Measuring trust in buyer-seller relationships: Design of a prototype fuzzy model

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i Abstract

In recent years technological organizations, often characterized by a high supply risk in their supply chain, have an increased motivation to build long term relationships with their suppliers. The performance of suppliers is regarded as an indicator for the trust level in business relationships. However in current supplier evaluation methods, performance is never linked to inter-organizational trust. A fuzzy model, suitable for quantitative analysis of the performance of a supplier and how this reflects the trust level, was designed and evaluated by five procurement experts from technological organizations. A sensitivity analysis of the model and feedback from the business environment suggest that evaluation of a supplier in terms of trust is suitable for predicting the behavior of a supplier in a long term relationship. The proposed fuzzy model is expert-driven and in future research focus on the design of a data-driven (neuro-)fuzzy model may lead to further improvements.

Keywords: buyer-seller relationships, inter-organizational trust, fuzzy model

ii Executive summary

In recent years the role of suppliers in the supply chain has shifted. Traditionally, a contract between the organization and a supplier simply prescribed all duties of the involved parties. Nowadays, organizations demand pro-active behavior from their suppliers in order to improve the business relationship in the long term. Many different methods exist for the evaluation of suppliers in terms of performance. These methods mostly cover both qualitative and quantitative aspects. Although, qualitative aspects certainly play a role in business relationships, they have an emotional dimension too. The role of emotion in the evaluation of a supplier may obscure the final verdict regarding the performance of that supplier. Furthermore, in current literature is described that organizations may benefit from stable long term business relationship, especially organizations with a high supply risk. Scholars indicate that for the commitment of these organizations in long term relationship with their suppliers, inter-organizational trust is one of the most important aspects. However, currently no method is found that relates supplier performance directly to inter-organizational trust on solely quantitative grounds. Therefore, this master thesis research has the following objective.

"The design of a model which enables organizations to quantitatively evaluate trust relationships with their suppliers."

The model is designed by the input of five procurement experts from industries characterized by a high supply risk. The final model is rooted in fuzzy theory and evaluates the key aspects (i) cost level, (ii) service level, and (iii) quality level by means of several quantitative key performance indicators. The number of key performance indicators for each level is four, four, and three, respectively. The key performance indicators are assigned an individual weight factor by the experts and according to these weight factors a rule base is formulated. The rule base prescribes a (fuzzy) output for the three trust levels, which is called the trust performance. Additionally, the experts have assigned the three trust levels a weight factor, from which a second rule base formulated. The three trust performances are used as input factors for this second layer of the model. The application of the second rule base to these input factors results in the overall trust level for a specific supplier. An organization may rank their suppliers according to their overall trust level and find the current status of their supply base. However, the model primarily enables organizations to identify bottlenecks at suppliers, which need to be at a certain level before committing their selves in long term business relationship with these suppliers. Moreover, the identification of bottlenecks may lead to the establishment of an improvement plan in order to get the supplier at the required trust level. Especially in business environments with a high supply risk an improvement plan is recommended, since organizations often are dependent on certain suppliers. Still, the fuzzy model has its limitations and needs further research. The main focus of this master thesis research project is on the design of the model. The implementation of the model in the business environment is out of scope. Furthermore, the expansion of the pool of experts may reveal similarities and discrepancies between the viewpoints on inter-organizational trust across industries. This helps to fit the model to the characteristics of the different business environments. Lastly, the sensitivity analysis in Matlab and the feedback from the experts indicate satisfactory robustness, correctness, and simplicity for a prototype model with the potential to improve. For example, the focus on testing and training the model against corporate data may result in the design of a data-driven (neuro-) fuzzy model which is capable to adapt to changing environments, like different industries. Nevertheless, this master thesis indicates that the topic does belong on the agenda of both scholars and organizations.

iii Preface

"Candid and generous and just. Boys care little whom they trust.
An error soon corrected – for who but learns in riper years.
That man, when smoothest he appears, is most to be suspected?"

- William Cowper -

The research project reported in this master thesis finalizes my academic study which commenced in September of the year 2005. However, my graduation may not have happened if I had not had several persons in my vicinity. At first, I would like to thank my supervisor, Jan van den Berg. I already started as graduation intern at KPMG, when I luckily got in contact with Jan. If I got stuck somewhere along the line, a short meeting always cleared my mind on how I should proceed, until the moment I got stuck again. Your ideas, your criticism, and your enthusiasm about fuzzy theory all contributed greatly to this master thesis. Secondly, I thank Ron Keur from KPMG. The effort you have put into supervising me for my six months at KPMG, I highly appreciated. In the third place, I kindly thank my co-reader Sander van Splunter for the constructive feedback on the topic and the designed model which further improved my master thesis. Furthermore, some important persons from outside the University contributed significantly to my graduation too. Most evidently my parents, who have continuously stimulated me to make the best out of myself. Secondly, people I encountered during the past years and now call friends. Last, I would like to thank Lisette. You slowed me down when I intended to recklessly rush into something and you motivated me when I lost my discipline. Thank you for being there, whenever I needed you.

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1 Introduction

The topic and background of this master thesis are introduced to concretize the research problem. The objective, methodology, and delimitation shapes the research framework in order to solve the research problem.

1.1 Background

1.1.1 Procurement

The acquisition of goods and services from other parties by organizations is called procurement. Traditionally, the procurement department negotiated the agreements and contracts with suppliers and evaluated their compliance to the contracts (Weele, 2010). However, a shift towards a more extensive role of the procurement department has taken place. Currently, procurement managers have taken a more strategic role, demanding better performances of their suppliers and managing the relationships with these suppliers more actively (Weele, 2010).

General procurement process

Every industry has its own characteristics and organizations have adjusted their procurement process to these characteristics. The procurement process has two distinctive elements. First, a procurement process starts with the identification of one or more suppliers that are capable to deliver the desired product. These suppliers are reviewed whether or not they are up to the standards of the organization. If not, a supplier is dropped from the selection process. Eventually, one or more suppliers are selected to start a business relationship. The second element is the evaluation of a supplier following the execution of the business. During this evaluation a supplier is reviewed whether or not it complied to all agreements. In case a supplier does not pass this evaluation step, the supplier is removed from the approved suppliers list. On the other hand, if the business with a supplier benefited the organization, the supplier qualifies as a potential long term business partner. The result is that the follow-up of this procurement process involves an intensification of the business relationship. Figure 1 visualizes the two elements of the procurement process. The six components of the initial procurement process and the evaluation are identified by Weele (2010).

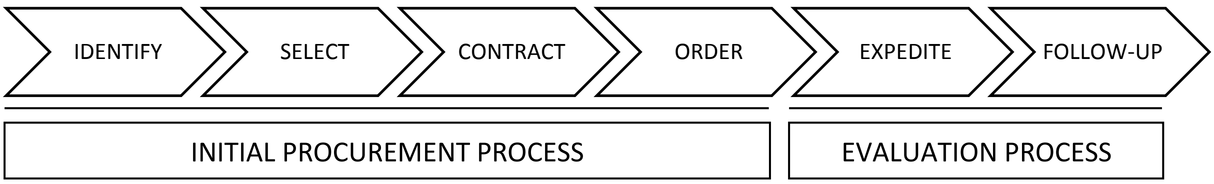

Figure 1. Overview of general procurement process (based on: Weele, 2010).

The four components of the initial procurement process are important, because the selection and the contracting of a high performance supplier may benefit the organization (Wuyts & Geyskens, 2005). However, the evaluation has a much higher impact on the organization. The initial procurement process relies mainly on speculations about the performance of a supplier, whereas in the evaluation the organization is capable to review its own experience with that supplier and whether or not the supplier really fulfilled the organization its expectations. Therefore, a sound evaluation method is therefore a necessity for each organization in order to establish a pool of high performance suppliers.

General supplier evaluation process

During the expediting and follow-up of the procurement process, the performance and attitude of the supplier as potential long term partner is evaluated. As mentioned, procurement managers are demanding higher performances from their suppliers and a fast check on whether or not the supplier complied to the contract is not a sufficient evaluation method anymore. Many different evaluation methods exist nowadays (e.g., Çelebi & Bayraktar, 2008; Wu & Blackhurst, 2009). The vast amount of evaluation methods generally contains similar components. The seven step approach by Gordon (2005) describes a full-fledged supplier evaluation in general terms.

1. Align supplier performance goals with organizational goals and objectives.
2. Determine an evaluation approach.
3. Develop a method to collect information about suppliers.
4. Design and develop a robust assessment system.
5. Deploy a supplier performance assessment system.
6. Give feedback to supplier on their performance.
7. Produce results from measuring supplier performance.

Whereas in the past compliance to agreements and contracts were leading in supplier evaluations, in the approach by Gordon (2005) they are only part of the bigger picture. Organizations may include whatever factor they find important with respect to their own goals and objectives. Nevertheless, it is key for an organization to select only those factors that truly reflect the performance of the supplier in a business relationship.

1.1.2 Buyer-seller relationships

In the past, buyer-seller relationships were seen rather as necessities than as potentially profitable processes. Since the introduction of new manufacturing practices, like *just-in-time manufacturing*, a new emphasis on supply base reduction came around (e.g., Weber, Current & Benton, 1991; Pearson & Ellram, 1995). As a consequence organizations worldwide pushed off part of their suppliers and tightened the relations with their remaining suppliers. The selection of suppliers became a strategic decision with the ability to maintain contact with only those suppliers that would benefit the business. To safeguard the organization its interests it is important to evaluate all suppliers periodically to determine whether or not expectations are being fulfilled and strategic alignment is still in place. If not, an attempt could be made to improve the performance of the supplier. In case this attempt fails, it might be better to end the business relationship. Therefore, supplier evaluations can be used to minimize risks and maximize the overall value for a customer (Zeydan, Çolpan & Çobanoğlu, 2011). The existence of this strategic potential of buyer-seller relationship management is also indicated by several other studies (e.g., Talluri & Sarkis, 2002; Sarkar & Mohapatra, 2006; Gordon, 2008). Furthermore, buyer-seller relationships where performance is paramount and performance is reviewed frequently are more successful than those relationships with less emphasize on performance (Laarhoven, Berglund & Peters, 2000). In order to determine the healthiness of a buyer-seller relationship, one should be able to measure and analyze the relationship.

Measuring the buyer-seller relationship

Nowadays, many different metrics regarding suppliers are being measured by organizations at different time intervals. Most of these metrics just measure non-critical business processes, whereas only some metrics reflect true strategic value drivers (Bauer, 2004). This kind of metrics are in fact Key Performance Indicators (KPIs), defined as quantifiable metrics measuring the performance of the organization in achieving its objectives (Bauer, 2004). The selection of the right KPIs from the total pool of metrics is necessary in performance management. Designating metrics wrongly as KPI can result in strategically disadvantageous decisions from supplier evaluations (Bauer, 2004). In this thesis the focus is on trust in buyer-seller relationships, so the selected KPIs to measure the performance of the supplier should reflect the concept trust accordingly.

1.1.3 Trust

Understanding of the concept trust is crucial for the selection of an appropriate set of KPIs that measures the trust performance of the supplier in a supposed buyer-seller trust relationship. The trust literature is ambiguous on how trust should be defined. Some scholars in the field view trust as a behavioral intention (Rousseau, Sitkin, Burt & Camerer, 1998). Others treat trust as a synonym for trustworthiness (McKnight et al., 1998). Still others reflect on trust as synonymous with cooperation and risk taking (Lewis & Weigert, 1985). These different viewpoints complicate the operationalization and direct measurement of trust enormously, although it remains an important task in order to link trust to performance (Sako & Helper, 1998). Furthermore, the difficulty does not only lie in the operationalization of trust but trust appears in different contexts too. Scholars have been distinguishing between personal trust (Rotter, 1980) and organizational trust (Schoorman, Mayer & Davis, 2007) and separated the latter type of trust even further into contractual trust, competence trust, and goodwill trust (Sako, 1992). Yet other scholars argue that trust requires categorization into the two dimensions cognitive trust and affective trust (e.g., Johnson & Grayson, 2005; Massey & Kyriazis, 2007). All in all, it seems that due to the comprehensiveness and complexity surrounding trust the current literature does not provide a conclusively clear approach to operationalize (organizational) trust.

1.2 Problem analysis

The background knowledge indicates that organizations may benefit from periodic supplier evaluations. In order to perform supplier evaluations a set of metrics must be selected which reflect the performance of a supplier. In the literature metrics to measure the performance of a supplier have been widely described in terms of inventory levels, lead times, quality controls, and financial indicators (Gordon, 2008). In fact all these metrics could be KPIs, but only if these metrics satisfy at least two requirements within the organization itself: a metric only passes as a true KPI if the metric (i) reflects a strategic value driver and (ii) is aligned with the vision and the goal of the organization (Bauer, 2004). Therefore, an organization needs to assess its own operations first before determining on KPIs to evaluate the performance of its suppliers. A substantiated set of KPIs may help the organization to identify suppliers which will add value to the organization and thus are eligible for long term business relationships (Gordon, 2008).

The common goal: trust

Although in daily business organizations have different goals, theoretically, organizations around the globe strive for a common goal. Scholars agree that the ultimate glue between organizations is trust (e.g., Costigan, Ilter & Berman, 1998; Claro, De Oliveira Claro & Hagelaar, 2006). Moreover, trust is ubiquitous in business relationships even though contractual agreements exist. Lindenberg (2000) argues unforeseeable events often occur in which the other party may circumvent the contractual agreements. Although both parties are aware of this possibility, they do trust the other party and commit their selves in a business relationship.

The common problem: trust

The development of buyer-seller trust relationships may benefit the business, but does not prevent the supplier to behave opportunistic. The execution of opportunistic behavior by the supplier might incur high costs for the organization as trust is breached. These costs are known as relationship termination costs (Morgan & Hunt, 1994) and resembles the prisoners' dilemma (Kreps, Milgrom, Roberts & Wilson, 1982). In order to minimize the likelihood that a supplier will enact opportunistic behavior, an organization should be able to evaluate whether or not the supplier can be trusted. However, due to the unambiguity in the current literature about trust, the selection of KPIs is complicated, and a supplier evaluation based on the common notion trust is rather troublesome.

1.3 Objective

The following objective is formulated to have a clear direction while addressing the research problem. The end of this thesis project is marked by a discussion in which the final result is evaluated regarding the achievement of this objective.

"The design of a model which enables organizations to quantitatively evaluate trust relationships with their suppliers."

The model will be used to predict the suitability of suppliers for strategic long term buyer-seller relationships based on historical data available in the own organization. Additionally, a good trust relationship with a particular supplier may serve as a template for improving a poor trust relationship with a supplier.

1.4 Methodology

In this thesis project, the goal is to design a model that enables organizations to evaluate the trust relationships with their suppliers. The approach to reach this goal is outlined in this section. A visual representation is presented in Figure 2, page 13.

First, the context of and the relation between trust and the performance are described on a high-level. This knowledge is later used to operationalize trust in business relationships between organizations and suppliers. The current literature on trust and supplier evaluations forms the input for this initial step.

Second, the operationalization of trust in business relationships comprises the identification of important aspects for the establishment of a trust relationship. The initial input for this step is the knowledge about the relations between trust and supplier performance from the current literature. Additionally, expert knowledge is used for the fine-tuning of the operationalization. The operationalization is visualized in a conceptual model, Figure 4 on page 18.

Hereafter, the requirements for the final model are formulated. According to these requirements the design method is selected. Furthermore, the functioning of the selected design method is explained in detail. The input for this step is current literature on design methodologies and expert knowledge.

The fourth step is the design of the model. The process starts with the identification of the input and output factors, followed by the other elements necessary to design the model. Experts provided the input for the design of the model.

The fifth step, a sensitivity analysis is performed to evaluate the functioning of the model. Additionally, the experts reviewed how the final model reflected their individual input.

The last step is a discussion of the design of the model. This discussion comprises a reflection on the design procedure, a reflection on the earlier formulated requirements, and the recommendations for future research.

1.5 Delimitation

The broadness of trust in buyer-seller relationships complicates the operationalization of the concept. The operationalization is simplified by scoping the objective. In order to have a clear view of what is in scope and what is out of scope, the delimitation is separated in these two sections respectively.

