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Prioritizing Offshore Vendor Selection Criteria for the North American Geospatial Industry

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This is to certify that the doctoral study by

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2014

Abstract

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by

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Doctoral Study Submitted in Partial Fulfillment

of the Requirements for the Degree of

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Abstract

The U.S. market for geospatial services totaled US $2.2 billion in 2010, representing 50% of the global market. Data-processing firms subcontract labor-intensive portions of data services to offshore providers in South and East Asia and Eastern Europe. In general, half of all offshore contracts fail within the first 5 years because one or more parties consider the relationship unsuccessful. Despite the high failure rates, no study has examined the offshore vendor selection process in the geospatial industry. The purpose of this study was to determine the list of key offshore vendor selection criteria and the efficacy of the analytic hierarchy process (AHP) for ranking the criteria that North American geospatial companies consider in the offshore vendor selection process. After the selection of the initial list of factors from the literature and their validation in a pilot study, a final survey instrument was developed and administered to 15 subject matter experts (SMEs) in North America. The SMEs expressed their preferences for one criterion over another by pairwise comparisons, which served as input to the AHP procedure. The results showed that the quality of deliverables was the top ranked (out of 26) factors, instead of the price, which ranked third. Similarly, SMEs considered social and environmental consciousness on the vendor side as irrelevant. More importantly, the findings indicated that the structured AHP process provides a useful and effective methodology whose application may considerably improve the quality of the overall vendor selection process. Last, improved and stabilized business relationships leading to predictable budgets might catalyze social change, supporting stable employment. Consumers could benefit from derivative improvements in product quality and pricing.

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Dedication

I dedicate this study to the people who made it possible that I could start this so important phase of my life. To my beloved partner, Mayra, who pushed me to start this program and was an eternally patient motivator, companion, editor, and sparring partner. To my late father, Wolfgang Musäus, who planted in me the seed of lifelong learning and of never giving up when facing a challenge. To my late mother Beate Musäus, who fostered the value of creative thinking in me, and to my two children Jasmina and Manuel, in the hope that it may be a motivation to them to pursue the degree themselves. To my friends Andreas Dunker and Udo Becker, who have supported me during these years and accepted the reduced time I could dedicate to them.

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Section 1: Foundation of the Study

The growing demand for rapid, accurate, and comprehensive digital geodata has led to a transformation of the traditional cartographic service providers, mainly small and medium businesses (SMBs), into supply chain members of a global, geospatial industry (Litan, Velicanu, & Copcea, 2011). The digital geodata form a base for geo-enabled Internet search engines, navigation systems, and management systems for transportation logistics. Often, specialized SMBs provide services as subcontractors with airborne or satellite data for global map engines, such as Microsoft Bing Maps, Google Earth, Nokia, and Apple Maps (M. Lee, 2010).

To satisfy the large demand in time and on budget, leaders of geospatial companies ("the buyers") decide to send digital imagery or laser data, locally captured with airborne, spaceborne, or terrestrial sensors, for processing to providers ("the vendors"), mainly to high-tech, low-labor cost centers in India, Eastern Europe, China, and South-East Asia (Schroth, Wang, Dun, & Mayr, 2008). Supply chains in the geospatial area are sequential or network-like combinations of negotiated buyer-supplier relationships. An increasing demand for just-in-time production in all consumer markets has created a stronger emphasis on risk management along the supply chains to avoid costly errors. Accurate and correct decisions in the supplier (or vendor) selection and evaluation processes have become mission critical for the procurement process.

Various factors affect the decision of a buyer to enter into a business relationship with a vendor, thus making the decision itself a complex, multicriteria process. This complexity had led previous researchers to develop and apply multicriteria decision

analyses, focusing on the procurement processes of large manufacturing and retail companies. The results indicated that even if some factors seem to be more relevant than others are, the relative importance among them does not remain static over time, over companies, and/or across business segments. Consequently, an analysis from one industry does not necessarily apply to another. However, according to Bai and Sarkis (2010) and Cheraghi (2011), the categories of factors that researchers identified in many studies included cost (compliance with sector behavior, cost-reduction activities, low initial price), time (delivery speed, product development time, partnership formation time), and quality (consistent delivery, quality systems, prompt response). These authors referred to these three basic factors as *performance measures*. Other researchers have found that flexibility (product volume changes, service capability, conflict resolution), innovativeness (new product launch, new use of technologies), culture (feeling of trust, management and structural compatibility), technology (platform compatibility, development speed, technical capability), and relationship (closeness, integrity, openness) significantly influence the selection process (S.-I. Chang, Yen, Ng, & Chang, 2012; Khan et al., 2011). Lastly, the globalization of supply chains and added emphasis on offshore outsourcing require the addition of geographical and time zone-related aspects to the list of relevant factors.

