accurate ranking between the top five or so candidates with a pair wise evaluation. After that it can be decided which one(s) of the candidates is chosen for further actions. Service criteria can be found in table 5.

Table 5. Criteria overview

Must-have criteria	Technical criteria	Service criteria
ISO 17025 accreditation	Capacity	Lead time for fire tests and test reports
Location of the facility	Age of facility	Test preparation process
	Size of testing oven	Schedule flexibility
	Suitability for elevator doors	Installation equipment and service
	Fulfils specific fire testing standards	Familiarity with elevators
	Accreditation to EN81-58	Accreditations to different standards
		Costs of full scale, small scale and material testing
		Additional costs
		Certification costs
		Willingness to learn and to commit
		Reputation
		Management capabilities
		Financial status

The criteria presented in table 5 were chosen amongst many criteria as the most important criteria specific to the problem in hand. They were selected based on the theoretical frame for guidance and then assessed with KONE's door fire testing experts. The weighting of these criteria is presented in the next phase. There were more criteria to consider but it would only complicate the decision model and increase time taken with marginal benefits.

Lead time is one of the important factors to consider as it affects time-to-market and product development in general by delaying the process. By reducing lead time it is possible to gain sales permission faster. Test preparation should be a simple process that both parties form together with mutual interest as it can increase the work load of both parties and increase the lead time of the whole process dramatically if done imperfectly. Installation equipment are evaluated for convenience reasons during installation as normally KONE personnel install the doors to the testing oven. If there are no cranes, forklifts or tools available it can be rather difficult or impossible to install door. In the least favorable scenario all the tools must be brought by the installing party. The last aspect of wholly service related criteria is flexibility in the process which means the agreed process can be rushed if the need arises. Sometimes it is critical to save a few weeks time in bureaucracy to get a sales permission.

Elevator know-how is also an important factor to consider. If the testing party has not burned elevator doors before it can be time consuming to learn technical aspects and to develop best practices for testing, and training expenses will increase. Accreditation for testing (ISO 17025) is a must-have criteria but it is beneficial if the testing body is accredited for inspection (ISO 17020) or certification (EN 45011) as well. Moreover, accreditation to EN81-58 can be considered as a technical criterion but also as a service criterion because it requires know-how and experience to expertly conduct the testing of a specific standard. Also, other testing accreditations are considered a bonus, for example BS476:22 and UL 10B.

The costs of doing business are always important to consider and they cannot be ignored in the evaluation criteria either. The costs of full scale fire testing is the main issue as it the largest single expense but small scale fire testing and material testing costs are also important factors. Additional costs are meeting preparation and evaluation costs which are usually measured in Euros per hour. Certification costs are also considered when choosing the testing provider as at some point it might be beneficial to certify a product at the same location where it was tested.

The rest of the criteria are important as well but they can be hard to measure and generate. Depending on the background research done for the candidates some of the criteria may have to be left out of the evaluation if information is not available. Willingness to commit and willingness to learn are important areas especially for new businesses with little technical knowledge of elevators. Also, willingness to accredit missing standards and agreeing to KONE training sessions is crucial. Management capabilities can be hard to evaluate but can be evaluated based on the pre-negotiation between both parties and the way of organizing the meetings and the general feel of managerial activity. Financial status should be checked for continuity. If a financial background check shows some concerns the relationship could suddenly change for the worse. The last criterion is reputation which can be assessed based on previous association with the candidate or recommendations from KONE's other partners.

8.2.4 Certification criteria

Certification criteria have far less criteria than the fire testing criteria as there are less factors and importance involved in choosing the certifying body. Certification could be evaluated only based on one criteria which would be accreditation for certification, EN 45011. However, it is beneficial to know a bit more about the certifying body. These factors are costs, how long they have been certifying, especially elevator product fire certifications, what is their reputation and their financial background. The list of certifying criteria can be found in table 6.

Table 6. Main areas of certifying criteria

Must-have criteria	**Certification criteria**
Accreditation to EN 45011 (certification)	Costs: certification cost and additional costs
	Previous experience of certification
	Financial statement
	Reputation
	Previous experience with fire tests and elevator fire tests
	Flexibility

To make it to the list of potential candidates of fire test certifiers the standard EN 45011 must be accredited. Previous experience implies the supplier's processes are tuned and the best practices have developed. Financials are considered for the same reason as for fire testing, to ensure continuity. Reputation and the opinions of others are also considered to get an outside view of the candidate. In addition, previous experience with fire testing can be a good or bad sign depending whether their way of conducting business is aligned with KONE. Flexibility and suitability to KONE's processes is also important in addition to finding the mutual solution for certification.

After both sets of criteria are defined the list of alternatives can be composed for both fire testing and certification. The first list for fire testing should include roughly 20 to 40 candidates which are ranked already with the must-have criteria. After that the list will be evaluated again with the technical criteria and some of the candidates will be further eliminated in this step. When the evaluation of service begins the list should include approximately 15 to 30 candidates. They are then ranked and the top five candidates are chosen for a pair wise comparison for accurate evaluation. The certifiers are listed based on the must-have criteria as well and after that ranked based on the certification criteria. The initial list should consist of approximately 15 to 25 candidates and the next list around 10 to 15 candidates as only the suitable are left. Certification criteria can be combined with the rest of the fire testing criteria if it is seen beneficial to the decision team.