1.5.1 In scope

This thesis aims at trust relationships in a procurement context. More specific, during the evaluation in a procurement process a supplier is reviewed whether or not the supplier is suitable as a long term business partner. Trust is an important asset in long term relationships and the establishment of a trust relationship depends on the performance on several aspects. The scope of this thesis is the identification of these aspects and the design of a model to evaluate these aspects quantitatively. This model is expert-driven, but a roadmap for future research towards a data-driven model is provided.

1.5.2 Out of scope

The execution of the follow-up steps in the roadmap towards a data-driven model are out of scope. These steps comprise the testing, the training, and the validation against corporate data.

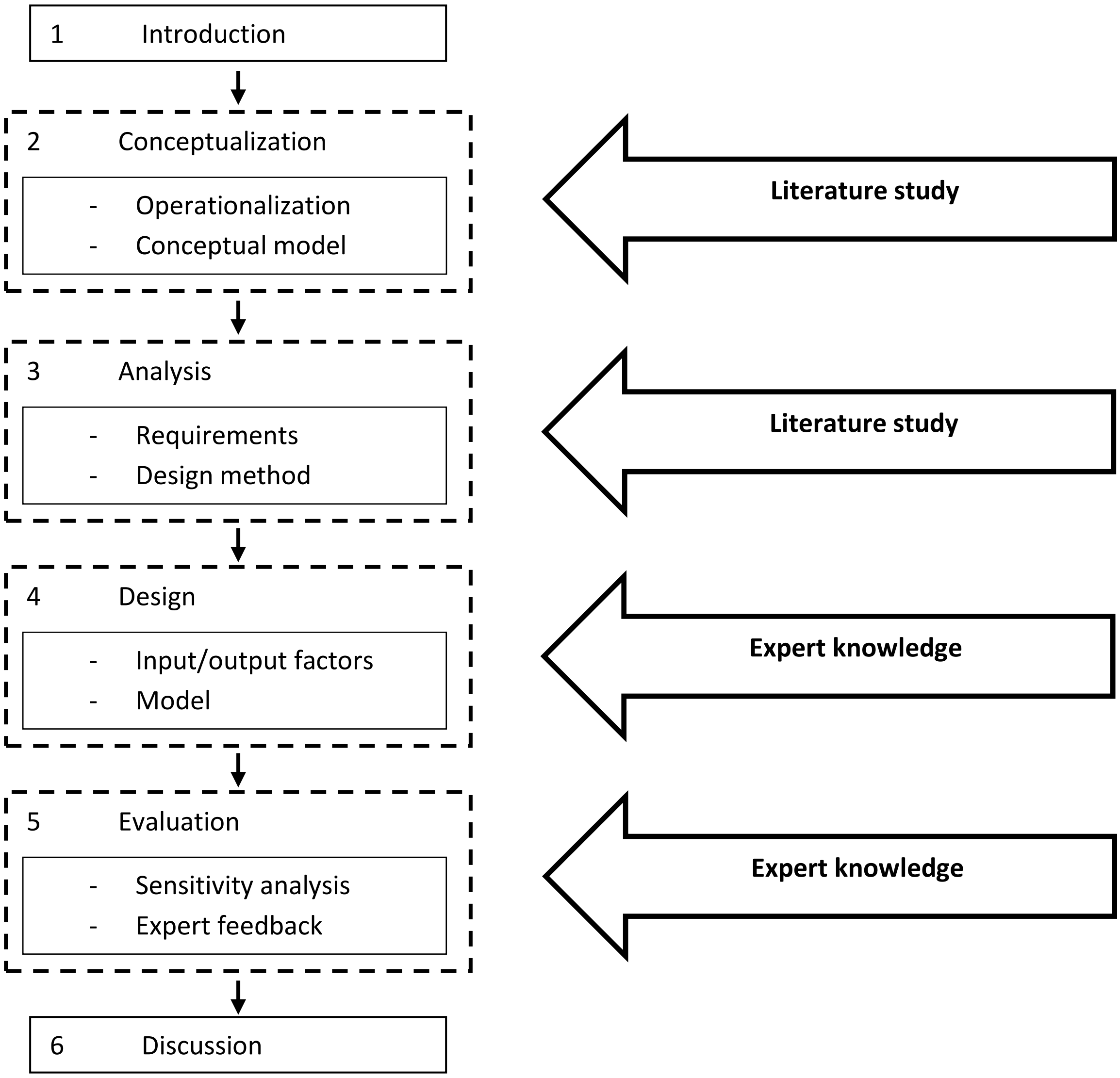

Figure 2. The methodological approach.

2 Trust in business environments

The conceptualization of trust in supplier evaluations is described. The conceptualization provides in-depth knowledge, an operationalization, and an outline of the conceptual model.

2.1 Context

Trust relationships between organizations and their suppliers is rather broad definition of the topic of this thesis. The following paragraphs provide detailed descriptions of buyer-seller trust relationships and the business environment at stake to promote a better understanding of the context in which this thesis is conducted.

2.1.1 Buyer-seller trust relationship

A trust relationship is described by the willingness of one party or trustor to rely on the actions of another party or the trustee (Schoorman et al., 2007). A trust relationship is often directed towards the long term, in which the trustor accepts the risk that the trustee may behave opportunistic in the future. In order to control that risk, the trustor assesses the trustee continuously on several expectations. The satisfaction of these expectations by the trustee forms the basis for a trust relationship. Whereas psychologists tend to focus on inter-personal trust (Rotter, 1980), organizations focus on inter-organizational trust (Sako & Helper, 1998). In an organizational context, like a buyer-seller trust relationship, an organization would be the trustor and its supplier the trustee. In that setting the organization has formulated a set of expectations regarding the performance of its suppliers in accordance with its own vision and strategic goals (Bauer, 2004). With respect to the objective of this thesis, the two key elements are (i) the identification of expectations regarding the performance of a supplier, and (ii) how these expectations relate to trust in buyer-seller relationships.

2.1.2 Business environment

The products at stake in buyer-seller relationships may be characterized by their financial impact on, and the supply risk for an organization. Kraljic (1983) proposed a purchasing portfolio approach to establish purchasing strategies for different types of products. The two by two matrix in Figure 3, page 15, is a modified visualization of this portfolio approach as used by many others (e.g. Andersson & Norrman, 2002; Caniëls & Gelderman, 2007). The four quadrants represent the types of products in terms of their respective financial impact and supply risk.

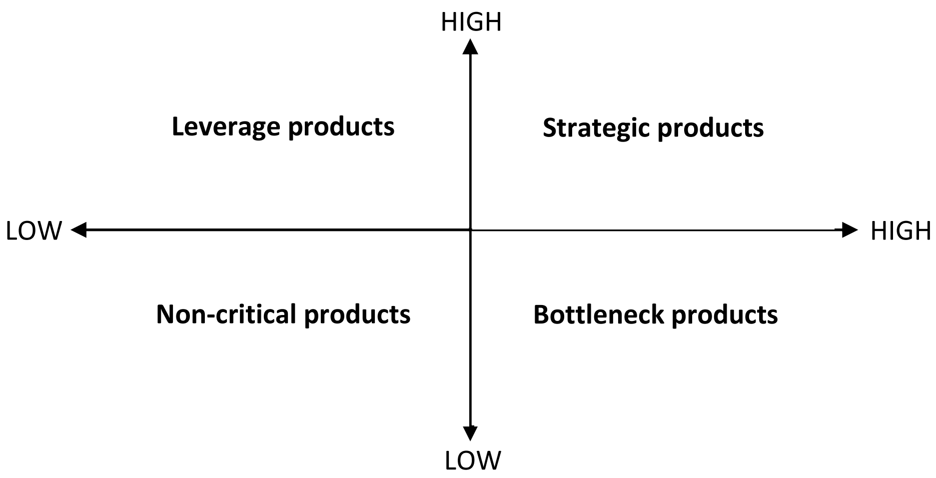

Figure 3. The purchasing portfolio matrix with (*vertical*) the financial impact and (*horizontal*) the supply risk (modified from: Kraljic, 1983).

In environments where the supply risk is low, organizations have an advantageous position with respect to their suppliers. Leverage products and non-critical products can be obtained from many alternative sources and business relationships are primarily established for financial benefits or routine (Caniëls & Gelderman, 2007). On the other hand, a high supply risk motivates organizations to intensify the business relationship with suppliers in order to secure future supply of their goods. Accordingly, the supplier benefits from the intensification of the business relationship too, because the turnover generated by the organization is more likely to sustain. Moreover, the high supply risk creates a highly interdependent environment in which trust and commitment are very important (Geyskens, Steenkamp, Scheer & Kumar, 1996). For example, a technological industry resemble a business environment with a high supply risk, because low-quality or late deliveries for instance already may incur high costs due to loss of work-in-process, production delays, and switching costs (Mayer, Nickerson & Owan, 2004). Therefore, the experts who provided the input for the design of the model are active in technological industries (e.g., biotechnological, petrochemical, and aviation).

2.2 Inter-organizational trust

Buyer-seller trust relationships are related to organizational trust. The operationalization of organizational trust requires further investigation in aspects underlying this type of trust. A more differentiated view of organizational trust may reveal possibilities to specify concrete metrics or KPIs. As buyer-seller trust relationships evolve between organizations, this type of trust relationships are rather explained as inter-organizational trust. Sako (1992) made an attempt to further delineate inter-organizational trust. The result was the identification of three subtypes of inter-organizational trust and referred to them as contractual trust, competence trust, and goodwill trust. Furthermore, other scholars proposed the existence of two dimensions of trust in a business environment (e.g., Doney & Cannon, 1997; Johnson & Grayson, 2005; Massey & Kyriazis, 2007). These two dimensions are named cognitive trust and affective trust. The following sections describe the three subtypes and the two dimensions of trust to get a grasp of the notion inter-organizational trust. The resulting conceptual model of trust in long term buyer-seller relationships is presented in Figure 4, page 17.

2.2.1 Contractual trust

The trust resulting from contractual agreements is named contractual trust and covers the expectation that a particular supplier complies with these contractual agreements (Sako, 1992). Contractual trust is particularly important in developing business relationships, because trust problems are most likely to arise in the initial stage of the business relationship. Ruiter, Lippe and Raub (2003) describe trust problems in relation to uncertainty about competence and values. Moreover, trust problems create possibilities and even function as incentives for opportunistic behavior by suppliers. To overcome initial trust problems the establishment of a contract may be useful (Sitkin, 1995).

2.2.2 Competence trust

As mentioned above, trust problems are related to the competence of a supplier (Ruiter et al., 2003). Initial uncertainties about the competence of a supplier may be covered by the contract prescribing procedures in case the supplier turns out to be incompetent. However, a request to include all possible events resulting from incompetence of the supplier gives the impression of a non-cooperative attitude on the account of the organization (Lindenberg, 2000). Sako (1992) referred to trust resulting from proven competence as competence trust. Moreover, competence trust reflects the expectation that a supplier is capable of doing what it claims it will do. The dependency of an organization on the competence of the supplier and the inability to include all competence-related events in a contract advocate to monitor the overall competence separately from the contractual agreements. The use of competence trust complementary to contractual trust to evaluate inter-organizational trust is argued by Lui and Ngo (2004).

2.2.3 Goodwill trust

Simultaneous to the use of competence trust, Lui and Ngo (2004) investigated the contribution of goodwill trust in the performance of an supplier too. They found empirically that goodwill trust and contractual agreements serve as substitutes for each other. Goodwill trust was distinguished by Sako (1992) as third subtype of inter-organizational trust. This trust reflects the expectation that a supplier will deploy a proactive attitude towards mutual beneficial initiatives. Although goodwill trust and contractual agreements are regarded as substitutes, this does not directly imply that goodwill trust is redundant in cases where a business relationship is sealed with contractual agreements. Instead, an emphasis on goodwill trust is advocated in business environments with typically less contractual agreements (Lui & Ngo, 2004).

2.2.4 Cognitive and affective trust

Additional to the three subtypes of inter-organizational trust, scholars posit that trust is either cognitive or affective in nature (e.g., Doney & Cannon, 1997; Johnson & Grayson, 2005). These two dimensions are opposites with on the one hand cognitive trust which is based on a rational approach, like the performance of a supplier. On the other hand affective trust is determined by emotions, like the enjoyment of the relationship with a particular supplier. Nevertheless, Johnson and Grayson (2005) found that both cognitive and affective trust contribute significantly to the willingness to engage in a long term business relationship. However, rational considerations by the involved parties diminish once competence, integrity and dependability are established (Massey & Kyriazis, 2007). Since both cognitive and affective trust contribute significantly to decision-making processes about future long term relationships with suppliers, a diminished rational contribution is detrimental to the decision-making. With the proposed model an attempt is made to secure the observance of cognitive considerations in decision-making regarding future long term buyer-seller trust relationships.

2.3 Operationalization

In the problem analysis, section 1.2, the operationalization of trust for usage in supplier selection methods was identified as troublesome due to the ambiguity among scholars about how trust should be defined. The reviewed literature provides an approach to overcome this ambiguity by subdividing inter-organizational trust into contractual trust, competence trust, and goodwill trust. However, the operationalization of inter-organizational trust in a procurement context further requires insight in what characterizes buyer-seller relationships.

2.3.1 Selection of trust levels

The vast amount of metrics measured in an organization complicates the direct selection of KPIs (Bauer, 2004). This corresponds with current literature in which many different metrics for measuring the performance of a supplier are described (e.g. Gordon, 2008; Gunasekaran, Patel & McGaughey, 2004). Gunasekaran et al. (2004) distinguishes between the four basic activities in a supply chain, being (i) planning, (ii) source, (iii) production, and (iv) delivery. Their empirical study included a questionnaire to find what respondents across various industries experience as important metrics to measure the performance of a supplier. The results are four lists with metrics ranked as highly important, moderately important, or less important. The metrics indicated as highly important and moderately important are presented in Table 1.

Table 1. *List of metrics indicated as highly and moderately important in the study by Gunasekaran et al. (2004) with (left) the four basic activities in a supply chain, and (right) the identified metrics*.

Planning	Level of customer perceived value of product, variances against budget, order lead time, information processing cost, net profit vs. productivity ratio, total cycle time, total cash flow time, customer query time, product development
Source	Supplier delivery performance, supplier lead time against industry norm, supplier pricing against market, efficiency of purchase order cycle time
Production	Percentage of defects, cost per operation hour, capacity utilization, range of products and services
Delivery	Quality of delivered goods, on time delivery of goods, flexibility of service systems to meet customer needs, effectiveness of enterprise distribution planning schedule, effectiveness of delivery invoice methods, number of faultless delivery notes invoiced, percentage of urgent deliveries, information richness in carrying out delivery

Although the highly and moderately important metrics are categorized into planning, source, production, and delivery, metrics resembling the same aspect are scattered over the four basic activities. A quick look at the metrics learns that they all represent indicators for either the cost level, the service level, or the quality level of the supplier. Furthermore, the identified metrics by Gunasekaran et al. (2004) correspond with findings by Gordon (2008) and Ho, Xu and Dei (2010).

Their studies indicate that the supplier performance is most often evaluated by measuring the performance on inventory levels, lead times, quality control, and financial indicators. Obviously, these metrics relate to the cost, service and quality level too. Therefore, a new categorization of the metrics into the cost, service and quality level is made. In the following sections these levels are referred to as trust levels. Table 2 outlines the new categorization.

Table 2. *Overview of the trust levels with (left) the three levels and (right) the corresponding metrics*.

Cost level	Level of customer perceived value of product, variances against budget, information processing cost, net profit vs. productivity ratio, , total cash flow time, supplier pricing against market, cost per operation hour, effectiveness of delivery invoice methods, number of faultless delivery notes invoiced
Service level	Order lead time, total cycle time, customer query time, supplier delivery performance, supplier lead time against industry norm, efficiency of purchase order cycle time, capacity utilization, range of products and services, on time delivery of goods, flexibility of service systems to meet customer needs, effectiveness of enterprise distribution planning schedule, percentage of urgent deliveries, information richness in carrying out delivery
Quality level	Product development, percentage of defects, quality of delivered goods

2.3.2 Conceptual model

The interpretation of the three trust levels is subject to the three subtypes of inter-organizational trust. In Figure 4 the conceptual model is presented. The input of the model are the contractual, competence and goodwill trust KPIs. At least one of each subtype of trust is present for each trust level. In the first layer these KPIs are evaluated, which results in a trust performance for each trust level. In the second layer the trust performances function as the inputs for the second layer. The final outcome is the overall trust level for a particular supplier.