In summary, procurement specialists of geospatial companies, such as those in the United States of America or Canada, often use a tedious and multicriteria selection process to evaluate all available vendors. This selection process is transparent only to the few decision makers in the buyer companies, while vendors are often unaware of the

specific factors leading to a successful award and business relationship. Thus, the development of a clear selection and ranking process is essential to find the right match for an offshore relationship between the buyer and suppliers of geospatial data.

The objective of the study was the prioritization of key criteria that North American geospatial companies consider in the offshore vendor selection process and the determination of the efficacy of the analytic hierarchy process (AHP) for ranking these criteria. Saaty (2013) designed AHP as a multicriteria decision technique to convert individual decision maker preferences into ratio scale weights. The result of the analytic hierarchy process is a linear combination of the weights for each alternative. The resultant weights then form the base for comparison and ranking of the alternatives, and hence, assist the decision maker in making a final choice. As such, AHP enables buyers and offshore vendors in the geospatial industry to make objective partnership decisions consistently, transparently, and quickly.

Background of the Problem

The focus of the study was on the offshore vendor selection process in the geospatial industry. The topic was worthy of study given the increasing amount of data-processing services that outsource providers performed outside the United States of America and Canada (Geospatial Today & FICCI, 2009). Outsourcing occurs when managers of a company subcontract business functions to an outside-supplier (Tate & Ellram, 2009). Tate and Ellram (2009) defined offshore outsourcing as a particular case of outsourcing: "hiring an external organization outside the firm's country of origin to perform some or all business functions" (p. 256). Since the beginning of the 1990s,

offshore outsourcing has stepwise entered the business models of almost all major industries, from IT services to manufacturing (Kusaba, Moser, & Rodrigues, 2011). Leaders of the IT and IT-enabled services (ITES) industry adopted the offshoring paradigm early, which explains why today's Indian IT business process outsourcing (IT-BPO) sector accounts for an export of about $50 billion per annum (NASSCOM, 2009). The global market of geospatial services, data, and applications amounted to $4.4 billion per annum in 2010, of which U.S. companies and governmental agencies generated about 50% (Daratech, 2011). Even if the geospatial data and application sector in India represented only a fraction of the aforementioned volume of IT outsourcing, with a total value of about $700 million in 2008, it was still of considerable magnitude (Geospatial Today & FICCI, 2009).

Researchers have suggested that correct vendor selection reduces the risk of a failing offshore business relationship (Khan et al., 2011; Manning, Lewin, & Schuerch, 2011; D. D. Wu, Zhang, Wu, & Olson, 2010). In IT-related offshore relationships, vendor development is necessary, which requires a considerable investment on the buyer side, and the cost of switching vendors may become high (Poston, Simon, & Jain, 2010). The focus of research has been mainly on vendor selection for the IT and manufacturing industries, and there is a lack of publications on research in the service-sector specializing in geographical information. In addition, most of the geospatial companies in North America are small and medium-sized businesses; thus, the results of previous studies that focused primarily on the practices of globally operating enterprises are not always applicable (Aspelund & Butsko, 2010; Roza, Van den Bosch, & Volberda, 2011).

The problem of a missing transparency in the selection process can be significant for both vendors and buyers. Knowledge about the relative importance of the key evaluation factors that buyers used would enable vendors to focus their efforts on the requirements in a particular industry. An improved orientation of dollar investment and higher customer satisfaction score, which generate stable income and long-term relationships, are the expected benefits from more transparency (Aksoy & Öztürk, 2011). For buyers, the use of a clear ranking system combining the most relevant factors may reduce the time of due diligence with vendors, and increase the probability of finding partners who apply processes according to industry standards (Calvi, Le Dain, Fendt, & Herrmann, 2010).

The field of decision sciences contains a powerful set of techniques for ranking alternatives, and their wide acceptability in the business world is a motivating factor for their selection in this study. Creating the foundation for future expansion of the results into geographical zones other than the US and Canada is an area of potential development. A particular area of interest is to develop a comparison by examining combinations of other decision models such as *multiattribute utility theory* (MAUT; Hurson & Siskos, 2014); *analytic network process* (ANP; Sipahi & Timor, 2010); *fuzzy set theories* (Che, 2010); and *goal programming* (GP; Sadeghieh, Dehghanbaghi, Dabbaghi, & Barak, 2012). Data for this research were accessible through direct business involvement, which enabled me to develop and test the model that will allow North American managers to evaluate subproviders.