8.3 Selection phase

After the criteria are defined for fire testing and certification, and the list of potential alternatives has been analyzed based on must-have criteria it is time to evaluate the candidates further. In the selection phase the criteria are weighted, the selection tool is chosen and used to rank the alternatives. At the end of this phase there should be roughly five top candidates chosen for the final decision and a recommendation of the most favorable candidate. The key areas of the selection phase are seen in figure 20.

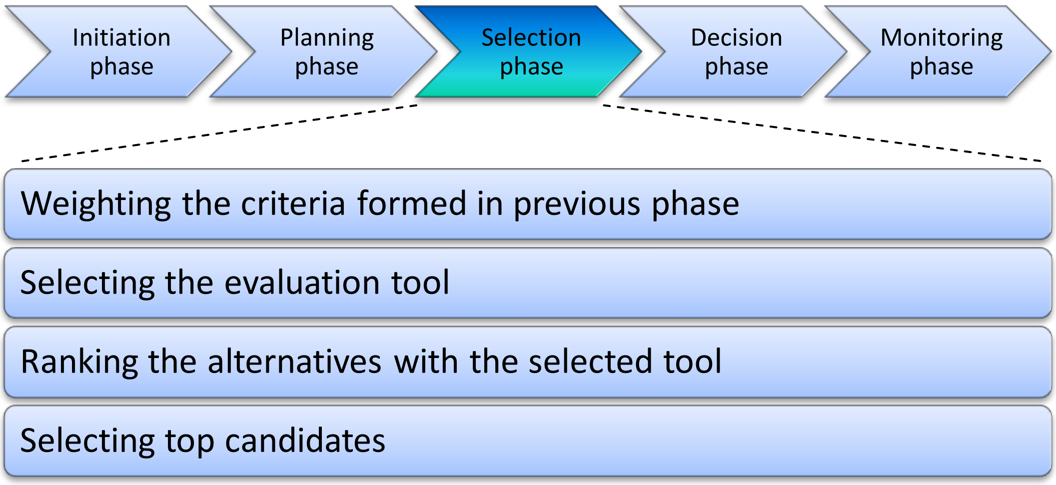

Figure 20. Key aspects of selection phase

The criteria are weighted based on the opinions of the decision group with the help from the fire testing experts. The importance of weighting the criteria cannot be stressed enough as they form the foundation of a reliable decision model. Enough time should be used when deciding the weighting scale of the first model which will be presented in this thesis using the linear weighted-sum criteria matrix. This tool excels when there are many candidates involved in the evaluation but the results must be accurate and objective. The down-side is that weighting can be difficult between qualitative and quantitative areas, and it can be difficult to compare and rank the alternatives in qualitative factors by giving specific corresponding number. However, a pair wise comparison with so many candidates would be inaccurate due to inconsistency building up and too much effort compared to the quality of the results.

At first, the technical evaluations are considered. The candidates are ranked based on the criteria created in the previous phase. The weighted-sum criteria matrix can be seen in table 7 where part of the potential alternatives that qualified the must-have criteria are presented. The weighting is seen on the left side. Each alternative is graded from 1 to 5, 5 being the best. This grade is then multiplied with the corresponding weight of the criteria, and finally the weighed grades are summed up in the total row. In this example comparison, there is an EN81-58 criterion which means the technical feasibility of this standard. If EN81-58 is impossible to implement to the testing equipment, or the candidate is not willing to invest in the testing equipment and accreditation, the candidate is eliminated. Based on this rule, alternatives 4 and 5 would be dropped out.

Table 7. Technical evaluation example

Technical evaluation	Weighting	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
Capacity (Annual maximum capacity/simultaneus tests)	0,2	2	5	2	5	3	2
Age of facility	0,1	2	1	4	3	5	3
Size of testing oven	0,1	3	3	4	5	4	3
Suitability for elevator doors	0,2	3	4	3	2	2	4
EN81-58, accredited, possible, impossible	0,4	5	3	3	1	1	5
Total score	1	3,5	3,4	3	2,6	2,3	3,8

When the technical ranking is done and the unqualified alternatives have been dropped it is time for evaluating the service concepts. This is done in the same way as technical evaluation except the criteria are divided into groups to make analyzing the result easier. For example, all the different cost criteria are placed under costs. An example service evaluation is found in appendix 1. In this example the technical evaluation is included as part of the complete service evaluation as it is still an important part of the total score. As seen in appendix 1 alternatives 4 and 5 are dropped and each main criterion is given a weighting. The sum of each main criterion is then multiplied with the weighting factor and summed up to form the grand total for each alternative. In the example, alternative 2 received the highest overall score.

Certification evaluation follows the same principle as technical evaluation except there are no must-have criteria deployed within the ranking system. Criteria are weighted and then different alternatives are given an appropriate score for each criterion. The total score is calculated by summing up the weighted grades of each criterion.