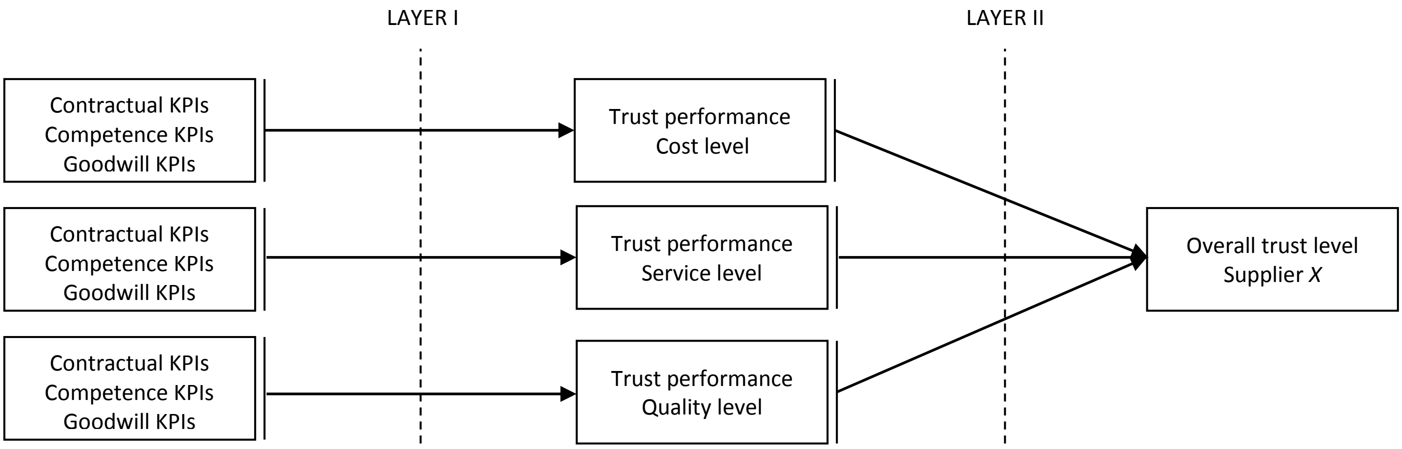

Figure 4. The conceptual model with (*left*) the trust KPIs for the cost level, service level, and quality level, (*middle left*) the first layer of the model, (*middle*) the trust performances for each level, (*middle right*) the second layer of the model, and (*right*) the final output.

3 Analysis

The requirements for the model are identified. An appropriate design method is selected with regards to these requirements. The motivation and the methodological approach are discussed accordingly.

3.1 Requirements for the model

The model is aimed for implementation in procurement departments of organizations. These organizations should be able to establish a follow-up plan according to the output of the model. In order to establish that plan, the organization must interpret the output. Depending on how the organization interprets the output, the relationship with a supplier is terminated or intensified. The high impact of the output requires that the interpretability of the model is unambiguous. However, interpretability is regarded as the antagonist of accuracy. This is known as the interpretability-accuracy dilemma (Glorennec, 2004). To illustrate, suppose one tries to model the speed of a parachutist in a free fall. A linear model would result in the average speed which is highly interpretable, however in real-life the parachutist its speed is not constant but increases during the free fall. Therefore, the linear model is not very accurate for estimating the speed on different times during the free fall. In order to improve the accuracy one should use a more complex or less interpretable model. Therefore, a trade-off between interpretability and accuracy must be made. Since the input for the design of the model is provided by experts the interpretability of the model is already rather high. To prevent the accuracy to diminish several other requirements are identified. These requirements are robustness, correctness, and simplicity. The following paragraphs further discuss why these requirements are selected.

3.1.1 Robustness

The business environment benefits from a robust model for several reasons. First, if the output is completely different every time the input changes little, the interpretability of the model is negatively affected. In other words, similar inputs should result in similar outputs. Secondly, a robust model is able to cope with uncertainty resulting from faulty inputs. So, despite one or more input numbers are erroneous or even missing, the model produces sensible outputs. The fulfillment of this requirement is evaluated by means of the sensitivity analysis.

3.1.2 Correctness

Due to the high impact of the evaluation process the model should be correct, meaning that the aspects incorporated in the model truly reflect inter-organizational trust between an organization and a supplier. Because, if the model is not correct the organization interprets the output wrongly which on its turn may result in adverse follow-up actions. For example, the output indicates a bad trust relationship with a particular supplier while in fact the supplier is highly suitable as a long term business partner. Then the organization may decide to terminate the business relationship and to start a new initial procurement process with all associated costs, whereas actually the organization should have been investing in tightening the ties with that supplier. The fulfillment of this requirement is evaluated by means of the sensitivity analysis and the experts.

3.1.3 Simplicity

The requirement that the model should be simple is best explained by the principle of parsimony, often referred to as Occams' razor (Blumer, Ehrenfeucht, Haussler & Warmuth, 1987). This principle promotes the usage of hypotheses with minimal complexity. Translating this to the objective of this thesis, the principle of parsimony implies that the model should be designed with the least amount of indicators to evaluate buyer-seller relationships. However, these indicators should reflect inter-organizational trust completely. The fulfillment of this requirement is evaluated by the experts.

3.2 Selection of design method

As mentioned, the identification of KPIs for the three trust levels, to evaluate inter-organizational trust, must correspond with the strategic vision of the organization (Bauer, 2004). However, both trust and strategic visions are most often expressed in linguistic terms instead of crisp numbers (Fodor, Perny & Roubens, 1998). This calls for a different approach, since linguistic terms have a certain degree of vagueness compared to crisp numbers. To illustrate this vagueness, suppose that the speed of the parachutist varies from 0 kilometer per hour (km/h) up to 300 km/h. One person may label the speed of the parachutist between 0 km/h and 50 km/h as slow, whereas another person labels a speed between 0 km/h and 100 km/h as slow. Since different persons may attribute the same linguistic term to different speed ranges, the description of speed in linguistic terms is rather complex. In case of inter-organizational trust, it is not common to attribute a crisp number to specify the trust level, but one would rather speak of a low or a high trust level without knowing exactly where low ends and high starts. In other words, inter-organizational trust is rather vague and complex. Current literature describes a method to deal with this kind of vagueness and complexity which is called fuzzy logic modeling (FLM). FLM originates from fuzzy set theory (Zadeh, 1975).

3.2.1 Motivation for fuzzy logic modeling

In general terms it is possible to say that for complex problems, like human reasoning around uncertain and imprecise concepts, fuzzy set theory is more powerful than classical theories (Türksen, 2004). Supportive to Türksen (2004) is the study by Fodor et al. (1998), which indicates that FLM is a good alternative for linear modeling in situations where factors are expressed rather linguistically. The linguistic nature of (inter-organizational) trust and corporate strategies designates the objective of this thesis as complex. This complex problem may benefit from FLM. Furthermore, a fuzzy model may be expert-driven or data-driven. For example, if it is not clear what data is required to model a problem, it suffices to first design an expert-driven model and then collect the appropriate data to design a data-driven model. This feature makes fuzzy modeling a rather versatile method. Since this thesis describes the first attempt to design a model to quantitatively evaluate trust relationships, it is unclear what data is required. Therefore, this thesis aims to design a fuzzy expert-driven model.

3.2.2 Methodological approach for the design of the fuzzy model

Bosma, Berg, Kaymak, Udo and Verreth (2012) proposed a generic methodological approach for developing fuzzy models. This approach describes the process from the conceptualization to the implementation of the real-life model. Since the conceptualization is already discussed and the model is expert-driven instead of data-driven, the approach is adjusted. Table 3, page 21, outlines the adopted methodological approach for this thesis. The design of the model starts with the determination of the model input and output factors. Secondly, the fuzzy inference system (FIS) describes how the output(s) of the two layers are calculated from the different input factors. Steps 3 to 5 cover the determination of the linguistic term sets, the memberships functions, and the rule base, respectively. The last two steps are part of the evaluation of the designed model. At first, a sensitivity analysis is conducted, followed by an outline of the feedback from the experts. Below Table 3 each step of the approach is explained in more detail.

Table 3. *The methodological approach with (left) the stage of the approach, (center) the activities to perform and (right) the resulting state in the thesis project (modified from: Bosma et al., 2012).*

DESIGN	1	Determination of model input and output factors.	Set of operational input and output factors
DESIGN	2	Identification of the structure of the fuzzy inference system.	Structure of the conceptual model
DESIGN	3	Determination of the linguistic term sets.	Linguistic term sets for the universes of discourse
DESIGN	4	Determination of membership functions.	Parameterized membership functions for all factors
DESIGN	5	Determination of fuzzy rules.	Rule base replicating the supplier evaluation process
EVALUATE	6	Sensitivity analysis of fuzzy model	Feedback on functioning of fuzzy model
EVALUATE	7	Evaluation of fuzzy model by experts	Feedback from business environment on fuzzy model

Step 1: Determination of model input and output factors

Initially, to determine the input and output factors in the first layer of the model the three trust levels (i.e. quality, service, and cost) are further explored in current literature. This exploration is performed by searching on quality and supplier performance, service and supplier performance, and cost and supplier performance. This results in several indicators for each trust level. These indicators are translated into KPIs. Next, the relations between the KPIs and the subtypes of inter-organizational trust are identified. At last, these KPIs and their relation to contractual trust, competence trust, and goodwill trust are discussed with the experts to verify their contribution to the buyer-seller trust relationship. In the remainder of this thesis the input factors are referred to as trust KPIs. The intermediate outputs (i.e. after the first layer) are the performances on the three trust levels or the trust performances, and the final output of the model (i.e. after the second layer) represents an indication of the trust relationship or overall trust level. See Figure 4, page 18, for the conceptual model.

Step 2: Identification of the structure of the fuzzy inference system

The fuzzy inference system (FIS) is the backbone of the fuzzy model as it encompasses to the reasoning scheme to translate the trust KPIs into the trust performances, and the trust performances into the overall trust level. However, different reasoning schemes exist for a FIS and the selected configuration requires extensive motivation, because it is highly related to the following steps of the design stage.

Step 3: Determination of the linguistic term sets

An universe of discourse and the coherent linguistic term set is best explained by the example of the parachutist again. Remember that this speed during the free fall could range from 0 km/h to 300 km/h. This range is called the universe of discourse for the speed of the parachutist during the free fall. Furthermore, if one may decide to describe the speed in terms of slow, moderate, and fast. In that case the linguistic term set for the speed of the parachutist in free fall is slow, moderate, and fast. So, in step 3 the linguistic term sets for the trust KPIs, the trust performances, and the overall trust level are determined.

Step 4: Determination of the membership functions

The universes of discourse and linguistic term sets for the input and output factors form the bases for defining the membership functions (MFs). A MF maps each linguistic term of an input or output factor to a degree of membership between 0 and 1. The experts provided the ranges for the linguistic term sets for the trust KPIs. The averaged values are used to define the MFs covering the universe of discourse for each trust KPI.

Step 5: Determination of the fuzzy rules

Fuzzy rules define the consequences for the trust performance or overall trust level given a certain combination of outputs for the trust KPIs or trust performances, respectively. Each rule is formulated in an *if-then* form and the total of fuzzy rules underlying the model is called the rule base. Although normally each fuzzy rule is discussed with the experts, the limited availability demanded an alternative approach. In this thesis the rule base is formulated by the author based on the weight factors assigned to the trust KPIs and the trust levels by the experts.

Step 6: Sensitivity analysis of fuzzy model

The sensitivity analysis is executed to review the robustness and the correctness of the fuzzy model. For the analysis multiple scenarios are implemented in the model to find out how the output is affected by minor and major changes in the input (AscoughII, Green, Ma, & Ahjua, 2005).

Step 7: Evaluation of fuzzy model by experts

The fuzzy model is evaluated with the experts earlier consulted for input on the trust KPIs, the linguistic term sets, and the weight factors underlying the rule base. These evaluation sessions are planned to acquire feedback from the business environment.

4 Design of the fuzzy hierarchical model

The design process from the selection of the input and output factors to a complete fuzzy hierarchical model is described. The main source for the design stage is expert knowledge from technological industries.

4.1 General approach for the design

The design of the fuzzy model comprises the first stage of the methodological approach as outlined in Table 3, page 21. The five steps of the design stage are displayed again in Table 4.

Table 4. *The approach for the design of the model with (left) the stage of the approach, (center) the activities to perform and (right) the resulting state in the thesis project (modified from Bosma et al., 2012).*

DESIGN	1	Determination of model input and output factors.	Set of operational input and output factors
	2	Identification of the structure of the fuzzy inference system.	Structure of the conceptual model
	3	Determination of the linguistic term sets.	Linguistic term sets for the universes of discourse
	4	Determination of membership functions.	Parameterized membership functions for all factors
	5	Determination of fuzzy rules.	Rule base replicating the supplier evaluation process

Again, the steps of design approach are based on current literature, or expert knowledge, or a combination of the two. An overview of the consulted experts and their professions are attached in Appendix I.

4.2 Input and output factors

The input and the output factors in the conceptual model are described in general terms, page 18. The initial input factors are the trust KPIs reflecting contractual, competence or goodwill trust for the cost level, the service level, and the quality level. The resulting intermediate outputs are the trust performances on the three levels, whereas the final output is the overall trust level of the supplier with respect to the organization.

4.2.1 Specification of input factors

The formulation of the trust KPIs to determine the trust performances on the three levels are based on the metrics as identified by Gunasekaran et al. (2004). First, for each trust level quantifiable KPIs are specified that essentially cover all the highly and moderately important metrics for that trust level. Secondly, each KPI is associated with either contractual, competence or goodwill trust in order to become a true trust KPI. The process of associating the KPIs to the subtypes of inter-organizational trust is initially performed according to the insight of the author. The reason for this was the lack of information about what exactly is included in a business contract between an organization and a supplier, and what reflects the competence and goodwill of a supplier. These initially formulated trust KPIs are presented in Table 5, page 24. Later, these trust KPIs were discussed with the experts. Their feedback is described below Table 4 and the revised trust KPIs are outlined in Table 6, page 24.

Table 5. *The initial formulated trust KPIs with (left) the trust levels and (right) the contractual trust, competence trust and goodwill trust KPIs*.

Cost level	Contractual: Percentage of correct invoiced costs in relation to contractual agreements about costs. Competence: Percentage of processed orders that do not cause an overrun on the allocated budget. Goodwill: Percentage of decrease in costs per unit during product lifecycle.
Service level	Contractual: Percentage of correct deliveries in relation to contractual agreements about deliveries. Competence: Percentage of satisfactory arrangements in relation to total requested priority orders. Goodwill: Percentage of informed justification by the supplier in relation to total overdue orders by supplier.
Quality level	Contractual: Percentage of products with appropriate quality in relation to contractual agreements about quality. Competence: Percentage of products with constant quality within specification. Goodwill: Number of innovative ideas submitted concerning quality improvement over last 12 months.

The experts acknowledged that the initial formulated KPIs are important in measuring supplier performance and that the KPIs were essentially associated with either contractual, competence or goodwill trust. However, it was indicated that some KPIs may reflect more than one type of inter-organizational trust. For example, a notification to the organization in case a supplier expects or already knows that a delivery becomes overdue is a sign of goodwill from the supplier. But, often this condition is included in a contract too, due to the fact that the planning of the organization is optimized for fixed deliveries. Furthermore, it was recommended to add one extra trust KPI to the cost level and one extra trust KPI to the service level. The extra trust KPI for the cost level is related to cost efficient operations of the supplier, whereas the extra trust KPI for the service level measures the performance of the supplier to achieve a decrease in the product lead time.

Table 6. *The revised trust KPIs according to the feedback of the experts with (left) the trust levels and (right) the contractual trust, competence trust and goodwill trust KPIs*.

Cost level	Contractual: Percentage of correct invoiced costs in relation to contractual agreements about costs. Competence (1): Percentage of processed orders that do not cause an overrun on the allocated budget. Competence (2): Percentage of cost efficient orders in relation to all orders. Goodwill: Percentage of decrease in costs per unit during product lifecycle.
Service level	Contractual: Percentage of correct deliveries in relation to contractual agreements about deliveries. Contractual / goodwill: Percentage of informed justification by the supplier in relation to total overdue orders by supplier. Competence / goodwill: Percentage of satisfactory arrangements in relation to total requested priority orders. Goodwill: Percentage of decrease in lead times during product lifecycle.
Quality level	Contractual: Percentage of products with appropriate quality in relation to contractual agreements about quality. Competence: Percentage of products with constant quality within specification. Goodwill: Number of innovative ideas submitted concerning quality improvement over last 12 months.