Problem Statement

The United States accounted for 50% of the global market for geospatial services in 2010, with a value of $4.4 billion (Daratech, 2011). In 2008, India's geospatial industry alone absorbed $700 million in services and applications for offshore outsourcing relationships (Geospatial Today & FICCI, 2009). The general business problem addressed in this study is that partners terminate 50% of offshore contracts within the first 5 years because parties consider the relationship unsatisfactory (Khan et al., 2011). Ideally, decision makers in vendor services outsourcing should be evaluating and awarding contracts based on an objective or quantifiable set of universally accepted criteria for a particular industry (Khan et al., 2011). Roza et al. (2011) offered that evaluation criteria vary significantly across industries and firm sizes, thus making it difficult to isolate or quantify such a set. This limitation, according Gandhi, Gorod, and Sauser (2012), equated to the inability of procurement specialists to quantify and thus manage the risk that can lead to contractual failures and associated financial losses for both buyer and vendor. The specific business problem is that geospatial managers have limited, structured methods for identifying and weighting an appropriate set of criteria to implement an effective and efficient offshore vendor selection process.

Purpose Statement

The purpose of this quantitative descriptive research was to examine the efficacy of AHP for the creation of a structured vendor selection model for use in the geospatial industry in the United States and Canada. The results could help in the creation of sustainable business relationships with offshore vendors. The expectation was that the

research would provide managers in the geospatial industry in US and Canada with a quantitative model based on AHP. Decision makers in geospatial companies could apply the model in a due diligence process before starting a distance business relationship and thus reduce exposure to any later operational risks.

The steps included the development of an initial list of potential criteria and associated variables that influenced vendor selection in the literature review and later, validation of the list through a pilot survey in the geospatial industry. A purposeful sample of 15 SMEs then ranked the relative importance of each criterion from the validated list. The results formed the input for an application of AHP to generate an overall relative weight for each factor. The SMEs are managers with outsourcing experience from my personal contact list or other members of the American Society for Photogrammetry and Remote Sensing (ASPRS). Improved and stable business relationships with concomitant employment and predictable budgets could catalyze social change. Consumers might benefit through derivative improvements in product quality and pricing.

Nature of the Study

This quantitative descriptive study included data from surveys among various procurement experts/practitioners to determine the relative priorities of certain factors leading to a decision in the offshore-vendor selection process in the geospatial industry. Although the descriptive nature might have indicated that a qualitative design would have been preferable, there were certain reasons opposing that. Parylo (2012) described qualitative strategies as (a) ethnographic, (b) grounded theory, (c) case study, (d)

phenomenology, and (e) narrative research. Ethnographic and narrative research did not, *ex ante,* qualify, as neither a cultural group in its natural environment nor stories of lives of individuals were within the purpose of the study (Parylo, 2012).

Grounded theory was not applicable as the theoretical framework is already part of the defined field of decision sciences. A phenomenological design would have required the researcher to explore relationships among the lived experiences of individuals related to a specific phenomenon. Another possible design was the case or multicase study, which various researchers have included as the qualitative part of a mixed-method approach in some AHP-related studies (K.-L. Peng, Lin, & Baum, 2012; Xenias & Whitmarsh, 2013). However, in-depth investigation of only one or few companies would not have served the purpose of obtaining a generalizable process for benefiting the multitude of stakeholders in the North-American markets. Parylo (2012) distinguished within quantitative strategies survey research and experimental research. At the core of the present study was the observation of an existing business practice in a defined market segment, and the participant group would not receive treatments. Hence, survey research provided the correct choice, and the design envisioned for the study was quantitative descriptive.

The specific business problem intersected with multicriteria decision methods (MCDM), and the theoretical framework formed part of decision sciences as described in the following paragraphs. Not all factors leading to a decision are numerically commensurable on a fixed scale, but it is possible to describe verbally the relative importance compared to other factors in qualitative terms, for example “X is much

more/much less important that Y." Some MCDM, like AHP, provide the user with the possibility to integrate both qualitative and quantitative factors in the same analysis and allow for simultaneous consideration of non-commensurable criteria. The evaluator would assign a relative weight to each criterion resulting from a ratio-scale determination. In particular, the concept of the analytic hierarchy process includes pairwise comparisons to generate the measurement on a ratio-scale while maintaining its inherent usefulness to handle some inconsistencies of human judgment, which seemed to offer the best framework to structure complex, multicriteria based decision problems (Saaty & Shang, 2011).

Since its introduction, many practitioners have employed AHP in multiple industries to develop factor lists for vendor selection (Subramanian & Ramanathan, 2012). These lists often contain identical or similar factors. Due to their generic nature and missing connection to a specific industry, many factors were potentially relevant for the present study. To assure an industry-relevant outcome of the study, a smaller sample *of subject matter experts* (*SME*s) received the initial list of factors, identified from the literature and my own experience and knowledge, for validation in a pilot survey. In a second step, a larger group of SMEs individually expressed the relative importance among the factors of the initial list by comparing them pairwise.

Research Question

The main research question (RQ) of the study was as follows: How can practitioners apply the AHP multifactor decision process to develop a set of prioritized factors for the selection of offshore geospatial data processing vendors?

The study included four sub questions:

SQ1: What are the top five critical factors in the vendor selection for an offshore-outsourcing relationship in the geospatial industry?

SQ2: How do social responsibility-related factors rank when compared to delivery, quality, and cost-related factors?