The final ranking of the top five or so candidates is done by using the analytic hierarchy process, or AHP. As explained in the literature review AHP uses pair wise comparison to weight the criteria against each other. This is an accurate tool for measuring both qualitative and quantitative criteria when there are only a few alternatives to choose from. These alternatives are also compared against each other in a pair wise comparison. These results can be compared against the initial weighted-sum criteria matrix results to cross-check whether there are differences in the ranking of the alternatives. If ranks differ, it should be checked where the difference is formed. AHP is relatively flexible tool and easily conducted sensitivity analysis is one of its benefits, especially when the comparison is done with dedicated AHP software.

To form the AHP model the same type of approach is used as when using the weighted-sum criteria matrix: first the goal is formed, then the criteria, and after that the subcriteria for these criteria. The hierarchy of the AHP model is presented in figure 21. When these criteria are input to the AHP software the next step is pair wise comparison. The user weights the criteria against each other normally on a scale of one to nine, five being the neutral correlation. After that subcriteria under each criterion are compared against each other. When the criteria hierarchy is formed the software automatically forms the correct matrices and checks the model for inconsistency. If inconsistency is too high the model should be fine tuned further.

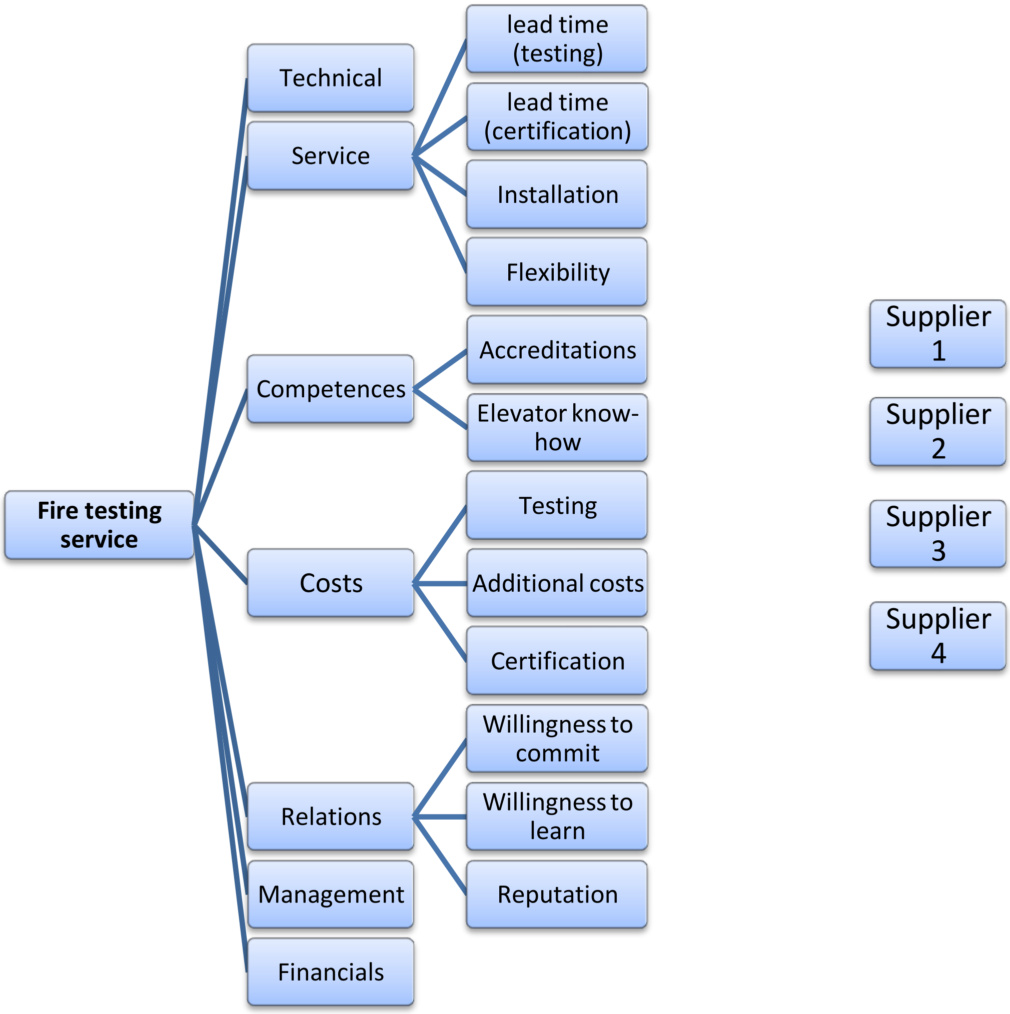

Figure 21. Decision-making hierarchy

When the final candidates are ranked with AHP it should be kept in mind that the ranking is only as accurate as the model itself and how well the decision team has done its research on the candidates to evaluate them in the first place. At this point of the process knowledge of the final candidates should be thorough and the pair wise comparison should be kept as objective as possible, which could be hard if pre-negotiations are already underway with some candidates, or the decision team has settled on a favorite candidate already. At best, the AHP-model is a supportive tool for the decision team and it should not be relied blindly as it can never take all matters into account.