For convenience reasons are in the remainder of this thesis the trust KPIs referred to with working titles. These working titles are outlined in Table 7, page 25.

Table 7. *Overview of the working titles of the trust KPIs with (left) the trust KPIs, and (right) the working titles*.

Percentage of correct invoiced costs in relation to contractual agreements about costs. Percentage of processed orders that do not cause an overrun the allocated budget. Percentage of cost efficient orders in relation to all orders. Percentage of decrease in costs per unit during product lifecycle.	ContractualCost CostRange CostEfficiency DecreaseCost
Percentage of correct deliveries in relation to contractual agreements about deliveries. Percentage of informed justification by the supplier in relation to total overdue orders by supplier. Percentage of satisfactory arrangements in relation to total requested priority orders. Percentage of decrease in lead times during product lifecycle.	ContractualService OverdueOrders PriorityOrders DecreaseLeadTimes
Percentage of products with appropriate quality in relation to contractual agreements about quality. Percentage of products with constant quality within specification. Number of innovative ideas submitted concerning quality improvement over last 12 months.	ContractualQuality ConstantQuality QualityImprovement

4.2.2 Specification of output factors

Each of the two layers of the fuzzy model has its own output factors. The first layer results in three intermediate output factors or trust performances, whereas the second layer has one output factor, which is the overall trust level of the business relationship between an organization and its supplier. As the model consists of two layers the trust performances function as intermediate output factors for the first layer as well as input factors for the second layer. Figure 5 visualizes the relations between the input and output factors schematically.

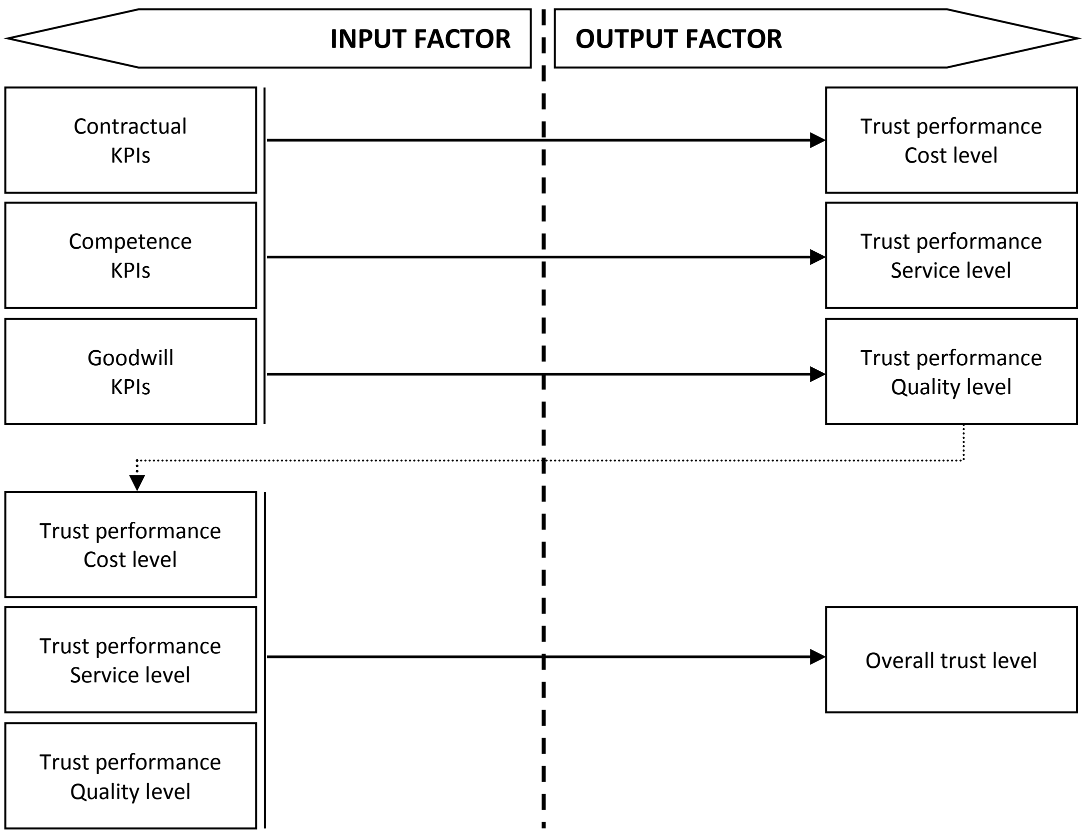

Figure 5. Schematic representation of the input and output factors in the design of the fuzzy model.

4.3 Fuzzy inference system

A FIS is a popular computing framework based on fuzzy set theory, fuzzy if-then rules, and fuzzy reasoning (Roger Jang et al., 1997). Five conceptual components form the basic structure of a FIS, namely (i) a rule base, which is the collection of fuzzy if-then rules, (ii) a database, which defines the memberships functions of the linguistic terms used in the fuzzy rules, (iii) a reasoning mechanism, which performs the inference procedure on the fuzzy rules, (iv) a fuzzification interface to transform the crisp inputs into degrees of membership for the linguistic terms, and (v) a defuzzification interface, which transforms the fuzzy output into a crisp output (Roger Jang, 1993). The FIS for this thesis is designed with the Fuzzy Logic Toolbox™ from the Matlab® 7.9.1 software package (MathWorks, 2009). The next paragraph explains the functioning of the FIS in Matlab in which the focus is on the reasoning mechanism, the fuzzification interface, and the defuzzification interface. The expert input for the construction of the database and the formulation of the fuzzy if-then rules is given in the subsequent sections.

4.3.1 Functioning of the fuzzy model in Matlab

Matlab provides the possibility to design two types of FISs, Mamdani and Sugeno. The final output of a Mamdani FIS is either fuzzy or crisp, depending whether or not a defuzzification interface is implemented in the design, whereas intermediate and final outputs of a Sugeno type are always crisp (Roger Jang et al., 1997). Additionally, Sugeno FIS are most appropriate for data-driven models. Although designing a Sugeno FIS is less time-consuming, the fuzzy model to evaluate buyer-seller trust relationships is implemented as a Mamdani FIS. Mainly because the fuzzy if-then rules for a Mamdani FIS contains only linguistic terms, which contributes more to the simplicity of the model than the fuzzy if-then rules of a Sugeno FIS, in which mathematical equations are included. Moreover, Mamdani FISs are known for their wide applicability and easy graphic interpretation (Roger Jang et al., 1997). Furthermore, an important feature of the FIS is the reasoning mechanism that performs the inference procedure on the fuzzy if-then rules in combination with the fuzzification interface to transform crisp inputs into degrees of membership for the linguistic terms. Fuzzy rules assume the form,

if x is A, then y is B,

for which *x is A* is called the antecedent and *y is B* the consequence. More specifically, *x* is the input factor with the linguistic term *A*, whereas *y* is the output factor with the linguistic term *B*. To illustrate the purport of fuzzy rules, an example of a fuzzy rule in daily life is,

if speed is fast, then apply the brake a little.

The design a of model to compute the output is rather simple as the only required information is what one assumes a fast speed in order to determine whether one should brake a little or not. However, the implementation of the fuzzy model to evaluate the trust relationship between organizations and their supplier in Matlab is much more complex. Instead of one input factor and one output factor, the model now comprises three levels with each three or four input factors. Therefore, each fuzzy rule in the first and second layer consists of three or four antecedents and one consequence. To complicate things even more, the fuzzy character of the model enables a crisp input to have a degree of membership between 0 and 1 for a linguistic term. This means that more than one fuzzy rule is applicable to that situation. In order to deal with these kind of situations a well-defined reasoning scheme is required. Matlab features two reasoning mechanisms for a Mamdani

FIS, namely the max-min composition and the max-product composition. Although the max-product composition is easily subjected to mathematical analysis, the max-min composition is used as the reasoning mechanism in this thesis because this mechanism corresponds to the traditional interpretation of the fuzzy logic AND operator (Horstkotte, 2000). The max-min composition reasoning mechanism relies on two set-theoretic operations, the union or disjunction and the intersection or conjunction (Roger Jang et al., 1997). Suppose, the union of two fuzzy sets A and B is fuzzy set C, which is written as C = A U B or C = A OR B. The formula for how the membership function of C relates to those of A and B is then,

$\mu_C(x) = max(\mu_A(x), \mu_B(x)) = \mu_A(x) \vee \mu_B(x)$,

On the other hand, the intersection of two fuzzy sets A and B is fuzzy set C, which is now written as C = A ∩ B or C = A AND B. The formula for how the membership function of C relates to those of A and B is now,

$\mu_C(x) = min(\mu_A(x), \mu_B(x)) = \mu_A(x) \wedge \mu_B(x)$.

In other words, if the antecedents are linked by the OR operator the maximum degree of membership is applied to the membership function of the output factor, whereas if the antecedents are linked by the AND operator the minimum degree of membership is applied to the membership function of the output factor. Figure 7, page 28, visualizes a two-rule Mamdani fuzzy inference system in which the antecedents are connected by the AND operator. Moreover, the OR operator is applied to the two output membership functions of the two fuzzy rules to obtain the aggregated output membership function. The last step is the defuzzification to transform the fuzzy output into a crisp output. Matlab provide the five defuzzification interfaces (i) centroid of area, (ii) bisector of area, (iii) mean of maximum, (iv) smallest of maximum, and (v) largest of maximum. The five defuzzification interfaces are illustrated in Figure 6.

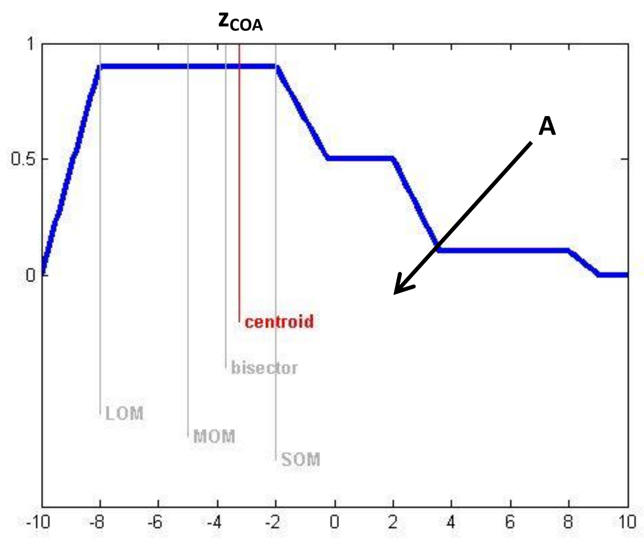

Figure 6. Example of an aggregated output membership function in which the five defuzzification interfaces are indicated.

One may see that the smallest of maximum and largest of maximum interfaces have a significant bias. Furthermore, the mean of maximum interface is mainly employed in Mamdani fuzzy logic controllers and is therefore not ideal for usage in this thesis. The choice is made to incorporate the centroid of area interface because it is the most widely adopted defuzzification strategy and therefore more convenient to use than the bisector of area. The formula for the transformation of a fuzzy output into a crisp output is,

$$Z_{COA} = \int_Z \mu_A(z)\, z\, dz \,/\, \int_Z \mu_A(z)\, dz.$$

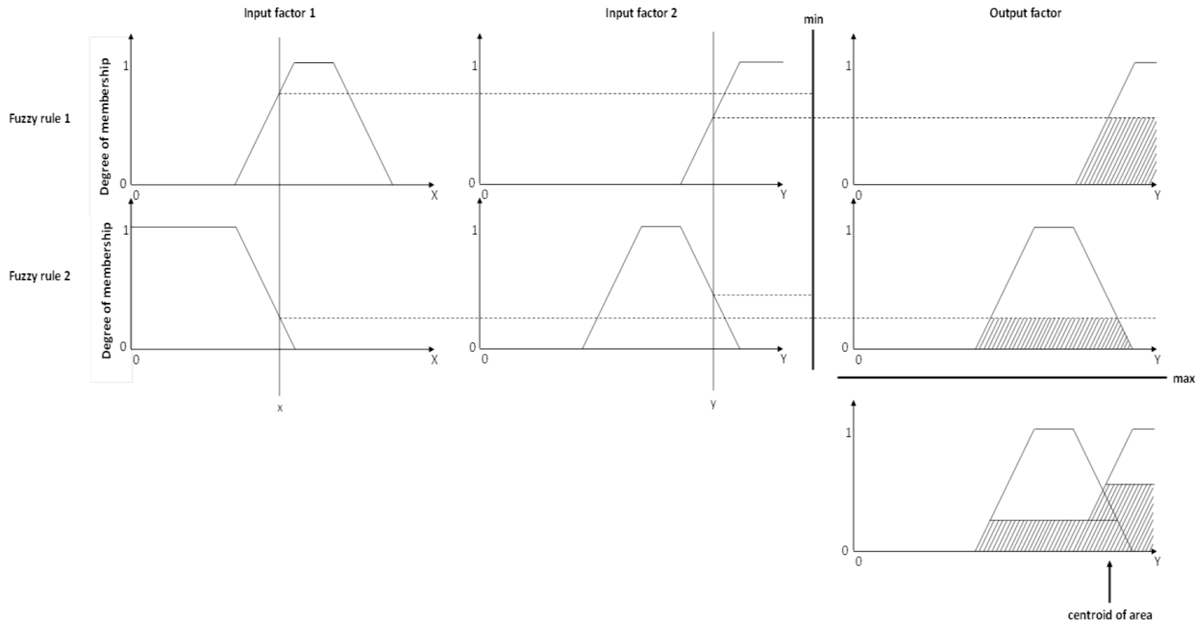

Figure 7. A two-rule Mamdani fuzzy inference system with two input factors.

4.4 Linguistic term sets

A linguistic term set is characterized by a linguistic variable to which several linguistic terms are assigned (Roger Jang et al., 1997). In the example of the parachustist, the linguistic variable is speed and the notions slow, moderate, and fast its linguistic terms. These linguistic terms cover the universe of discourse (UoD) of the linguistic variable speed. The procedure towards the determination of the linguistic term sets therefore starts with specifying the UoD for the linguistic variables, which in this thesis comprise the trust KPIs, the trust performances, and the overall trust level. Since the trust KPIs are operationalized in percentages the UoDs for these trust KPIs range from 0 % to 100 %, except for the trust KPI QualityImprovement. This trust KPI involves the number of submitted improvement plans and its UoD therefore ranges from 0 to 10. In Table 8, page 29, the UoD for the trust KPIs are presented. To continue, the trust performances resemble scores on the trust levels, whereas the overall trust level resemble the score for the buyer-seller trust relationship as a whole. The classical grading system at Dutch educational institutions inspired the author to set the UoD for the trust performances and the overall trust level at 0 to 10. The UoD for the trust performances are outlined in Table 9, page 29.

Table 8. *Overview of the UoD for all first layer input factors with (left) the trust levels, (center) the input factors or KPIs, and (right) the UoDs.*

COST	ContractualCost CostRange CostEfficiency DecreaseCost	0 % – 100 % 0 % – 100 % 0 % – 100 % 0 % – 100 %
SERVICE	ContractualService OverdueOrders PriorityOrders DecreaseLeadTimes	0 % – 100 % 0 % – 100 % 0 % – 100 % 0 % – 100 %
QUALITY	ContractualQuality ConstantQuality QualityImprovement	0 % – 100 % 0 % – 100 % 0 – 10

Table 9. *Overview of the UoD for all second layer input factors with (left) the trust levels, (center) the input factors, and (right) the UoDs.*

COST	Trust performance	0 – 10
SERVICE	Trust performance	0 – 10
QUALITY	Trust performance	0 – 10

In this master thesis the linguistic terms poor, average, and good are consistently used for all linguistic variables, which resembles a three-point Likert scale (Likert, 1932).