SQ3: How do cost-related factors rank compared to any other factor?

SQ4: How large is the variance of the aggregated factor weights?

Hypotheses

Although quantitative in nature, the analytic hierarchy process does not involve statistical analysis that would require establishing null hypotheses. With AHP, modelers use working hypotheses following the definitions of Oppenheim and Putnamo (1958). They posited that, in contrast to statistical hypotheses, working hypotheses would only serve as an initial point and assumption for the correct direction of research and would not be subject to the question of rejection or non-rejection. In this study, the focus was on the use of AHP to determine decision criteria for establishing an offshore business relationship for outsourcing geodata processing. The working hypotheses (WH) were as follows:

WH1: U.S. and Canadian business leaders decide to establish an offshore-relationship for data processing based on a process evaluating multiple criteria; thus, a multicriteria decision problem exists.

WH2: Decision makers give social responsibility criteria a quantifiable weight in the decision process.

WH3: Low cost alone is not the most influential decision criterion in vendor selection.

WH4: The aggregated weights for all factors derived from pairwise comparisons by the SMEs have low variance. Low variance would indicate that the results could become the base for a generalized decision system for offshore vendor selection in the geospatial industry.

These working hypotheses outlined different aspects of the work. WH1 contained the necessary precondition for the study, which means that if the results of the study had shown a rejection of WH1, a multicriteria decision problem would not aptly apply. Consequently, the AHP approach itself would have been inadequate for the problem.

WH2 related to the theoretical framework of sustainable supply chain management (SSCM) that Carter introduced (Carter & Easton, 2011). The basis for this direction of a working hypothesis was Carter's statement that if the management of a company improves socially sustainable behavior in the supply chain, transaction costs would decrease and the economic outcome would improve (Carter & Easton, 2011).

The common understanding of WH3 in the literature is that managers generally do not base supplier selection only on the lowest price, but also on other parameters related to delivery, quality of service and products, and response time (Bai & Sarkis, 2010; Ho, Xu, & Dey, 2010). Businesses in the geospatial industry are often SMBs in which management does not use scientific methods for evaluating and selecting supply-chain partners. Managers in SMBs also act under stricter financial constraints than in

large companies (S.-I. Chang et al. , 2012). Therefore, it seemed essential to focus on a working hypothesis that would relate to the importance of cost as a decision criterion.

WH4 is essential for potential generalization of the results within the research population. A low variance of the average weights for the decision factors would indicate that decision makers across the expert group used a similar set of decision criteria. A generalizable conclusion on the actual decision behavior would be possible only by testing whether procurement managers in fact apply the criteria consistently over time and award projects to the highest scoring vendor company. However, it was not in the scope of this study to investigate the consistency of judgment over time. Considerable doubt on the validity of WH4 would have indicated a lack of usability in an entirely generalizable model. This last statement also formed part of the assumptions and limitations of the study.

Survey Questions

The participants in the pilot survey validated a list of relevant factors in the field of supplier selection for geospatial offshore data processing. The pilot survey question was: "What is your opinion on the relevance of the following criteria in the selection process for an offshore-outsourcing vendor?" Participants were then able to (a) rate 32 criteria according to relevance, (b) comment on the clarity of a specific criterion, or (c) propose additional criteria.

In the follow-up survey, the participants gave information about the nationality of the company and then compared pairwise the criteria from the pilot survey's validated

list. (See Appendix B with the AHP tree for organization of the pairwise comparisons.) The follow-up survey contained three AHP levels, which means that, per the AHP methodology, each factor on Level 2, 3 and 4 contained as a cluster one or more subfactors on the next lower level requiring pairwise comparison. The next paragraph provides only an example of the survey questions in the follow-up survey. The term *Thurstone scale* indicates a placeholder for a graphic scale from -9 (*extreme preference for the left factor*) to 9 (*extreme preference for the right factor*) with the neutral point at 1 (*no preference for any factor*). See Appendix D for the complete set of survey questions and the graphic representation.

Top (Second) level AHP. Please state your degree of preference for. . .

Performance Measures against Organizational Factors. Thurstone scale

Third level AHP. Cluster Performance Measures

Please state by pairwise comparison your degree of preference for any of these factors in deciding on an offshore outsourcing relationship:

- Cost
- Flexibility
- Innovativeness
- Project management
- Delivery
- Quality

Please compare pairwise. . .

Quality <> Delivery. Thurstone scale

Quality <> Project management. Thurstone scale

Quality <> Innovativeness. Thurstone scale

Quality <> Flexibility. Thurstone scale

Quality <> Cost. Thurstone scale

Delivery <> Project management. Thurstone scale

Delivery <> Innovativeness. Thurstone scale

Delivery <> Flexibility. Thurstone scale

Delivery <> Cost. Thurstone scale

Project Management <> Innovativeness. Thurstone scale

Project Management <> Flexibility. Thurstone scale

Project Management <> Cost. Thurstone scale

Innovativeness <> Flexibility. Thurstone scale

Innovativeness <> Cost. Thurstone scale

Flexibility <> Cost. Thurstone scale

Fourth level AHP. Sub cluster Quality

Please state by pairwise comparison your degree of preference for any of these factors in deciding on an offshore outsourcing relationship:

- Product quality
- International certifications
- Reputation and track record

Please compare pairwise. . .