8.4 Decision phase

In the fourth phase it is time to make the final decision in which an alternative or alternatives are chosen. As described in the previous chapter the results should be analyzed to make sure the decision team knows why the model suggests such an answer. After the analyses are done it is time to decide which alternative is chosen, and start negotiations with them. The main points of the decision phase are found from figure 22.

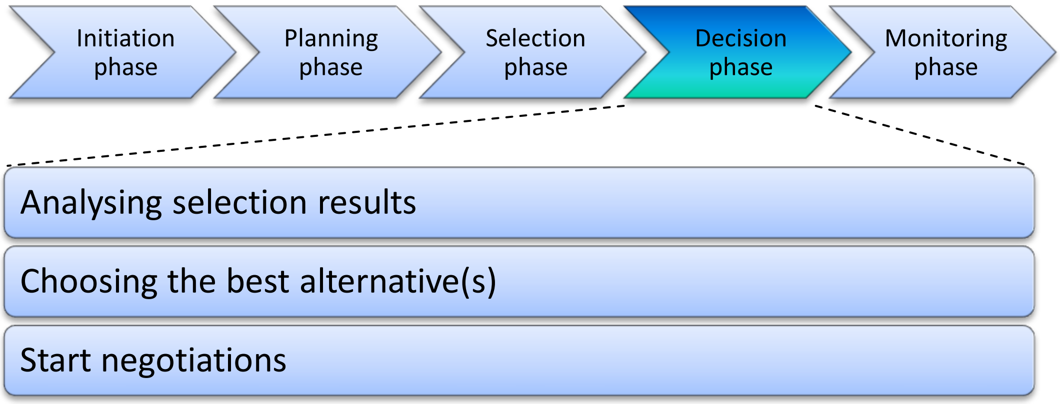

Figure 22. Key aspects of decision phase

Analyzing the results properly can give invaluable insight on the candidates and what is actually valued the most. Graphical demonstrations are common for AHP software and should be used in the analysis.

The final decision is then based on the results formed by the evaluation tools, analysis of the results and individual preference which is the least objective type of evaluation. Based on these factors, some candidates are chosen for negotiations and based on these negotiations the best alternative is chosen. There are multiple factors to consider when negotiating the terms of a partnership, and KONE has their own methodology of forming these partnerships which is why it is not discussed further in this thesis.

8.5 Monitoring phase

Monitoring phase consists of maintaining a suitable level of performance after the partner is chosen. In the monitoring phase continuous reviews of supplier performance are conducted and relationships are improved with continuous improvement and collaboration. The evaluation criteria are updated when necessary or new technology or standards arise. It is also important to appoint people to the roles for these tasks so that the monitoring phase stays on track. The key factors of the monitoring phase are also seen in figure 23.

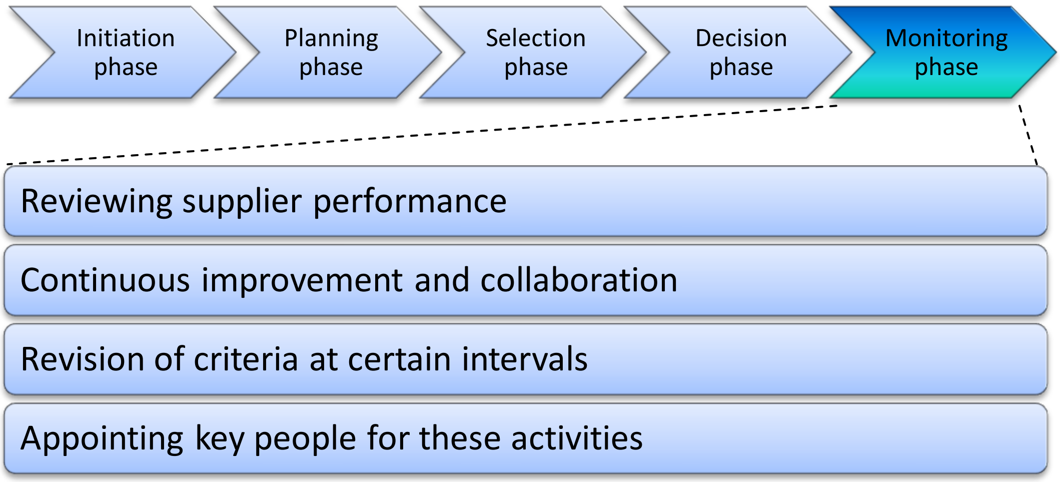

Figure 23. Key aspects of monitoring phase

KTO management at KONE has quarterly meetings, or two annual meetings, with its fire testing partners which are for checking schedules, agreeing on future fire testing and other managerial factors (Interviews). These meetings can be used as a base to review the performance of managerial activities of the testing company. Other factors such as costs, service level, and accreditations can be negotiated in these meetings, and they are then easier to review and evaluate. Technical aspects are simply, and without extra cost, monitored by technical fire testing crew from KONE when fire tests are conducted as they are required to be present in these tests.