4.5 Membership functions

The linguistic term sets are implemented in Matlab by defining the MFs for the trust KPIs and the trust performances. The MFs are defined in Matlab in a specific manner. The trapezoidal shapes require four numbers to specify (i) the range where the degree of membership increases from zero to one (e.g., line *ab* for *poor* in Figure 8, page 30), (ii) the range where the degree of membership is one (e.g., line *bc* for *poor* in Figure 8), and (iii) the range where the degree of membership decreases from one to zero again (e.g., line *cd* for *poor* in Figure 8). The overlap of the defined MFs for linguistic term sets of the trust KPI gives the model its fuzzy character. The formulation of trapezoidal MFs is performed according to the formula,

$$trapmf(x; a, b, c, d) = \max\left(\min\left(\frac{x-a}{b-a}, 1, \frac{d-x}{d-c}\right), 0\right)$$

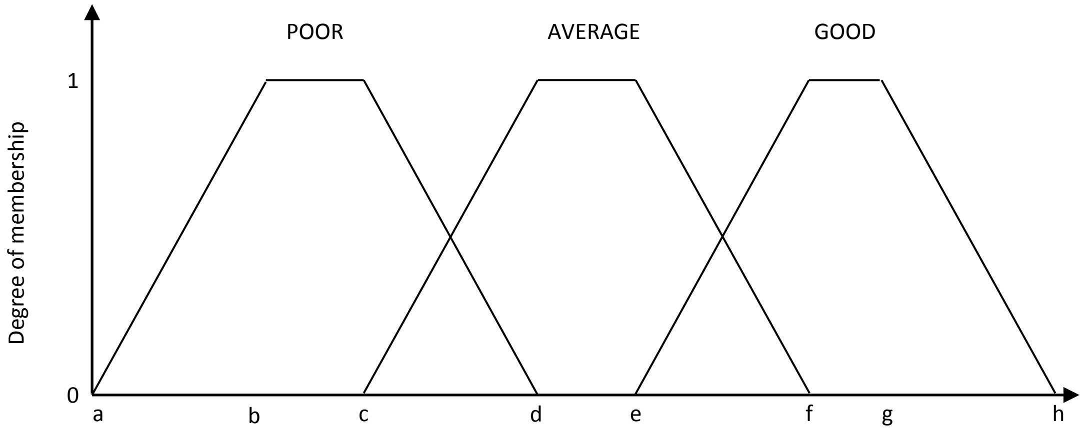

Figure 8. A generic fuzzy membership function distribution with an UoD ranging from *a* to *g* and the linguistic terms *poor*, *average*, and *good*.

The limits of the ranges for the MFs are derived from the input of the five experts. The individual input per expert is attached in Appendix II. The inputs are averaged to obtain a final set of input ranges to define the MFs. This final set is presented in Table 10, page 31. Figure 9 is supportive to the explanation of the procedure to obtain the values in Table 10, starting at the next page.

Figure 9. Distribution of input values for *poor* by the experts for the trust KPI ContractualCost with two of five times the input value *90*, and three of five times the input value *95*.

Figure 9 visualizes how the averaged input ranges for the limit of the linguistic term *poor* for the trust KPI ContractualCost is derived. Two of the five experts indicated that a *poor* performance on ContractualCost ranges from 0 to 90, whereas the other three experts claimed this range to be from 0 to 95. By averaging the input values from the five experts the range for a *poor* performance on ContractualCost is set on 0 to 93. Accordingly, this procedure is performed for all trust KPIs. The final set of input ranges for the trust KPIs is presented in Table 10. However, a few remarks are applicable to these averaged input ranges in Table 10. Firstly, not all ranges for the linguistic terms are specified by some experts, since these trust KPIs where not applicable for their organization. These gaps are represented by *n/a* in the tables in Appendix II. Secondly, some linguistic terms are assigned a single input value instead of an input range. These single input value are already covered by another input range, and therefore not included in the calculation of the averaged input range for that linguistic term.

Table 10. *Overview of linguistic term sets for input factors with (left) the trust levels, (center) the trust KPIs, (right) the linguistic term sets for the input factors*.

		POOR	AVERAGE	GOOD
COST	ContractualCost	0 – 93,00	93,33 – 98,67	95,25 – 100
	CostRange	0 – 72,50	63,33 – 88,17	91,83 – 100
	CostEfficiency	0 – 55,00	36,67 – 93,33	90,00 – 100
	DecreaseCost	0 – 25,00	12,50 – 50,00	40,00 – 100
SERVICE	ContractualService	0 – 90,60	89,50 – 96,00	94,75 – 100
	OverdueOrders	0 – 83,50	79,67 – 90,00	88,33 – 100
	PriorityOrders	0 – 71,30	78,30 – 89,00	86,25 – 100
	DecreaseLeadTimes	n/a	0,00 – 20,00	10,00 – 100
QUALITY	ContractualQuality	0 – 92,00	88,33 – 94,33	94,50 – 100
	ConstantQuality	0 – 78,00	65,00 – 82,67	85,75 – 100
	QualityImprovement	0 – 2	1 – 3	2 – 10

The input ranges in Table 10 are used to construct the database for defining the MFs of the first layer. However, the construction of the database for the second layer the UoD for the trust performances and the overall trust level is subject to the classical grading system at Dutch educational institutions. In this system the turning point from poor to average and from average to good is at 5.5 and 7.5, respectively. The resulting ranges to construct the database for defining the MFs of the second layer are outlined in Table 11.

Table 11. *Overview of linguistic terms sets for intermediate input factors with (left) the trust levels, and (right) the linguistic term sets for the intermediate output factors*.

	POOR	AVERAGE	GOOD
Cost level	0 – 6	5 – 8	7 – 10
Service level	0 – 6	5 – 8	7 – 10
Quality level	0 – 6	5 – 8	7 – 10

4.5.1 Membership functions for the first layer

In Figure 10 one may see that the input ranges for the trust KPIs either overlap or have a gap in between them. In case two input ranges overlap, the lower limit of the better linguistic term points out where that better linguistic term start increasing from 0 to 1 and where the worse linguistic term start decreasing from 1 to 0. On the other hand, the upper limit of the worse linguistic term points out where that worse linguistic term losses its degree of membership completely and the better linguistic term gains a degree of membership of 1. For example, see the linguistic terms *poor* and *average* for the trust KPI CostRange. The linguistic term *poor* for this trust KPI ranges from 0 to 72,50, whereas the linguistic term *average* ranges from 63,33 to 88,17. The MFs for these linguistic terms obviously overlap. So, the lower limit of *average*, 63,33, marks the point where that linguistic terms starts increasing and the linguistic term *poor* starts decreasing. Moreover, the upper limit of *poor*, 72,50, points out where that linguistic term reaches a degree of membership of 0 and the linguistic term *average* reaches a degree of membership of 1. In the other case, where two input ranges have a gap in between them, the upper limit of the worse linguistic term and the limit of the better linguistic term marks the point where both linguistic terms have a degree of membership of 1. For example, now see the linguistic terms *average* (63,33 – 88,17) and *good* (91,83 – 100) for the trust KPI CostRange. The upper limit of *average*, 88,17, and the lower limit of *good*, 91,83, marks the point where these linguistic terms have a degree of membership of 1. The aforementioned example is visualized in Figure 10.

Figure 10. MFs for trust KPI CostRange with overlapping input ranges, and input ranges with a gap.

As mentioned, the databases to define the MFs for the input factors, the intermediate output factors, and the final output factor are implemented in Matlab in a specific manner. The UoD, the shapes of the MFs, and the definitions of the MFs are specified individually for each factor. Figure 11, page 33, presents a screenshot of Matlab in which these three elements are highlighted. More specifically, the UoD and the definition of the MF are between brackets, and the trapezoidal shape is chosen from a list of all possible shapes.

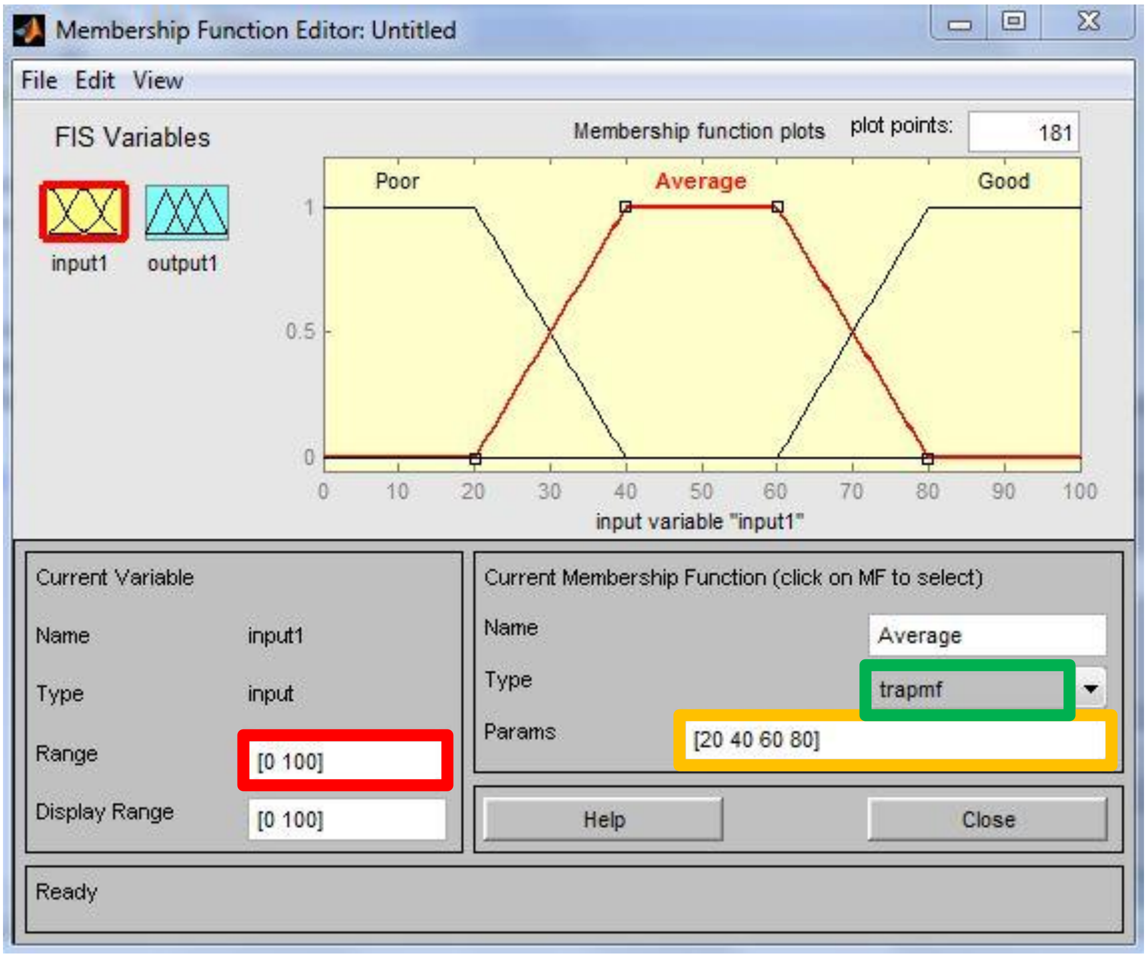

Figure 11. Screenshot of Matlab with (*red*) the area to specify UoD, (*green*) the area to specify the shape of the MF, and (*yellow*) the area to specify the definition of the MF.

4.5.1.1 Cost level

In Table 12 the database for defining the MFs for the cost level is displayed.

Table 12. *Database for defining the MFs for the cost level with (left) the distinction between input factors and output factor, and (right) the trust KPIs with UoD and the definitions of the MFs for the linguistic terms*.

Input factors	ContractualCost [0 100]: poor, trapmf[0 0 93.00 93.33]; average, trapmf[93.00 93.33 95.25 98.67]; good, trapmf[95.25 98.67 100 100] CostRange [0 100]: poor, trapmf[0 0 63.33 72.50]; average, trapmf[63.33 72.50 88.17 91.83]; good, trapmf[88.17 91.83 100 100] CostEfficiency [0 100]: poor, trapmf[0 0 36.67 55.00]; average, trapmf[36.67 55.00 90.00 93.33]; good, trapmf[90.00 93.33 100 100] DecreaseCost [0 100]: poor, trapmf[0 0 12.50 25.00]; average, trapmf[12.50 25.00 40.00 50.00]; good, trapmf[40.00 50.00 100 100]
Output factor	TrustPerformanceCostLevel [0 10]: poor, trapfm[0 0 5 6]; average, trapmf[5 6 7 8]; good, trapmf[7 8 10 10]

4.5.1.2 Service level

In Table 13, page 34, the database for defining the MFs for the service level is displayed.

Table 13. *Database for defining the MFs for the service level with (left) the distinction between input factors and output factor, and (right) the trust KPIs with UoD and the definitions of the MFs for the linguistic terms*.

Input factors	ContractualService [0 100]: poor, trapmf[0 0 89.50 90.60]; average, trapmf[89.50 90.60 94.75 96.00]; good, trapmf[94.75 96.00 100 100] OverdueOrders [0 100]: poor, trapmf[0 0 79.67 83.50]; average, trapmf[79.67 83.50 88.33 90.00]; good, trapmf[88.33 90.00 100 100] PriorityOrders [0 100]: poor, trapmf[0 0 71.30 78.30]; average, trapmf[71.30 78.30 86.25 89.00]; good, trapmf[86.25 89.00 100 100] DecreaseLeadTimes [0 100]: average, trapmf[0 0 10.00 20.00]; good, trapmf[10.00 20.00 100 100]
Output factor	TrustPerformanceServiceLevel [0 10]: poor, trapfm[0 0 5 6]; average, trapmf[5 6 7 8]; good, trapmf[7 8 10 10]

4.5.1.3 Quality level

In Table 14 the database for defining the MFs for the quality level is displayed.

Table 14. *Database for defining the MFs for the quality level with (left) the distinction between input factors and output factor, and (right) the trust KPIs with UoD and the definitions of the MFs for the linguistic terms*.

Input factors	ContractualQuality [0 100]: poor, trapmf[0 0 88.33 92.00]; average, trapmf[88.33 92.00 94.33 94.50]; good, trapmf[94.33 94.50 100 100] ConstantQuality [0 100]: poor, trapmf[0 0 65.00 78.00]; average, trapmf[65.00 78.00 82.67 85.75]; good, trapmf[82.67 85.75 100 100] QualityImprovement [0 10]: poor, trapmf[0 0 1 2]; average, trimf[1 2 3]; good, trapmf[2 3 10 10]
Output factor	TrustPerformanceQualityLevel [0 10]: poor, trapfm[0 0 5 6]; average, trapmf[5 6 7 8]; good, trapmf[7 8 10 10]

4.5.2 Membership functions for the second layer

In Table 15 the database for defining the MFs for the overall trust level is displayed.

Table 15. *Database for defining the MFs for the overall trust level with (left) the distinction between input factors and output factor, and (right) the trust performances with UoD and the definitions of the MFs for the linguistic terms*.

Input factors	TrustPerformanceCostLevel [0 10]: poor, trapfm[0 0 5 6]; average, trapmf[5 6 7 8]; good, trapmf[7 8 10 10] TrustPerformanceServiceLevel [0 10]: poor, trapfm[0 0 5 6]; average, trapmf[5 6 7 8]; good, trapmf[7 8 10 10] TrustPerformanceQualityLevel [0 10]: poor, trapfm[0 0 5 6]; average, trapmf[5 6 7 8]; good, trapmf[7 8 10 10]
Output factor	OverallTrustLevel [0 10]: poor, trapfm[0 0 5 6]; average, trapmf[5 6 7 8]; good, trapmf[7 8 10 10]

4.6 Rule base

In order to formulate the rule base for the FIS the experts are asked to assign weight factors to the trust KPIs and the trust levels, ranging from 1 to 4. For example, if an expert assigned the value 4 to a trust KPI, he appraises that trust KPI four times more important than a trust KPI valued 1. Based on these weight factors the author could discriminate between more important and less important aspects for a buyer-seller trust relationship. The input from the five experts was averaged to obtain a workable set of weight factors. These averaged weight factors are used to formulate the fuzzy if-then rules. During the formulation of the rule base two assumptions were taken into account. First, a poor trust KPI or trust level with an averaged weight factor equal to 4 automatically results in a poor trust performance or overall trust level. For example, suppose the following antecedent,

If A is good and B is average and C is average and D is poor,

in which factor *D* has an averaged weight factor equal to 4. Then, the consequence is undoubtedly,

then E is poor.

In case no averaged weight factor equal to 4 is assigned to the trust KPIs or the trust performance of a trust level, the consequence is determined by canceling out the input factors in the antecedent according to their averaged weight factors.