Product quality <> International certifications. Thurstone scale

Product quality <> Reputation and positive track record. Thurstone scale

International certifications <> Reputation and positive track record. Thurstone scale

Theoretical Framework

The scope of this study was to examine aspects of vendor selection in global supply chains with particular attention to offshore outsourcing in the geospatial industry. The theoretical framework for this study refers to the application of complex decision making processes to the fields of decision sciences (Agarwal, Sahai, Mishra, Bag, & Singh, 2011) and supply chain management in the context of offshore outsourcing (Tate & Ellram, 2009). Both areas emerge in a wider perspective from the field of operations management (OM; Subramanian & Ramanathan, 2012). Figure 1 represents the various precursors and elements motivated the study.

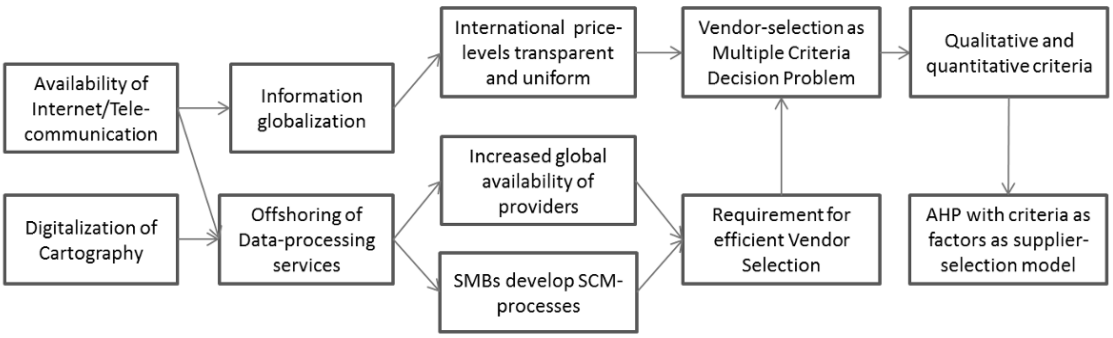


Figure 1. Justification chain for the use of AHP in the study.

OM originated in the early days of the 20th century when Frederick W. Taylor synthesized his observations about the steel-industry (Myers, 2011). OM concepts

evolved from the fields of factory and industrial management. Its application expanded with the Second World War's demands for increased production. In the post-war years, the emphasis in OM turned to effectiveness and responsiveness, which eventually led to total quality management (Radnor & Barnes, 2007). In the 1980s and 1990s, "process reengineering" and "balanced scorecard" were milestones in the evolution of business concepts (Faeltholm & Nilsson, 2010; Tayler, 2010).

One pillar of OM, performance measurement, emerged from the wider field of applications for industrial management (Radnor & Barnes, 2007). Radnor and Barnes (2007) concluded that performance assessment had transitioned from a focus on purely cost and output to a larger set of factors including flexibility, quality, dependability, and delivery speed. Consequently, decisions about selecting the correct sourcing partners in operational planning and in managing optimization of production systems had become more complex and required more advanced methods (Subramanian & Ramanathan, 2012). In the field of procurement, Dickson's established a list of 21 evaluation factors, which researchers consider the first systematic description of vendor selection criteria (Bai & Sarkis., 2010; Dickson, 1966; J. Peng, 2012).

Decision sciences as part of OM or more specifically, the concepts of multicriteria decision methods (MCDM) or multiattribute decision methods (MADM) address the inability of human beings to consider, in a consistent manner, a multitude of criteria that influence the outcome of a decision. Saaty and Shang (2011) claimed that due to their short-term memory and their ability to discriminate—their *channel* ability—humans could handle only seven concurrent threads—far fewer than required for complex and/or

crucial problems. In the field of decision sciences, various structured approaches, mostly transferred into mathematical models, emerged in the second half of the 20th century. Saaty introduced the analytic hierarchy process as a structured decision making technique and then developed it into a more generalized model, the analytic network process (ANP; Sipahi & Timor, 2010).

The topic of the present study includes the relationship of buyer companies and offshore outsourcing vendors in a global supply chain. The Council of Supply Chain Management Professionals defined supply chain management as "encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all Logistics Management activities. Importantly it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers" (Naslund & Williamson, 2010, p. 13). Sourcing is a partial or complete transfer of business processes to a different entity and can take various forms. While the terms *nearshore* or *offshore sourcing* indicate the geographical distance between the sourcing partners, the organizational relation between buyer and supplier remains undetermined. Only the term *outsourcing* makes it clear that the sourcing partner on the supply side belongs to a different company.