It is important to monitor the activities of partner organizations but it is also important to set specific levels for measuring these activities, at least when such measurable levels are possible. For example, what is the maximum price for a single fire test, or how many co-determination negotiations are acceptable within a specific time period, as it usually states changes in an organization. These levels can be also mutual agreements such as how many training sessions will be provided by KONE.

At certain intervals the evaluation criteria should be reviewed with a view to checking if they are still accurate, and whether they can be used to evaluate the existing requirements as well as before. If required accreditations change or if KONE door offering changes, especially the certification method has to be re-evaluated and checked.

To keep monitoring as effectively as possible the monitoring phase has to be managed properly. To accomplish this, several key roles must be created and divided amongst appropriate people at KONE. Such activities that need monitoring are technical, managerial, and relationship activities. By setting these roles and responsibilities the monitoring task is kept systematic and continuous as monitoring becomes an operational task for the key people.

8.6 Make or buy decision

After the best possible partner has been found and negotiations are underway it is beneficial to examine whether it would be reasonable not to buy these services but to fire test the doors within KONE facilities. For this reason the decision team should assemble a team to evaluate this important decision.

Matters which should be taken into account when deciding whether to make or buy are KONE core competences, how outsourcing fits the company strategy and how doing it yourself fits the strategy, what would be the scope of outsourcing and what type of partnership should be formed, what would be the costs of outsourcing and fire testing at KONE facilities, and what would be the costs to build these facilities.

Competences should be evaluated at the top management level whether fire testing doors should be kept in-house or outsourced. It is beneficial for a company to focus on its core competences and keep these activities in-house as they create opportunities, competitive advantage, and are hard to imitate by competitors. However, fire testing has not been one of KONE's core competences and in this light it might be feasible to outsource.

When it comes to KONE strategy, safety is one of the high priority areas and also part of the KONE megatrends. As stated previously, landing doors are one corner stone in elevator safety especially in hazardous fire situations. But does in-house fire testing add additional safety compared to third-party professionals, is a question to be asked when deciding whether to make or buy. In addition, one strategic high priority area is simplification which can be aimed towards focusing on core competences and know how.

One important thing to consider is the costs of making compared to buying. Buying fire testing and certification services mainly consist of fire tests themselves, pre fire tests, logistical costs, and administration costs of the third party. These are mainly variable costs which are based on the amount of fire testing done annually. If the fire tests were to be conducted in-house there would be a lot of initial costs at first from building the facility, accrediting the testing standards, and investing in testing equipment. After the initial investment there would be fixed costs from maintenance, calibration of testing equipment, and training. Also, variable costs from fire tests and certification would still remain except now they would be done using KONE resources.

In the light of these points it appears outsourcing seems like an attractive option as the conducting method for fire testing. However, make or buy decision should be made by the KONE KTO (Door Category) management in association with top management and the decision team who evaluated the fire testing candidates. If outsourcing is chosen as the method to conduct fire testing the type of partnership should be chosen next. Purely written contracts are riskier than deeper partnerships but both have benefits and downsides as well. A partnership type is likely to be case specific and should be decided when the actual testing laboratory is chosen.

9 RESULTS AND SUGGESTIONS

In this chapter some of the practices for evaluating fire testing are discussed including how the process should start and what type of methods could be used in acquiring the initial candidates. Also, how information should be collected and how much information should be available at each phase to make the optimal decisions. Benefits of the new evaluation model are described and what could be improved further.

To find faults and to test the newly created evaluation process the new process was followed in order to find possible fire testing laboratories, acquire information of them, and to test the evaluation criteria and AHP model. This thesis presents the newly created Excel forms that were used to collect data and to evaluate the candidates and how this process functioned during the assessment. In this evaluation procedure the focus is on the EN81-58 testing standard and finding a suitable testing and certification laboratory for the KES 201 door family in the Mid-to-Northern European region.

9.1 Forming the candidate base

In the beginning of the candidate mapping phase it was clear that there would be a lot of fire testing laboratories in the chosen region. These laboratories would have to be mapped effectively but without missing promising opportunities. The must have criteria for laboratories were accreditation to testing, which is ISO 17025, and their location in Europe.

The fire testing service mapping began with a rough internet scan to come up with as many potential candidates as possible. Most of the candidates were found from the member list of EGOLF (European Group of Organizations for Fire Testing, Inspection and Certification). It was beneficial to start the search from EGOLF as they require ISO 17025 testing accreditation to become a member. In short, EGOLF is “the main representative body for third party, independent and nationally recognized organizations involved at a European level in fire safety testing, inspection and certification activities. EGOLF activities are mainly centered on passive fire protection.” (EGOLF, 2013) With this description EGOLF members alone presented a promising start.

After the internet search, a list of over 50 candidates was created for evaluation. It was clear at this point that the first step of ranking the candidates would be quite rough due to limited time and resources with the challenge that potential candidates would be dropped. The selected candidates were chosen using only the ISO 17025 criteria. Further on, the candidates that did not have EN81-58 accreditation were eliminated. After dropping candidates without certification accreditation according to the EN 45011, and which had an unsuitable location, 12 candidates remained.