The second assumption is related to the implemented max-min composition. The fuzzy if-then rules are connected by the AND operator and, therefore, the minimum degree of membership of the antecedents is applied to the output MFs. Consequently, to obtain the aggregated output MF the OR operator is applied to the individual output MFs. Figure 12 depicts a screenshot of the rule editor in Matlab to visualize how the rule base is implemented.

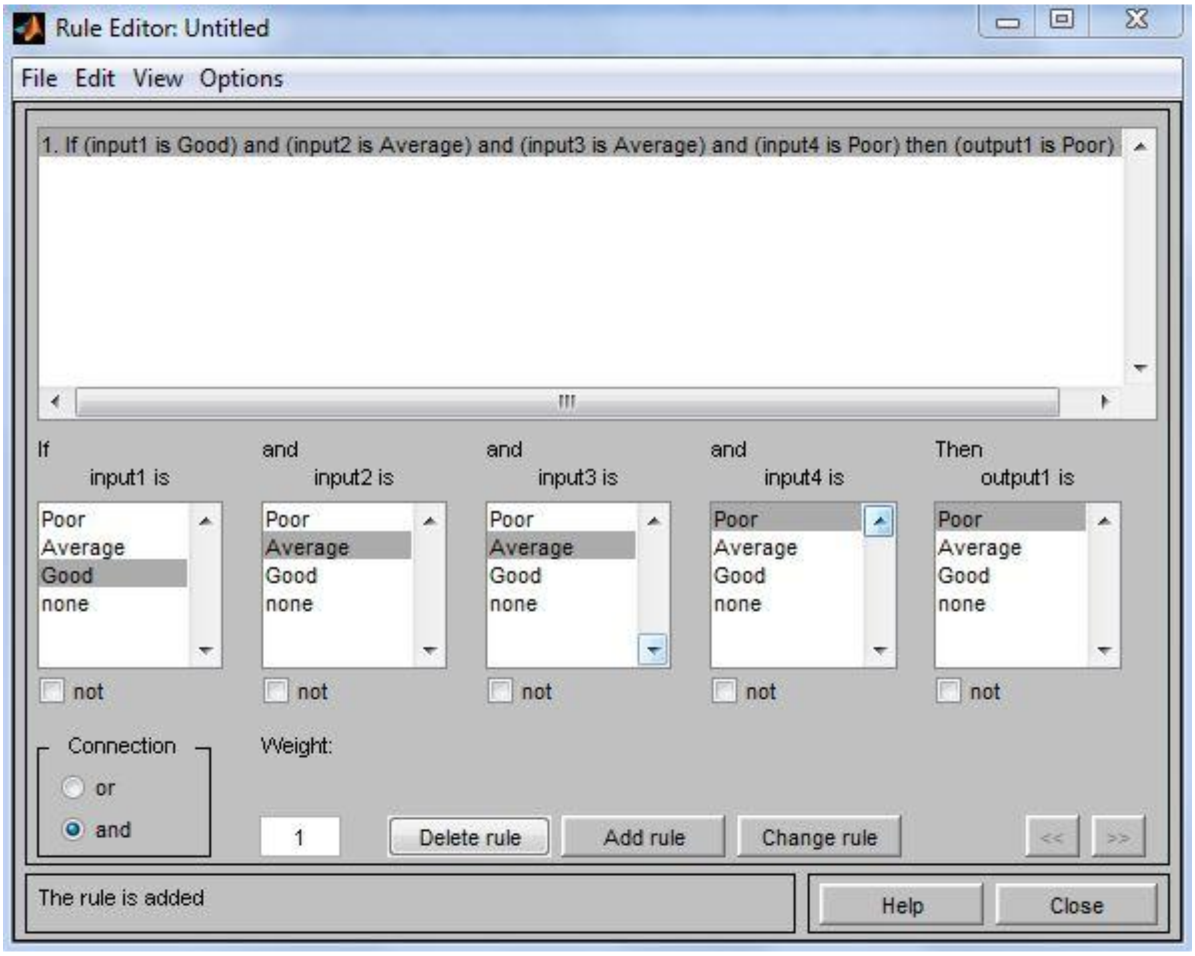

Figure 12. Screenshot of the rule editor in Matlab.

Furthermore, as a starting point the complete rule base is taken and the number of fuzzy rules is gradually reduced by trimming (Bosma et al., 2012). Trimming is performed to cope with the potential explosion of fuzzy rules, which depends on the number of trust KPIs and linguistic terms. For example, a FIS with four input factors and three linguistic terms results in a rule base of 81 rules (i.e. 3 x 3 x 3 x 3). The definition of constraints led to a different number of fuzzy rules.

The following two sections outline (i) the fuzzy rules for the first layer per trust level, and (ii) the fuzzy rules for the second layer. The sections start with overviews of the weight factors.

4.6.1 Layer I

The weight factors for the formulation of the rule base for the first layer are outlined in Table 16. A detailed overview of the weight factors of the trust KPIs for determination of the trust performances for each trust level as identified by each expert is attached in Appendix III. To illustrate, the weight factors from the experts for ContractualCost are 1, 4, 2, 2 and 1. The average of these five weight factors is calculated and is then rounded to the nearest integer. In this case, the result is 2. The averaged weight factors for the other trust KPIs are calculated accordingly.

Table 16. *Overview of the averaged weight factors for the trust KPIs with (left) the trust levels, (center) the working titles of the trust KPIs, and (right) the weight factors of the trust KPIs*.

Trust level	Trust KPI	Weight factor
COST	ContractualCost	2
	CostRange	3
	CostEfficiency	3
	DecreaseCost	3
SERVICE	ContractualService	4
	OverdueOrders	3
	PriorityOrders	2
	DecreaseLeadTimes	4
QUALITY	ContractualQuality	4
	ConstantQuality	3
	QualityImprovement	3

4.6.1.1 Fuzzy rules for cost level

The initial number of fuzzy rules for determination of the trust performance on the cost level (4 input factors with 3 linguistic terms) is 81. Trimming resulted in a new number of fuzzy if-then rules (56). The final set of rules for the cost level is found in Appendix V.

4.6.1.2 Fuzzy rules for service level

The initial number of fuzzy rules for determination of the trust performance on the cost level (1 input factors with 2 linguistic terms and 3 input factors with 3 linguistic terms) is 54. Trimming resulted in a new number of fuzzy if-then rules (20). The final set of rules for the service level is found in Appendix VI.

4.6.1.3 Fuzzy rules for quality level

The initial number of fuzzy rules for determination of the trust performance on the cost level (3 input factors with 3 linguistic terms) is 27. Trimming resulted in a new number of fuzzy if-then rules (13). The final set of rules for the quality level is found in Appendix VII.

4.6.2 Layer II

The weight factors for the formulation of the rule base for the second layer are outlined in Table 17. A detailed overview of the weight factors of the trust performances for determination of the overall trust level as identified by each expert is attached in Appendix IV. To illustrate, the individual weight factors from the experts for TrustPerformanceCostlevel are 2, 2, 3, 1 and 2. The average of these five weight factors is calculated and is then rounded to the nearest integer. In this case, the result is 2. The averaged weight factors for the other trust performances are calculated accordingly.

Table 17. *Overview of the averaged weight factors for the trust levels with (left) the trust levels, (center) the working titles of the intermediate output factors, and (right) the weight factors of the trust performances*.

COST	TrustPerformanceCostLevel	2
SERVICE	TrustPerformanceServiceLevel	3
QUALITY	TrustPerformanceQualityLevel	4

4.6.2.1 Fuzzy rules for the overall trust level

The initial number of fuzzy rules for determination of the trust performance on the cost level (3 input factors with 3 linguistic terms) is 27. Trimming resulted in a new number of fuzzy if-then rules (18). The final set of rules for the overall trust level is found in Appendix VIII.

5 Evaluation of the fuzzy hierarchical model

The functioning of the model is evaluated by means of a sensitivity analysis and expert feedback from the experts.

5.1 General approach for the evaluation

The evaluation of the model comprises the first stage of the methodological approach as outlined in Table 3, page 21. The two steps of the evaluation stage are displayed again in Table 18.

Table 18. *The general evaluation approach with (left) the stage of the approach, (center) the activities to perform and (right) the resulting state in the thesis project (modified from Bosma et al., 2012).*

EVALUATE	6 Sensitivity analysis of fuzzy model	Feedback on functioning of fuzzy model
	7 Evaluation of fuzzy model by experts	Feedback from business environment on fuzzy model

5.2 Sensitivity analysis

A sensitivity analysis aims to assess the effects of input changes on the output to inform the user and to determine the optimal space of the parameter for calibration (AscoughII et al., 2005). Sensitivity analysis is considered necessary before deciding on fitness of the model for general applicability in the business environment (Thacker et al., 2004). Data about the sensitivity of the model is obtained by running the model several times for the crucial ranges of the input values. In this thesis the crucial ranges are the overlapping areas of the linguistic term sets. Therefore, during the sensitivity analysis is focussed on these areas for the overall trust level. The series of results are outlined in Table 19, page 39.

Table 19. *Overview of the results from the sensitivity analysis with (left) the intermediate output for the cost level, (center left) the intermediate output for the service level, (center right) the intermediate output for the quality level, and (right) the final output*.

<table>
<tr><th>Cost level trust performance</th><th>Service level trust performance</th><th>Quality level trust performance</th><th>Overall trust level</th></tr>
<tr><td>5</td><td>5</td><td>5</td><td rowspan="5">2.98</td></tr>
<tr><td>5</td><td>5</td><td>5.5</td></tr>
<tr><td>5</td><td>5</td><td>6</td></tr>
<tr><td>5</td><td>5</td><td>7.5</td></tr>
<tr><td>5</td><td>5</td><td>8</td></tr>
<tr><td>5</td><td>5.5</td><td>8</td><td>4.04</td></tr>
<tr><td>5</td><td>6</td><td>8</td><td rowspan="3">7.00</td></tr>
<tr><td>5</td><td>7.5</td><td>8</td></tr>
<tr><td>5</td><td>8</td><td>8</td></tr>
<tr><td>5.5</td><td>8</td><td>8</td><td>7.96</td></tr>
<tr><td>6</td><td>8</td><td>8</td><td>9.02</td></tr>
<tr><td>7.5</td><td>8</td><td>8</td><td>8.96</td></tr>
<tr><td>8</td><td>8</td><td>8</td><td>9.02</td></tr>
</table>

Table 19 visualizes how the final output or overall trust level varies when prone to small changes in the intermediate output. This approach to the sensitivity analysis is regarded sufficient as the trust performances directly result from the input factors. Moreover, due to the fuzzy rule,

if TrustPerformanceQualityLevel is poor, then OverallTrustLevel is poor,

the quality level is rather a determinant for the overall trust level. Therefore, the setup of the sensitivity analysis is chosen as outlined in Table 19. Furthermore, the overall trust level gradually increases form poor to good as the preceding trust performances increase. The scores 2.98 and 4.04 both indicate a poor overall trust level, after which a turning point to an average overall trust level is present. An average trust level follows from a poor trust performance for the cost level, and an average or good trust performance for the service and quality levels. At the moment the trust performance for the cost level tends to an average score (i.e. 5.5), the overall trust level starts tending to a good score (i.e. 7.96). To continue, once the trust performance for the cost level reaches the average score, the overall trust level becomes good. However, a partial degree of membership for average and good for the cost level causes a little decline in the overall trust level. The implications of this sensitivity analysis are discussed with respect to the three requirements, page 41.

5.3 Expert feedback

Additional to the sensitivity analysis, the final fuzzy model is evaluated by the experts too. The collected feedback relates primarily to the topic of this thesis, and the design of the model. The suggested improvements are included in this section, hence excluded from the recommendations in the discussion, next chapter. The specific feedback from the experts is outlined in separate paragraphs.

5.3.1 Feedback on the topic

The development of methods for the evaluation of trust relationships between organizations and their suppliers is perceived as good, but a few remarks are made by the experts. The first remark relates to the quantitative approach in modeling inter-organizational trust. In trust relationships between organizations and suppliers some qualitative aspects do matter too. Examples of qualitative aspects of trust are the reputation and references of the supplier, as well as the personal interaction between the organization and the supplier. Especially, the last one is suggested by the experts as important in granting a contract to a supplier. In order to design a more complete model, future scholars should focus on finding a way to transform the aforementioned qualitative into quantitative variables. Secondly, although trust is important in business relationships, one expert doubts whether the quantification of trust is really a viable method. The expert reasons that both organizations and suppliers are aware that trust in the supply chain is important for mutual growth. Therefore, it is likely that both parties will already agree only on reasonable terms regarding the costs, service, and quality. To conclude, an evaluation of the trust relationship is regarded important only for organizations with strategic and bottleneck suppliers because these suppliers have a high impact on the organization. This last remark in line with the aim of this thesis and therefore invigorates the performed study.

5.3.2 Feedback on the design of the model

Four components of the design are commented by the experts. The first component relates to the implemented trust levels. The experts agree that costs, service, and quality are important in establishing trust relationships with suppliers, however it is suggested to incorporate improvement as a separate trust level. In this thesis the notion improvement is included in the quality trust level, while an expert indicates that innovative behavior of a supplier is truly valuable for the trust level in a business relationship, due to the potential strategic benefits for the organization. Therefore, future research should explore the incorporation of an improvement trust level with KPIs that reflect contractual, competence and goodwill trust. Secondly, the applied linguistic term set is regarded as satisfactory. The model uses a three-point Likert scale (i.e. poor, average, and good) for the fuzzy input and output factors. One expert suggests to try a five-point Likert scale in future research, however this may turn out to be too detailed. To continue, the third component concerns the averaged input values compared to the individual input values provided by the experts. Although the expert consider the averaged input values used to construct the databases as appropriate, deviations are present between the individual input from the experts and the averaged input. One expert particularly indicated that the lower individual input for the trust KPI CostEfficiency than the averaged values is most probably due to the fact that research and development is the main activities of his organization. Hence, all deviations may originate from the different core businesses of the experts their organizations. The last commented component comprises the averaged weight factors. The experts indicated that these values correspond sufficiently with their view on the relative importance of the trust KPIs and the trust performances.

6 Discussion

The implementation of the three requirements in the final model is reflected upon. Furthermore, the limitations, the coherent recommendations, and the roadmap towards a data-driven model are discussed.

6.1 The three requirements of the fuzzy model

The sensitivity analysis and the feedback from the experts are used to discuss the fulfillment of the three requirement for the model.

6.1.1 Robustness

The main source of information for the evaluation of this requirement is the sensitivity analysis. As outlined in Table 19 small changes in the intermediate output resulted in sensible scores for the overall trust level. The only unexpected score is the one with good trust performances for the service and quality level, and where the trust performance for the cost level is in the overlapping region for average and good. Although the overall trust level remains good in linguistic terms and the robustness of the model is not really challenged by this unexpected result, one and other indicates that the robustness may need improvement prior to the implementation in the business environment.

6.1.2 Correctness

This requirement is evaluated by means of the sensitivity analysis and the feedback from the experts. First, the results from the sensitivity analysis indicate that based on the inputs from the experts the model produces sensible outputs. However, the fulfillment of this requirement is questioned by the unexpected score as explained in the previous paragraph. Although this has less impact on the robustness of the model, the impact on the correctness is higher because the same may happen at a crucial point. For example, on the transition from poor to average where the overall trust level is actually average but where the model gives a poor output. The implication of such an incorrect output may have serious consequences for the business relationship.

6.1.3 Simplicity

The fulfillment of this requirement follows from the feedback of the experts. They indicate that the proposed model covers important aspects of a trust relationship between organizations and their suppliers, but may improve by extending it with a separate trust level regarding innovations and improvements by the supplier. Although this may seem like a considerable increase in the complexity of the model, it is expected that the main effect of this extension is the increase of the robustness and correctness.

6.2 The design procedure

The following two paragraphs discuss the considerations in the design procedure from a scientific viewpoint and a managerial viewpoint.