Definition of Terms

The terms in this chapter relate to the specific field of this study and herein to decision sciences and geospatial markets. Other authors might have applied some of the

terms with a different meaning. Therefore, for this study the following definitions are valid.

Aggregation of individual judgments (AIJ): Used during the application of AHP to consolidate the evaluations of individuals belonging to a group with the same goal and who, thus, subordinate their own preferences to the one of the organization (Pirdashti et al., 2009, p. 1151).

Aggregation of individual priorities (AIP): Used during the application of AHP to consolidate the evaluations of individual experts belonging to different value groups or systems (Pirdashti et al., 2009, p. 1151).

Analytic hierarchy process (AHP): A theory within the field of decision sciences based on the determination of relative priorities or ratio-scales among factors through pairwise comparison by an expert group (Saaty, 2013, p. 1103). Factors form groups of clusters and sub-clusters that build the branches of the hierarchical tree.

Analytic network process (ANP): An extension of the analytic hierarchy process including feedback loops for modeling interdependent relationships inside and among the AHP clusters (Sipahi & Timor, 2010, p. 776).

Consistency: Consistency can have the two forms (a) *ordinal* and (b) *cardinal consistency*. *Ordinal consistency* is that if A is *preferred to* B and B is *preferred to* C, then A is *preferred to* C. *Cardinal consistency* exists when A is two times *preferred to* B and B is three times *preferred to* C and A is six times *preferred to* C (Siraj, Mikhailov, & Keane, 2012, p. 423).

Geospatial industry: The total of all industry sectors providing software, hardware, and services related to the generation of geoinformation, that is the cartographic representation of appearance and phenomena occurring on the surface of the Earth (Geospatial Today & FICCI, 2009).

MAUT: Multiattribute utility theory is one of the largely accepted evaluation methodologies for multicriteria decision making problems. In the frame of this theory, the different criteria contribute with individual weights. The alternatives or choices receive utilities with weighted scores, which represent the elements of a utility function for evaluation (Chung, Kim, Kim, & Sohn, 2010, p. 131). The mathematical model inherits the axiomatic structure von Neumann and Morgenstern developed and requires strict adherence to transitivity (Subramanian & Ramanathan, 2012, p. 21). Some authors consider AHP/ANP sub-methods within the MAUT.

Multicriteria decision making (MCDM): All methods used for ranking various alternatives characterized by a set of multiple criteria (Zavadskas & Turskis, 2011, p. 402).

Outsourcing: Occurs when a "company subcontracts business functions to an outside supplier" (Tate & Ellram, 2009, p. 256).

Offshore outsourcing: A specific case of outsourcing, that authors defined as transferring activities that managers of a firm had previously performed in-house to a service provider outside the national boundaries of the country of operation of the firm (Lewin & Volberda, 2011, p. 241; Mukherjee, Gaur, & Datta, 2013, p. 377).

SMBs: Small and medium businesses or small and medium enterprises. The U.S. Small Business Administration (SBA) gives size standards for Small Businesses for different service industries. For the geospatial industry the North American Industry Classification System (NAICS) Sector 54 "Professional, Scientific, and Technical Services", NAICS-Code 541370 "Surveying and Mapping" would be applicable. A small business has by average annual receipts not exceeding $14 million (U.S. Small Business Administration, 2012).

SME: Subject matter experts are individuals with specific and high domain knowledge or expertise and the ability to apply it (Hamilton, Harrison, O'Connell, & Walker, 2012). In the study, the term *SME* refers to procurement experts on the geospatial industry designing and operating offshore outsourcing relationships.

Transitivity: A mathematical axiom, which in the frame of MCDM, requires that if a criterion or choice A is *preferred to* a criterion, or choice B and B *is preferred to* C, then A must be *preferred to* C (Subramanian & Ramanathan, 2012, p. 21). In MAUT, transitivity and consistency of all statements is mandatory, perfectly maintaining the magnitude of relation between the choices or criteria; however, AHP/ANP allows for small inconsistencies.

Assumptions, Limitations, and Delimitations

Assumptions

There were several assumptions underlying this study. The first assumption was that decision makers in geospatial companies in the United States and Canada do follow some defined set of two or more criteria (factors) during their supplier selection process,

as stated in the theoretical framework, and that they intuitively prioritize such factors. This first assumption was relevant as it justified the use of a technique for resolving a multicriteria decision problem with defined factors.

The second assumption was that the survey instrument—with an AHP-Thurstone scale as a key element—was adequate so that the SMEs could clearly express their judgments. This second assumption was the basis for using the chosen instrument without inducing bias.