9.2 Ranking the candidates

To collect more information of the candidates for evaluation an Excel form was created to acquire the most important technical and service criteria. This Excel form was sent as a part of a concluding email after calling all the candidates. This Excel form is seen in appendix 2. The main information gathering areas were facility, service, competence, costs, and other aspects such as willingness to commit to a partnership, and recommendations. From the 12 candidates we were able to acquire answers from 7 candidates and we were forced to eliminate the rest at this point due to the limited time frame and the fact that the information was necessary for the accuracy of the evaluation.

The information of the seven main candidates was then inserted to the evaluation Excel file and each candidate was graded from one to five in each evaluation criteria. The criteria were weighted as seen in appendix 1. The Excel then provided four candidates that were very close to each other and above the competition and they were moved on to the next phase and the three candidates that had the least points were eliminated.

The top four candidates were then compared against each other in an AHP pair wise comparison. The AHP model and the weight of the main evaluation criteria can be seen from figure 24. It is interesting to notice that costs were the least significant factor and competences and other issues were the most important issues to consider. The subcriteria which were included under the main criteria can be seen from appendix 3.

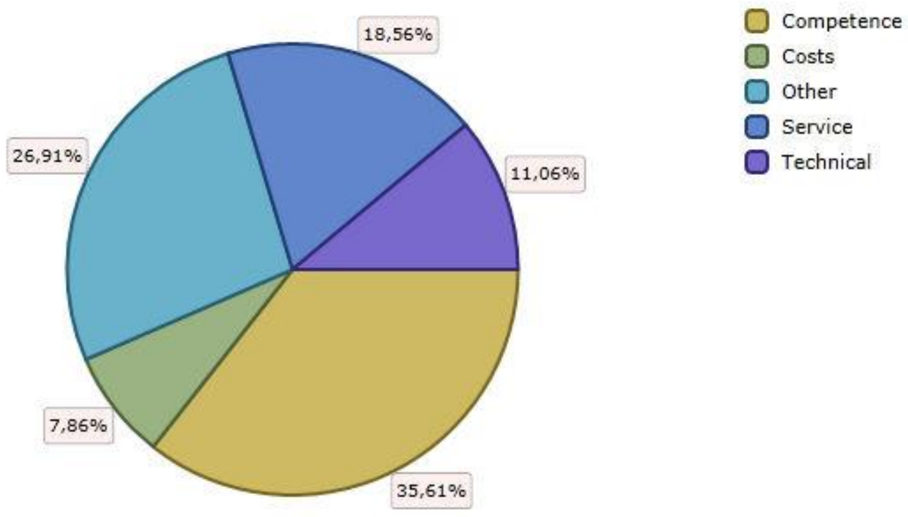

Figure 24. AHP criteria weights

These relations between different criteria were done using pair wise comparison. After the criteria and subcriteria were weighted the four different alternatives were compared against each other with another pair wise comparison. The final results of the AHP evaluation are shown in figure 25. The image shows the relative comparison between the alternatives and what criteria affected the result the most.

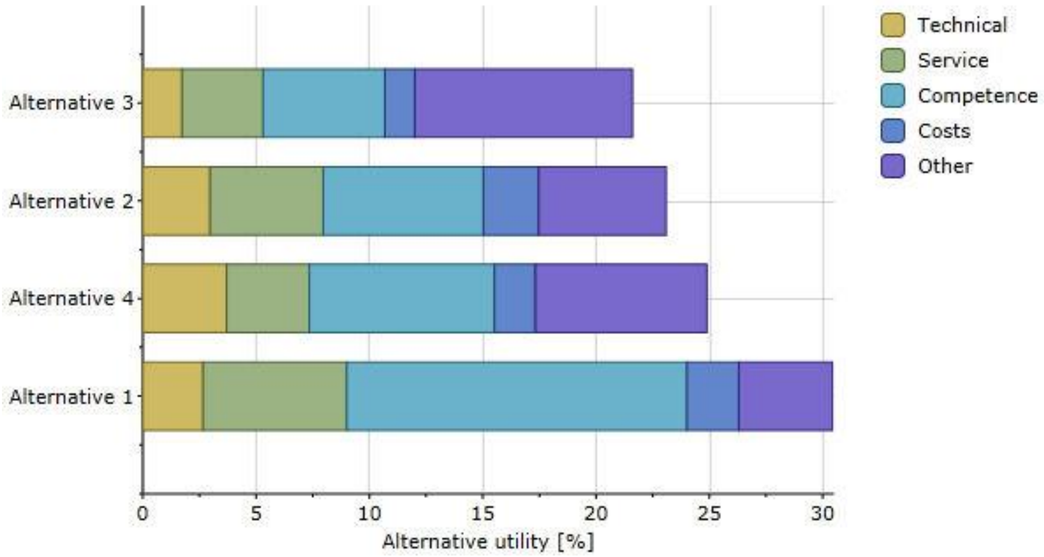

Figure 25. Results of AHP evaluation

Alternative 1 was the clear winner due to its good competences with elevator fire testing and the service it provided. These factors were also the highest valued properties in the criteria which ultimately led to this result. As also seen from figure 25, the cost and technical criteria did not play a large role in this comparison.