6.2.1 Scientific consideration

The literature study to get insight in how inter-organizational trust and buyer-seller relationships are related was complicated, due to the many existing definitions and dimensions of trust. The categorization by Sako (1992) into the three subtypes contractual trust, competence trust, and goodwill trust seemed the most appropriate for the objective of this thesis. This was later confirmed by the experts. Although, it was indicated that particularly goodwill trust affects the overall trust relationship, since contractual agreements with and the competence of the supplier are rather fixed and verifiable. The next step was the identification of suitable aspects in buyer-seller relationships which are quantifiable and affect the inter-organizational trust level. The three resulting trust levels (cost, service, and quality) were regarded as very important for an organization for several reasons. First, the experts indicated the quality level as the most important for the trust relationship. Because, if the quality of the product is not up to the required level the whole operation of the organizations shuts down. Secondly, right behind the quality level is the service level. The service level is important because poor service may dramatically delay the operation of the organization. At last, the inclusion of the cost level is two-fold. On the one hand, the trust level decreases if a supplier is not capable to do its invoicing right, if the product from a particular supplier causes a lot of overwork, and if a supplier is not capable to work cost efficiently or improve its cost efficiency. On the other hand, the cost level is related to the other two trust levels too as poor quality and poor quality incur high costs for an organization. Furthermore, it was indicated that innovation or improvement may be included as an extra trust level. The trust KPIs assigned to the three trust levels followed from the current literature. Relating each trust KPI to one or two subtypes of inter-organizational trust was an attempt to get a complete as possible trust performance for the cost level, the service level, and the quality level. In this thesis marginal attention is paid to these relations between the trust KPIs and subtypes of inter-organizational trust, because the final overall trust level was considered the most important element in this model. However, during the research project it became clear that the design of a full-fledged validated model was an unachievable operation and that, perhaps, more attention should have been paid to the relation between the KPIs and contractual, competence, and goodwill trust. Nevertheless, the experts did recognize the relations between the trust KPIs and the subtypes. To continue, the standard approach to the design of a fuzzy model requires a close collaboration with the experts to fine-tune the linguistic terms, the database, and the fuzzy rules. In this thesis another approach is attained, due to the enormous time consuming nature of the standard approach and the limited available time of the experts. More specifically, the experts were asked to provide (i) ranges for the linguistic terms poor, average, and good with respect to the trust KPIs, and (ii) weight factors for the trust KPIs and the trust levels. The ranges are used to construct the databases for defining the MFs and the weight factors are used to formulate the rule base. Obviously, this approach is less meticulous than the standard approach and may therefore bias the fuzzy model to some degree. Nevertheless, the degree of fulfillment of the three requirements proves this model is an appropriate first attempt to design a fuzzy model to quantitatively evaluation trust relationships.

6.2.2 Managerial consideration

The objective of this thesis was to design a model to enable organizations to quantitatively evaluate the trust relationship with their suppliers. Although a fuzzy model has been designed, the model needs further improvement prior to the implementation in the business environment. Therefore, it is more appropriate to refer to the fuzzy model as a prototype. In the preparation of the prototype for implementation in the business environment two issues have to be taken into account. The two issues relate to the metrics currently measured within organizations. First, it is important to explore how organizations have to arrange their information technology systems (IT systems) for measuring the trust KPIs. Secondly, the functioning of the model currently relies on the administration of inputs for all trust KPIs. If for one trust KPI no input is administered the overall trust level cannot be determined. Therefore, in case organizations are currently unable to retrieve the right information from their IT system to generate the required input for the model, the discrepancies and the inherent costs to rearrange the IT system should be identified.

6.2.3 Practical barriers

In general the expert-driven approach results in a highly interpretable fuzzy model design. Simultaneously, the high interpretability implies a rather poor accuracy. To the contrary, data-driven model are more accurate and less interpretable. One and other is called the interpretability-accuracy dilemma (Berthold & Hand, 2007). The effect of this dilemma reduces by transforming the standard fuzzy model to a neuro-fuzzy model (e.g., Berthold & Hand, 2007; Kasabov, 2001; Roger Jang, 1997), which is detailed in section 6.4.3. Furthermore, several other barriers related to the implementation of the model in the business environment exist. The first barrier is obtaining the right data for the model. As mentioned, the proposed fuzzy model requires the inclusion of all trust KPIs. Organizations need to invest in the architecture of their IT systems to assure that the performance of all trust KPIs can be determined. The second barrier is the difference in perception of inter-organizational trust across industries. This thesis aimed at technological industries and the experts from these industries acknowledged the important of a good trust relationship between organizations and their suppliers. Despite the similarities of technological industries, the differences between their products are not taken into account and may affect the perception of inter-organizational trust too. For now, organizations are advised to only use the model for the industries incorporated in this thesis until experts from other industries are consulted. Thirdly, testing and training of the model is not only required for improvement in the performance in the model but also to prove to the business environment that the proposed model is a reliable method for evaluating trust relationships in a procurement context. This is difficult due to the dogma of interpersonal trust involved in trust relationships. The scientific community may play a significant role in this as scholars have the tools to investigate the performance of the model in the business environment. The fourth barrier is about the operationalization of the trust KPIs and relates somehow to the first barrier. Organizations may have difficulty with matching their currently measured metrics to the trust KPIs, although they involve similar attributes. The most important message here is that organizations are aware that the trust KPIs touch upon the attributes that significantly affect the trust relationship between the organization and a supplier. As a consequence, organizations are allowed to reformulate the trust KPIs to some extent as long as the expression of the trust KPIs in percentages and the essence of the trust KPIs remains.

6.3 Limitations

The design of the fuzzy model has several limitations. The first limitation relates to the amount of consulted experts. The input for the model was obtained from five experts. These experts all had several years of experience in procurement, so their input is assumed valid. However, the input from five experts was difficult to average because for some KPIs the linguistic term sets varied widely. Furthermore, the five experts cover four different industries but the generality of the model improves in case the number of covered industries increases too. The second limitation is that in this research project no attention is paid to what and how metrics are currently measured by organizations, but only to what metrics organizations should measure. Therefore a lack of insight in how this model could be implemented by organizations in their current IT systems is present. The third limitation is related to the rule base which underlies the fuzzy model. The rule base is determined by the weight factors as assigned to the KPIs by the experts. Although the rule base is evaluated with and approved by the experts, the model may improve by the formulation of each fuzzy rule by the experts. The fourth limitation concerns the use of the three trust levels cost level, service level, and quality level. These three aspects in buyer-seller relationships are important for building trust, but depending on the strategy and vision of the organization the evaluation of a trust relation may demand more aspects to include in the model, besides an improvement trust level as suggested by the experts. The last limitation relates to the sensitivity analysis in Matlab and the feedback from the experts. The results of the sensitivity analysis and the feedback indicates that the three requirements are not yet completely covered in the fuzzy model. The coverage of the requirements may improve by testing and training the model against corporate data. Especially training of the model has the potential to contribute to the transformation to a data-driven model.

6.4 Future research

Next to the recommendations following from the five limitation described previously, some general recommendations exist for future research projects towards trust in long term buyer-seller relationships. First, these general recommendations are discussed, and secondly, the specific recommendations to eliminate the aforementioned limitations.

6.4.1 General recommendations

The fuzzy model is implemented in the Fuzzy Logic Toolbox™ from the Matlab software package. Although the toolbox is user-friendly and does not require special training the toolbox has a limitation. Since the model is designed to evaluate the trust relationship between organizations and their suppliers by means of historical data the toolbox should import that data from the organization its IT system automatically. However, a feature to automatically import historical data from these systems directly is currently not available in the toolbox. This may hamper the implementation in the business environment. The recommendation is to search for a software package which is able to import historical data from IT systems directly. Another general issue to take into account is related to the limitation on the number and background of the experts. Whereas this limitation addresses the lack of large numbers of experts from different industries to increase the generality of the model, trust in buyer-seller relationships may differ across industries even if these industries have a high supply risk in their supply chain. A future research project may identify the differences across the industries which on their turn may improve or extend this first attempt to design a fuzzy model for inter-organizational trust.

6.4.2 Specific recommendations

One of the three requirements was to design a correct model. The correctness of the designed model is limited due to the amount of five experts from four different industries. In future projects more experts from different industries should be consulted. An ideal situation would be if each technological industry is represented by multiple experts from different organizations. Secondly, case-studies with the fuzzy model improve the accuracy and precision of the model. Furthermore, in future research a step may be included to identify what metrics organizations currently measure and how they measure these metrics. This knowledge could be used to write a plan for the implementation of the model in the business environment. To continue, although the formulation of the rule base by means of the weight factors attributed to the KPIs by the experts was possible, the model may benefit from formulating the fuzzy rules with the experts. The recommendation for future researchers is to schedule enough time with each expert to ensure that the linguistic term set, the database, and the rule base can be discussed extensively. This process is very time consuming, especially with more than five experts because each appointment with an expert will take over two hours. The last recommendation is to discuss the trust levels with experts too. In this thesis project the three trust levels were derived from the current literature on inter-organizational trust a procurement context. However, experts in the field may shed light on what trust levels could capture inter-organizational trust in a more complete fashion.

6.4.3 The roadmap towards a data-driven fuzzy model

The proposed expert-driven model in this thesis is the first attempt to evaluate trust relationships between organizations and their suppliers. The first next step is to design a data-driven model which is based on the expert-driven model. This step requires corporate data to test and train the model. For testing the model case-studies are suitable to identify possible flaws in the model, whereas training refers to the process of learning the model to recognize patterns and to adapt themselves to cope with changing environment. Therefore, these models seem able to evaluate trust relationships between organizations and suppliers across different industries. These features are characteristic for neuro-fuzzy models (Roger Jang, 1997). The second step is the development of a neuro-fuzzy model. The learning or adaptation of such models is dependent on the derivatives of the MFs with respect to its argument and parameters as represented in the earlier given formula,

$$trapmf(x; a, b, c, d) = \max\left(\min\left(\frac{x-a}{b-a}, 1, \frac{d-x}{d-c}\right), 0\right)$$

The gradient descent approach in parameter space enables a better approximation of the input-output relationship (Berthold & Hand, 2007). Therefore, the interpretation-accuracy dilemma is less eminent in neuro-fuzzy models. The final and third step is to further develop the neuro-fuzzy model into a so-called evolving neuro-fuzzy model. These specialized models learn incrementally through locally tuned elements (Kasabov, 2001). In other words, this type of neuro-fuzzy systems grow over time as more data becomes available to the system during the operation of the system. Moreover, the learning focusses on optimizing elements of the system. Kasabov (2001) proposed a method for structure optimizing through so-called rule aggregation for on-line, lifelong learning. Meaningful abstractions can be derived during this process and therefore seems very suitable for evaluating the complex trust relationships between organizations and their suppliers.

7 Conclusion

The most important findings and implications are recapitulated.

The expert-driven fuzzy model prototype quantitatively evaluates trust relationships between an organization and its suppliers. The evaluation of the trust relationship is performed according to eleven KPIs. More specifically, the trust relationship between an organization and a supplier is a form of inter-organizational trust with its subtypes contractual trust, competence trust, and goodwill trust. Furthermore, a set of eleven KPIs are identified from current literature because they are regarded as moderately or highly important indicators for the performance of a supplier. These KPIs are linked to the subtypes of inter-organizational trust and therefore called trust KPIs. The eleven trust KPIs are categorized into the cost level, the service level, and the quality level. As inter-organizational trust is rather expressed in linguistic terms than crisp numbers, fuzzy set theory is applicable. The input for the design of the fuzzy model is obtained from five experts active in technological industries. Based on this input the linguistic term sets, the databases for defining the MFs, and the rule base is established. The fuzzy model is implemented in Matlab as a two-layer Mamdani inference system with max-min composition. Moreover, testing and training of the proposed model may lead to the design of a data-driven fuzzy model. The interpretability and the accuracy of the model can be further improved by designing a neuro-fuzzy model, which is capable to adapt to changing environments. Several limitations are applicable to this thesis. First, the input for the model is obtained from five experts. Since this number is rather low the generality of the model is compromised. Second, the trust KPIs are determined to reflect inter-organizational trust to the best. However, what organizations can and do measure with respect to the performance of a supplier is not taken into account. The identified trust KPIs may require high investments to adapt the IT system architecture of the organization in order to enable direct measurement of the trust KPIs. Third, the formulation of the rule base in this thesis is different than the standard procedure. The fuzzy rules may therefore differ from the rule base if this was obtained according to the standard procedure. Fourth, the proposed model evaluates the trust relationship on three separate levels. Although indicated as important for the establishment of trust, more aspects may play a role. Last, The robustness, correctness, and simplicity of the model are considered satisfactory but need improvement prior to implementation in the business environment. All in all, this thesis implicates that inter-organizational trust is quantifiable. The proposed model uses this capability and enables organizations to make informed decisions on whether the suppliers in their current supply base embody potential long-term business partners.

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APPENDIX I Information about experts

Name Academic title Profession Organization Industry	XXX XXX XXX XXX Biotechnology
Name Academic title Profession Organization Industry	XXX XXX XXX XXX Biotechnology
Name Academic title Profession Organization Industry	XXX XXX XXX XXX Energy & Petrochemical
Name Academic title Profession Organization Industry	XXX XXX XXX XXX Food and Beverage
Name Academic title Profession Organization Industry	XXX XXX XXX XXX Aviation

APPENDIX II Linguistic term sets per expert

	EXPERT I	POOR	AVERAGE	GOOD
COST	ContractualCost CostRange CostEfficiency DecreaseCost	0 – 90 0 – 80 n/a 0 – 40	n/a 80 – 95 n/a 40 – 60	90 – 100 95 – 100 n/a 60 – 100
SERVICE	ContractualService OverdueOrders PriorityOrders DecreaseLeadTimes	0 – 80 0 – 50 0 – 50 n/a	80 – 90 50 – 75 50 – 75 n/a	90 – 100 75 – 100 75 – 100 n/a
QUALITY	ContractualQuality ConstantQuality QualityImprovement	0 – 80 0 – 50 0	80 – 90 50 – 75 1 – 2	90 – 100 75 – 100 2 – 10

	EXPERT II	POOR	AVERAGE	GOOD
COST	ContractualCost CostRange CostEfficiency DecreaseCost	0 – 95 0 – 70 n/a n/a	n/a 70 – 85 n/a 0 – 70	95 – 100 85 – 100 n/a 70 – 100
SERVICE	ContractualService OverdueOrders PriorityOrders DecreaseLeadTimes	0 – 95 0 – 95 0 – 50 n/a	n/a n/a 50 – 80 n/a	95 – 100 95 – 100 80 – 100 n/a
QUALITY	ContractualQuality ConstantQuality QualityImprovement	0 – 95 0 – 95 0	n/a n/a 1 – 2	95 – 100 95 – 100 2 – 10

	EXPERT III	POOR	AVERAGE	GOOD
COST	ContractualCost CostRange CostEfficiency DecreaseCost	0 – 95 n/a 0 – 70 n/a	95 – 98 n/a 70 – 90 0 – 20	98 – 100 n/a 90 – 100 20 – 100
SERVICE	ContractualService OverdueOrders PriorityOrders DecreaseLeadTimes	0 – 85 n/a 0 – 85 n/a	85 – 95 n/a 85 – 95 0 – 20	95 – 100 n/a 95 – 100 20 – 100
QUALITY	ContractualQuality ConstantQuality QualityImprovement	0 – 95 0 – 95 0	95 – 98 95 – 98 1 – 2	98 – 100 98 – 100 2 – 10

	EXPERT IV	POOR	AVERAGE	GOOD
COST	ContractualCost CostRange CostEfficiency DecreaseCost	0 – 95 0 – 100 0 0 – 10	95 – 100 n/a 0 – 100 10 – 50	100 100 100 50 – 100
SERVICE	ContractualService OverdueOrders PriorityOrders DecreaseLeadTimes	0 – 98 0 – 99 0 – 99 n/a	98 – 100 99 – 100 99 – 100 n/a	100 100 100 n/a
QUALITY	ContractualQuality ConstantQuality QualityImprovement	0 – 100 0 – 100 0	n/a n/a 0 – 2	100 100 2 – 10

	EXPERT V	POOR	AVERAGE	GOOD
COST	ContractualCost CostRange CostEfficiency DecreaseCost	0 – 90 0 – 40 0 – 40 0	90 – 98 40 – 90 40 – 90 n/a	98 – 100 90 – 100 90 – 100 0 – 100
SERVICE	ContractualService OverdueOrders PriorityOrders DecreaseLeadTimes	0 – 95 0 – 90 0 – 90 n/a	95 – 99 90 – 95 90 – 95 0	99 – 100 95 – 100 95 – 100 0 – 100
QUALITY	ContractualQuality ConstantQuality QualityImprovement	0 – 90 0 – 50 0 – 2	90 – 95 50 – 75 2 – 3	95 – 100 75 – 100 3 – 10