The third assumption was that the SMEs are rational persons and do not arbitrarily choose among alternatives. At the time of both surveys, all SMEs were experts in their field of service procurement in the geospatial industry. As the companies were operating in the same market, the responsible managers would use similar criteria for vendor selection. This assumption was essential for justifying the use of a cross-sectional study for obtaining consistent information.

The fourth assumption was that all participating SMEs would be able to understand and compare pairwise the factors from results of the pilot survey. The fourth assumption was essential as it formed the base for an aggregation of the AHP results with AIJ or AIP, with all expert opinions contributing equally.

Limitations

The existing depth and breadth of research on the phenomenon of multicriteria decision making for vendor selection indicated that the study had no limitation due to uncertainties in the theoretical framework or in the phenomenon. However, people often do not take decisions along explicit parameters but by implicit judgment. The SMEs

might have interpreted factors differently, which may have led to a residual limitation to the accuracy of the ranking and reliability of results of this study.

With respect to the participants, there was a possibility that the study might not have attracted a high response rate. Therefore, the sample might have been smaller than the recommended 15 SMEs. As the mathematical model did not allow for the determination of saturation, and due to the use of expert participants, this limitation might not have been decisive. To increase the response rate, the potential participants received detailed information about the scope of the study during meetings at trade conferences. During the follow-up survey, close monitoring of the participation and personal support in facilitating the understanding of the questionnaire assured the achieved response rate.

The purpose of the study was to investigate the preferences for selection criteria that Canadian and U.S.-based SMEs would apply in their procurement processes. While the selection criteria themselves should be internationally valid, the geographical focus of the study was Anglo-American North America and any extrapolation of the specific results for weights of these criteria beyond might create biased results. North-American SMEs could have changed their outsourcing practices during the 2007-2008 economic crisis. Therefore, the study may not be historically complete as it covered general phenomena in offshore outsourcing in the geospatial industry of today.

Delimitations

This study was delimited to businesses in the geospatial industry in the U.S. and Canada. The factor list (from the pilot study) and the weights (from the follow-up survey) reflect only the opinions of experts in this industry and geography. The

exploratory design of the study should be sufficiently clear to allow for the process of model development for any other geography; however, the industry cannot change because the definition of decision factors and formulation of decision factors are specific to the geospatial field.

Although some authors saw relevance in (a) a joint view of buyer and vendor, as in a co-evolutionary perspective (Lahiri & Kedia, 2011) or in (b) a single view of the vendor (Palvia, King, Xia, & Palvia, 2010), this study covered only the buyer's perspective. The rationale for investigating the buyer's side was that only buyers could give details about information processing in their internal evaluation process. Vendors might have an opinion about the buyer's processes, but might lack insight into the breadth and depth of information available to buyers.

Significance of the Study

Contribution to Business Practice

Supplier selection has increasingly become an area of interest in both research and praxis in the last decade (Calvi et al., 2010; Cheraghi, 2011; Ho et al., 2010). The trend towards offshore outsourcing, a long-time privilege of multinational companies, has evolved into a new dimension for small and medium businesses. Increasing globalization with concomitantly increased interconnectivity and a resultant larger supply and demand base has changed the view of decision makers on the importance of optimizing supply chains in the service sector. This is especially notable in the IT service sector, with which the geospatial industry shares most attributes (Alvandi & Fazli, 2011; S.-I. Chang et al., 2012). The application of multicriteria decision methods for supplier selection,

instead of single criteria methods, is a recent development and has gained momentum only in the past two decades. Specifically methods such as AHP/ANP, DEA, fuzzy sets, and their respective hybrid methods have been successfully adapted in different industries (Agarwal et al., 2011; Alvandi & Fazli, 2011; Ordoobadi, 2010; Ravindran, Ufuk Bilsel, Wadhwa, & Yang, 2010).

The study sought to close the knowledge gap of AHP's efficacy for the process of selecting an offshore vendor in the geospatial industry, which accounts for about 5% of total sales in the IT/ITES industry. However, vendor selection offered an attractive field of research because the offshore buyer side consists almost exclusively of SMBs—a group that, today, is heavily dependent on offshore outsourcing (Geospatial Today & FICCI, 2009). The financial and organizational structure of SMBs usually does not allow for investment of funds in scientific research to optimize the business processes. The availability of a general model for selecting a geospatial data-processing supplier would strengthen the ability of the procurement managers and technical directors to improve their businesses by focusing on the requirements of the major markets in North America. A paucity of literature reflects the need to study offshore supplier selection in the geospatial industry for any geography. The model resulting from the current research could catalyze interest in the application of scientific methods for vendor selection and evaluation in industry.

Implications for Social Change

The focus of this research study did not explicitly include an investigation of expected social impact of business leaders' decisions. The results are expected to

reflected to which quantifiable extent related factors (e.g., economic, social, or environmental) influence the way SMBs select suppliers of offshore data-processing services. Carter and Easton (2011) used the term "sustainable supply chain management" and described a school of thought which stated that sustainable value can emerge only when all stakeholders in the (global) supply chain share the same understanding of the triple bottom line. If social and environmental responsibility made a significant contribution to the selection process, offshore suppliers would likely use the findings from this study to improve their scores on the specific selection criteria.