10 CONCLUSIONS

To provide awareness of the new process this chapter discusses the benefits of the new model and what could be improved further. In addition, what were the most important observations from the tested process and what are the steps that require the most attention.

10.1 Benefits of the new model

The benefits of creating this new system to evaluate fire testing methods come from making the process systematic and continuous. As the previous way was not systematic and it was not based on accurately defined criteria it was preventing optimal decisions from being made. These criteria can be used in the future to benchmark and review the current status of fire testing at KONE. A more urgent need comes from the current situation as KONE is mapping new candidates for KES 201 door family fire testing and the old certificates will expire in the near future.

By mapping a new, most optimal, fire testing service provider KONE can decide more easily whether it is useful to continue outsourcing the testing service or make an own facility. Now that the best candidate has been decided KONE can base the make or buy decision on the created criteria, and see whether it is possible to create an even better testing method than the best third party can offer.

Moreover, these evaluation tools and the process itself can be used for other purposes as well with a little modification. For example R&D can use these tools to evaluate the best manufacturer for a new product. The process is fairly similar as it follows the systematic decision making process pretty closely, basically just the criteria and weighting will change.

10.2 Improvement proposals

For improving the evaluation process further a new project chart could be created to show a timetable for each phase and who are responsible for these steps. In addition, a guiding document of the process would be the next step from this thesis to let others know how this process functions. Acquiring proper company-wide functioning AHP software that everyone at KONE could use would be beneficial to systemize important decisions throughout the company. This would require training on the software but in the long term it would be beneficial.

The involvement of necessary parties and units should be clarified in the first phase. By involving as many key people from different units the initial knowledge of testing providers increases and less research is required which leads to a shorter process lead time. Also, when people have formed contacts with the testing companies it is a lot quicker to acquire information from them which was also seen during the evaluation in this thesis. However, when there are a lot of people involved in of the process this could bring a lot of different opinions to the table, and harnessing all the data into a usable form could be complicated.

To go through the whole evaluation process it is important to point out the key people as stated in previous the chapter. If the project management is missing and the commitment to this process is weak it is highly unlikely that this process will succeed. This is unfortunately dependent on the work load of the people in charge of the process which ultimately affects to the success of the project, especially the lead time of the process. From the KONE Door Category team there should be one person appointed for this task who is responsible for managing and maintaining the process, and who also knows the process and the tools properly.

Due to the very specific technical requirements of elevator door fire testing methods there is no way to create a completely new way of conducting these tests. This is why evaluating the top testing service providers is important and emphasizing their competence and service quality. To further asses the top candidates it could be beneficial to pre-test a few doors in each of the top ranked laboratories to get a general feeling of the organization.

10.3 Observations

Finding information about suitable candidates was fairly easy due to EGOLF's database. The available information was enough for checking the locations and testing and certification accreditations for the first elimination round. The information required for ranking the candidates was more time consuming if no previous knowledge of the alternative was available. Time was used to make phone calls and exchange emails which was considered the most efficient method. Calling the laboratories was a quick way to find out about the accreditation to EN81-58 which was used as a must-have criterion, and establishing a direct connection for the follow-up emails. This human contact was considered an important issue in establishing a functioning and efficient relationship.

Choosing the best criteria and weighting the criteria was fairly time consuming, required a lot of technical expertise and previous fire testing experience. Choosing the evaluation method is beneficial to do before creating the criteria as it helps in determining the different criteria categories. Different evaluation methods also require knowledge them to use them properly. AHP-evaluation had not been used before and it was considered an interesting and useful tool. When ranking the alternatives the key is to remain objective and critical towards the favorite candidates.

Evaluation and selection phases were considered the most important parts of the process. The critical sections were especially defining and weighting the criteria, selecting the appropriate decision tool, and information gathering. To ensure the process does what it is intended the decision team must remain objective.

Even if the process is not followed completely it gives valuable knowledge about the possible testing laboratories which are available, what are the most important criteria to consider, what is the current situation, and is it feasible to continue outsourcing. In addition, introducing and getting to know new decision making tools can benefit other tasks as well.

11 SUMMARY

Fire testing of elevator landing doors is highly regulated by standards. The testing laboratories need to fulfill the required standards in order to conduct fire tests. In order to find the best method of fire testing one must first know the technical requirements and then evaluate the service of the candidates which fulfill the technical requirements.

The purpose of this thesis was to create a way to objectively evaluate the fire testing methods by defining necessary evaluation criteria and a systematic decision process. This process was based on systematic decision making and supplier selection literature. Based on these criteria it was possible to map new fire testing laboratories and then provide guidelines whether it would be sufficient to outsource, of if the laboratory should be built by the company.