APPENDIX III Weight factors of trust KPIs per expert

		EXPERT I	EXPERT II	EXPERT III	EXPERT IV	EXPERT V
COST	ContractualCost	1	4	2	2	1
	CostRange	3	2	n/a	1	4
	CostEfficiency	n/a	n/a	3	4	3
	DecreaseCost	4	1	4	3	2
SERVICE	ContractualService	3	4	3	4	4
	OverdueOrders	3	4	n/a	3	3
	PriorityOrders	1	1	2	3	1
	DecreaseLeadTimes	n/a	n/a	4	n/a	3
QUALITY	ContractualQuality	4	4	2	4	4
	ConstantQuality	2	4	2	3	3
	QualityImprovement	1	3	4	4	2

APPENDIX IV Weight factors of trust performances per expert

		EXPERT I	EXPERT II	EXPERT III	EXPERT IV	EXPERT V
COST	Trust performance	2	2	3	1	2
SERVICE	Trust performance	3	4	2	2	3
QUALITY	Trust performance	4	4	4	3	3

APPENDIX V Rule base for the cost level

1=`if ContractualCost is poor and CostRange is poor and CostEfficiency is poor, then TrustPerformanceCostLevel is poor';
2=`if ContractualCost is poor and CostRange is poor and DecreaseCost is poor, then TrustPerformanceCostLevel is poor';
3=`if ContractualCost is poor and CostRange is poor and CostEfficiency is average and DecreaseCost is average, then TrustPerformanceCostLevel is average';
4=`if ContractualCost is poor and CostRange is poor and CostEfficiency is average and DecreaseCost is good, then TrustPerformanceCostLevel is average';
5=`if ContractualCost is poor and CostRange is poor and CostEfficiency is good and DecreaseCost is average, then TrustPerformanceCostLevel is poor';
6=`if ContractualCost is poor and CostRange is poor and CostEfficiency is good and DecreaseCost is good, then TrustPerformanceCostLevel is average';
7=`if ContractualCost is poor and CostRange is average and CostEfficiency is poor, then TrustPerformanceCostLevel is poor';
8=`if ContractualCost is poor and CostRange is average and CostEfficiency is average, then TrustPerformanceCostLevel is average';
9=`if ContractualCost is poor and CostRange is average and CostEfficiency is good, then TrustPerformanceCostLevel is average';
10=`if ContractualCost is poor and CostRange is good and CostEfficiency is poor and DecreaseCost is poor, then TrustPerformanceServiceLevel is poor';
11=`if ContractualCost is poor and CostRange is good and CostEfficiency is poor and DecreaseCost is average, then TrustPerformanceServiceLevel is poor';
12=`if ContractualCost is poor and CostRange is good and CostEfficiency is poor and DecreaseCost is good, then TrustPerformanceServiceLevel is average';
13=`if ContractualCost is poor and CostRange is good and CostEfficiency is average, then TrustPerformanceServiceLevel is average';
14=`if ContractualCost is poor and CostRange is good and CostEfficiency is good, then TrustPerformanceServiceLevel is average';
15=`if ContractualCost is average and CostRange is poor and CostEfficiency is poor, then TrustPerformanceServiceLevel is poor';
16=`if ContractualCost is average and CostRange is poor and CostEfficiency is average and DecreaseCost is poor, then TrustPerformanceServiceLevel is poor';
17=`if ContractualCost is average and CostRange is poor and CostEfficiency is average and DecreaseCost is average, then TrustPerformanceServiceLevel is average';
18=`if ContractualCost is average and CostRange is poor and CostEfficiency is average and DecreaseCost is good, then TrustPerformanceServiceLevel is average';
19=`if ContractualCost is average and CostRange is poor and CostEfficiency is good and DecreaseCost is poor, then TrustPerformanceServiceLevel is poor';
20=`if ContractualCost is average and CostRange is poor and CostEfficiency is good and DecreaseCost is average, then TrustPerformanceServiceLevel is average';
21=`if ContractualCost is average and CostRange is poor and CostEfficiency is good and DecreaseCost is good, then TrustPerformanceServiceLevel is average';

22=`if ContractualCost is average and CostRange is average and CostEfficiency is poor, then TrustPerformanceCostLevel is average';
23=`if ContractualCost is average and CostRange is average and CostEfficiency is average, then TrustPerformanceCostLevel is average';
24=`if ContractualCost is average and CostRange is average and CostEfficiency is good and DecreaseCost is poor, then TrustPerformanceCostLevel is average';
25=`if ContractualCost is average and CostRange is average and CostEfficiency is good and DecreaseCost is average, then TrustPerformanceCostLevel is average';
26=`if ContractualCost is average and CostRange is average and CostEfficiency is good and DecreaseCost is good, then TrustPerformanceCostLevel is good';
27=`if ContractualCost is average and CostRange is good and CostEfficiency is poor and DecreaseCost is poor, then TrustPerformanceCostLevel is poor';
28=`if ContractualCost is average and CostRange is good and CostEfficiency is poor and DecreaseCost is average, then TrustPerformanceCostLevel is average';
29=`if ContractualCost is average and CostRange is good and CostEfficiency is poor and DecreaseCost is good, then TrustPerformanceCostLevel is average';
30=`if ContractualCost is average and CostRange is good and CostEfficiency is average and DecreaseCost is poor, then TrustPerformanceCostLevel is average';
31=`if ContractualCost is average and CostRange is good and CostEfficiency is average and DecreaseCost is average, then TrustPerformanceCostLevel is average';
32=`if ContractualCost is average and CostRange is good and CostEfficiency is average and DecreaseCost is good, then TrustPerformanceCostLevel is good';
33=`if ContractualCost is average and CostRange is good and CostEfficiency is good and DecreaseCost is poor, then TrustPerformanceCostLevel is average';
34=`if ContractualCost is average and CostRange is good and CostEfficiency is good and DecreaseCost is average, then TrustPerformanceCostLevel is good';
35=`if ContractualCost is average and CostRange is good and CostEfficiency is good and DecreaseCost is good, then TrustPerformanceCostLevel is good'.
36=`if ContractualCost is good and CostRange is poor and CostEfficiency is poor, then TrustPerformanceCostLevel is poor';
37=`if ContractualCost is good and CostRange is poor and CostEfficiency is average and DecreaseCost is poor, then TrustPerformanceCostLevel is poor';
38=`if ContractualCost is good and CostRange is poor and CostEfficiency is average and DecreaseCost is average, then TrustPerformanceCostLevel is average';
39=`if ContractualCost is good and CostRange is poor and CostEfficiency is average and DecreaseCost is good, then TrustPerformanceCostLevel is average';
40=`if ContractualCost is good and CostRange is poor and CostEfficiency is good, then TrustPerformanceCostLevel is average';
41=`if ContractualCost is good and CostRange is average and CostEfficiency is poor and DecreaseCost is poor, then TrustPerformanceCostLevel is poor';
42=`if ContractualCost is good and CostRange is average and CostEfficiency is poor and DecreaseCost is average, then TrustPerformanceCostLevel is average';
43=`if ContractualCost is good and CostRange is average and CostEfficiency is poor and DecreaseCost is good, then TrustPerformanceCostLevel is average';

44=`if ContractualCost is good and CostRange is average and CostEfficiency is average and DecreaseCost is poor, then TrustPerformanceCostLevel is average';
45=`if ContractualCost is good and CostRange is average and CostEfficiency is average and DecreaseCost is average, then TrustPerformanceCostLevel is average';
46=`if ContractualCost is good and CostRange is average and CostEfficiency is average and DecreaseCost is good, then TrustPerformanceCostLevel is good';
47=`if ContractualCost is good and CostRange is average and CostEfficiency is good and DecreaseCost is poor, then TrustPerformanceCostLevel is average';
48=`if ContractualCost is good and CostRange is average and CostEfficiency is good and DecreaseCost is average, then TrustPerformanceCostLevel is good';
49=`if ContractualCost is good and CostRange is average and CostEfficiency is good and DecreaseCost is good, then TrustPerformanceCostLevel is good'.
50=`if ContractualCost is good and CostRange is good and CostEfficiency is poor, then TrustPerformanceCostLevel is average';
51=`if ContractualCost is good and CostRange is good and CostEfficiency is average and DecreaseCost is poor, then TrustPerformanceCostLevel is average';
52=`if ContractualCost is good and CostRange is good and CostEfficiency is average and DecreaseCost is average, then TrustPerformanceCostLevel is good';
53=`if ContractualCost is good and CostRange is good and CostEfficiency is average and DecreaseCost is good, then TrustPerformanceCostLevel is good';
54=`if ContractualCost is good and CostRange is good and CostEfficiency is good and DecreaseCost is poor, then TrustPerformanceCostLevel is average';
55=`if ContractualCost is good and CostRange is good and CostEfficiency is good and DecreaseCost is average, then TrustPerformanceCostLevel is good';
56=`if ContractualCost is good and CostRange is good and CostEfficiency is good and DecreaseCost is good, then TrustPerformanceCostLevel is good'.

APPENDIX VI Rule base for the service level

1=`if ContractualService is poor, then TrustPerformanceServiceLevel is poor';
2=`if ContractualService is average and OverdueOrders is poor and PriorityOrders is poor, then TrustPerformanceServiceLevel is poor';
3=`if ContractualService is average and OverdueOrders is poor and PriorityOrders is average, then TrustPerformanceServiceLevel is average';
4=`if ContractualService is average and OverdueOrders is poor and PriorityOrders is good, then TrustPerformanceServiceLevel is average';
5=`if ContractualService is average and OverdueOrders is average, then TrustPerformanceServiceLevel is average';
6=`if ContractualService is average and OverdueOrders is good and PriorityOrders is poor, then TrustPerformanceServiceLevel is average';
7=`if ContractualService is average and OverdueOrders is good and PriorityOrders is average, then TrustPerformanceServiceLevel is average';
8=`if ContractualService is average and OverdueOrders is good and PriorityOrders is good and DecreaseLeadTimes is average, then TrustPerformanceServiceLevel is average';
9=`if ContractualService is average and OverdueOrders is good and PriorityOrders is good and DecreaseLeadTimes is good, then TrustPerformanceServiceLevel is good';
10=`if ContractualService is good and OverdueOrders is poor, then TrustPerformanceServiceLevel is average';
11=`if ContractualService is good and OverdueOrders is average and PriorityOrders is poor, then TrustPerformanceServiceLevel is average';
12=`if ContractualService is good and OverdueOrders is average and PriorityOrders is average and DecreaseLeadTimes is average, then TrustPerformanceServiceLevel is average';
13=`if ContractualService is good and OverdueOrders is average and PriorityOrders is average and DecreaseLeadTimes is good, then TrustPerformanceServiceLevel is good';
14=`if ContractualService is good and OverdueOrders is average and PriorityOrders is good and DecreaseLeadTimes is average, then TrustPerformanceServiceLevel is average';
15=`if ContractualService is good and OverdueOrders is average and PriorityOrders is good and DecreaseLeadTimes is good, then TrustPerformanceServiceLevel is good';
16=`if ContractualService is good and OverdueOrders is good and PriorityOrders is poor and DecreaseLeadTimes is average, then TrustPerformanceServiceLevel is average';
17=`if ContractualService is good and OverdueOrders is good and PriorityOrders is poor and DecreaseLeadTimes is good, then TrustPerformanceServiceLevel is good';
18=`if ContractualService is good and OverdueOrders is good and PriorityOrders is average and DecreaseLeadTimes is average, then TrustPerformanceServiceLevel is average';
19=`if ContractualService is good and OverdueOrders is good and PriorityOrders is average and DecreaseLeadTimes is good, then TrustPerformanceServiceLevel is good';
20=`if ContractualService is good and OverdueOrders is good and PriorityOrders is good, then TrustPerformanceServiceLevel is good'.

APPENDIX VII Rule base for the quality level

1=`if ContractualQuality is poor, then TrustPerformanceQualityLevel is poor';
2=`if ContractualQuality is average and QualityImprovement is average, then TrustPerformanceQualityLevel is average';
3=`if ContractualQuality is average and QualityImprovement is good, then TrustPerformanceQualityLevel is average';
4=`if ContractualQuality is average and ConstantQuality is poor and QualityImprovement is poor, then TrustPerformanceQualityLevel is poor';
5=`if ContractualQuality is average and ConstantQuality is average and QualityImprovement is poor, then TrustPerformanceQualityLevel is average';
6=`if ContractualQuality is average and ConstantQuality is good and QualityImprovement is poor, then TrustPerformanceQualityLevel is average';
7=`if ContractualQuality is good and QualityImprovement is good, then TrustPerformanceQualityLevel is good';
8=`if ContractualQuality is good and ConstantQuality is good, then TrustPerformanceQualityLevel is good';
9=`if ContractualQuality is good and ConstantQuality is poor and QualityImprovement is poor, then TrustPerformanceQualityLevel is average';
10=`if ContractualQuality is good and ConstantQuality is poor and QualityImprovement is average, then TrustPerformanceQualityLevel is average';
11=`if ContractualQuality is good and ConstantQuality is average and QualityImprovement is poor, then TrustPerformanceQualityLevel is average';
12=`if ContractualQuality is good and ConstantQuality is average and QualityImprovement is average, then TrustPerformanceQualityLevel is average';
13=`if ContractualQuality is good and ConstantQuality is good and QualityImprovement is good, then TrustPerformanceQualityLevel is good'.

APPENDIX VIII Rule base for overall trust level

1=`if TrustPerformanceQualityLevel is poor, then OverallTrustLevel is poor';
2=`if TrustPerformanceCostLevel is poor and TrustPerformanceServiceLevel is poor, then OverallTrustLevel is poor';
3=`if TrustPerformanceCostLevel is poor and TrustPerformanceServiceLevel is average and TrustPerformanceQualityLevel is average, then OverallTrustLevel is average';
4=`if TrustPerformanceCostLevel is poor and TrustPerformanceServiceLevel is average and TrustPerformanceQualityLevel is good, then OverallTrustLevel is average';
5=`if TrustPerformanceCostLevel is poor and TrustPerformanceServiceLevel is good and TrustPerformanceQualityLevel is average, then OverallTrustLevel is average';
6=`if TrustPerformanceCostLevel is poor and TrustPerformanceServiceLevel is good and TrustPerformanceQualityLevel is good, then OverallTrustLevel is average';
7=`if TrustPerformanceCostLevel is average and TrustPerformanceServiceLevel is poor and TrustPerformanceQualityLevel is average, then OverallTrustLevel is poor';
8=`if TrustPerformanceCostLevel is average and TrustPerformanceServiceLevel is poor and TrustPerformanceQualityLevel is good, then OverallTrustLevel is average';
9=`if TrustPerformanceCostLevel is average and TrustPerformanceServiceLevel is average and TrustPerformanceQualityLevel is average, then OverallTrustLevel is average';
10=`if TrustPerformanceCostLevel is average and TrustPerformanceServiceLevel is average and TrustPerformanceQualityLevel is good, then OverallTrustLevel is average';
11=`if TrustPerformanceCostLevel is average and TrustPerformanceServiceLevel is good and TrustPerformanceQualityLevel is average, then OverallTrustLevel is average';
12=`if TrustPerformanceCostLevel is average and TrustPerformanceServiceLevel is good and TrustPerformanceQualityLevel is good, then OverallTrustLevel is good';
13=`if TrustPerformanceCostLevel is good and TrustPerformanceServiceLevel is poor and TrustPerformanceQualityLevel is average, then OverallTrustLevel is average';
14=`if TrustPerformanceCostLevel is good and TrustPerformanceServiceLevel is poor and TrustPerformanceQualityLevel is good, then OverallTrustLevel is average';
15=`if TrustPerformanceCostLevel is good and TrustPerformanceServiceLevel is average and TrustPerformanceQualityLevel is average, then OverallTrustLevel is average';
16=`if TrustPerformanceCostLevel is good and TrustPerformanceServiceLevel is average and TrustPerformanceQualityLevel is good, then OverallTrustLevel is good';
17=`if TrustPerformanceCostLevel is good and TrustPerformanceServiceLevel is good and TrustPerformanceQualityLevel is average, then OverallTrustLevel is average';
18=`if TrustPerformanceCostLevel is good and TrustPerformanceServiceLevel is good and TrustPerformanceQualityLevel is good, then OverallTrustLevel is good'.