The technical criteria defined what type of facilities were included in the evaluation with a few must have criteria. Some of these technical criteria were listed in the testing standard that this thesis focused on, the EN81-58 standard, and some were included as "good-to-have" properties. A list of candidates was formed by eliminating alternatives that did not meet the technical criteria. After that the service criteria were created to evaluate the testing service of the alternatives. The evaluation was first done with an Excel based evaluation tool. In this phase roughly fifteen alternatives were ranked and four top candidates were chosen for further evaluation. The final four alternatives were ranked using an analytic hierarchy process pair wise comparison and in the end there was one candidate that was better than the rest.

Information was collected by using the internet for a rough scan and then creating an Excel form that was then sent to different laboratories. Before sending the information collection form each candidate was phoned and emailed beforehand to make sure the contact information was correct and to establish a direct connection.

Defining the criteria and weighting them required a lot of technical expertise on fire testing. Also, choosing the optimal decision making tools required knowledge of these tools. Due to these matters it is beneficial to include experts from different fields in the decision making team so that all the steps in the process are conducted as efficiently as possible. The process consisted of five different phases and phases two and three were the most critical ones as they involved defining the criteria and evaluating the alternatives.

By creating a systematic process for evaluating elevator door fire testing services the evaluation process became structured, objective, and it was based on defined criteria which make the result more rational than if the decision would be based on intuition. Appointing key people to monitoring tasks allows continuous collaboration and improvement between the two parties, the company and fire tester.

Introduction to new decision making tools allows personnel to use them in other important decisions as well. The process itself can be used for other decisions as well as it is tightly based on systematic decision making practicalities. Moreover, the process brings people together to think about the different aspects involved in fire testing and makes the evaluation and monitoring of fire testing more transparent.

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INTERVIEWS

Harri Anttila, Senior Expert

APPENDIX 1

Weighted-sum multi-objective evaluation with MS Excel

	Complete evaluation of fire testing services	Weighting	Alternative 1	Alternative 2	Alternative 3	Alternative 6
Technical		**0,15**				
	Capacity (Annual maximum capacity/simultaneous tests)	0,3	2	5	2	2
	Age of facility	0,2	2	1	4	3
	Size of testing oven	0,3	3	3	4	3
	Suitability for elevator doors (wall and oven construction etc.)	0,2	3	4	3	4
	Total score	1	2,5	3,4	3,2	2,9
Service		**0,2**				
	Lead time for fire tests	0,2	4	3	5	2
	Lead time for test reports	0,25	2	3	5	2
	Lead time for certificate	0,2				
	Schedule flexibility	0,15	2	5	4	5
	Installation easiness and safety	0,2	3	3	1	5
	Total score	1	2,2	2,7	3,05	2,65
Competences		**0,25**				
	Elevator know-how	0,5	2	5	1	2
	Accreditation to other fire tests (BS, UL, IMO)	0,1	3	4	5	2
	Accreditation: Inspection ISO 17020	0,1	1	3	3	5
	Accreditation: Certification EN 45011	0,3	2	5	3	1
	Total score	1	2	4,7	2,2	2
Costs		**0,15**				
	Testing costs	0,45	2	3	5	3
	Additional costs	0,3	5	3	2	4
	Logistical costs	0,1	3	5	2	2
	Certification costs	0,15	5	5	3	1
	Total score	1	3,45	3,5	3,5	2,9
Other		**0,25**				
	Willingness to commit and learn	0,3	3	5	2	3
	Reputation	0,25	2	5	2	2
	Management capabilities	0,15	4	3	4	2
	Financial status	0,3	5	3	3	2
	Total score	1	3,5	4,1	2,6	2,3
	Grand total	**1**	**2,7**	**3,8**	**2,8**	**2,5**

APPENDIX 2

Information collection form created with MS Excel

Facility	Capacity (Annual maximum capacity)	5 full scale fire tests
	Age	Founded 1950, modernized 1999
	Size of testing oven	2x full scale test owens, 5m x 5m x 4m
	Suitability for elevator doors	Yes, tests since 1994
Service	Lead time for fire test	2 months from technical clarification
	Lead time for test report	1 month after fire test
	Lead time for statement and certification	1 month after documentation clarification
	Other elevator companies as customers	yes
	Installation equipment	forklift, crane and tools available
	Personnel available at fire test	2 specialists, 6 operative, 1 manager
	Flexibilty	higher priority with extra payment (lead time)
Competences	Elevator know-how	swing- , automaticdoor and materials firetesting
	Accreditations	yes, ISO 17025 and EN 45011
	Accreditation: EN81-58	yes
	Accreditation: BS476: part 22	yes
	Accreditation: IMO MCS61/67	yes
Costs	Testing costs, full scale	5000 €, 2 tests at once 8000€
	Testing costs, small scale	2 000 €
	Testing costs, materials (eg. Insulation materials and glass)	2 000 €
	Additional costs	evaluation/meeting preparation 50€/h
	Certification costs	1 500 €
Other	Will to commit	yes, willing to accredit missing standards
	Will to learn	yes, willing to study elevator structure
	Recommendations	Recommendations from Wittur, Otis etc.
	Other	

Example

APPENDIX 3

Analytic hierarchy process evaluation hierarchy chart