The results of the study are of potential financial importance to vendors, buyers, and, finally, consumers. At a minimum, the results of the research could affect productivity gains by lowering the rate of product rejection, increasing average profitability of the geospatial data production, and by a longer relationship with the vendor. When evaluating proposals from vendors in the geospatial industry, SMEs often apply a list of evaluation criteria. However, the list is neither complete nor does it contain relative weights among criteria for scoring each vendor objectively. Often the process of selecting a vendor for offshore outsourcing involves an aggregation of the opinions of a number of internal experts, opinions that include their self-interests. This process can be time-consuming. An objective and streamlined process could save time and thereby reducing costs, through applying the findings from this research. In addition, having a list of prioritized criteria would ensure a degree of consistency and fairness in the application process.

The findings from this study might further eliminate some uncertainty caused by a lack of transparency in the vendor selection process and more transparency might be especially advantageous for smaller contracts between the United States or Canada and third country parties during the initial evaluation for due diligence. It is common knowledge that hourly rates for similar work are often at least five times higher in the U.S. and Canada than in India or China. This value difference provides US/Canadian procurement managers who properly evaluate and execute their sourcing, opportunities to maintain or increase their market share or profits. However, company leaders who are unable to make proper decisions due to uncertainty about risk are likely to lose ground and possibly incur losses in market share and profitability. Therefore, the findings of this study may support company leaders in making informed decisions, improve competitiveness, and reduce pricing, which ultimately benefits consumers.

A Review of the Professional and Academic Literature

Offshore outsourcing has reached a new level since the opening of the Indian Market to Internet and telephony-based services with the deregulation of the telecommunication sector in 1997 (C. Liu & Jayakar, 2012). The growing availability of high-speed Internet connections within the main offshore outsourcing locations of India, China, Philippines, Indonesia, and Eastern Europe has accelerated the growth of business process outsourcing (BPO) providers. The constant flow of technology-related foreign direct investments (FDIs) and on-site specialist training has also enabled the development of industries previously considered local, for example, geospatial data processing or map-making. Countries where IT/ITES offshore providers are operating successfully have a

solid technical educational framework that gives young people chance to find jobs easily in the new industry. The large demand for geospatial data in automated logistics, navigation systems, and mobile applications, drives the rapidly increasing number of providers.

Procurement specialists of companies in the United States and Canada, mostly from SMBs that previously had all processes vertically integrated, are now buying data processing services. These specialists must develop supply chain procedures, including systems for selecting suppliers. The purpose of this literature review is to provide a structured overview of (a) current studies on selecting vendors or suppliers, (b) sourcing, (c) multicriteria decision methods, and (d) various forms of surveys and quantitative methodologies that would yield data for this important component of business.

Strategy for Searching the Literature

To identify relevant literature, the following databases were used: ABI/INFORM Complete, IEEE Xplore Digital Library, ProQuest Central, and Science Direct. More than 500 articles were initially identified. The following topics were covered: (a) the geospatial industry, (b) multicriteria decision making, (c) sourcing with a focus on offshoring in international supply chains, and (d) survey methods. The following keywords were used in the databases: *AHP AND ANP, decision AND sciences, geospatial AND industry, MCDM, offshore AND outsourcing, vendor AND selection.*

Table 1

Statistics for References in the Literature Review

Category	*Result*
Total number of references	159
Total number of references published within the last 5 years	148
Total number of peer-reviewed references	146
Total number of peer–reviewed references published within the last 5 years	139
Percentage of peer-reviewed references published within the last 5 years	87.4

The Geospatial Industry

The geospatial or geoinformation industry comprises the totality of providers for data, processing-services, and applications related to geographical information (Indian Ministry of Science and Technology, 2011; Radwan, Alvarez, Onchaga, & Morales, 2003). The definition includes governmental entities such as national mapping agencies as well as private companies for land survey, aerial and spatial data capture, cartographic services, software developers, and database hosts and providers. In the 1960s national mapping agencies began to implement digital geoinformation to improve the quality and speed of supply for mapping services (Radwan et al., 2003). Geoprocessing is essentially the manipulation of spatial data, and according to ISO 19119, it is divided into (a) common geoprocessing, (b) thematic processing, temporal processing, and (d) metadata processing (Zhao, Foerster, & Yue, 2012). Since the 1960s, the need for current, consistent, and accurate geo-information, especially for private business and the consumer market, has rapidly increased, and the ability of national mapping agencies to satisfy the demand has lagged behind (Zhao et al., 2012). Private cartographic service providers grew considerably filling the gap between lengthy base mapping services of the

governmental authorities and the market requirements for large-scale data within a short time. Leaders of companies and institutions decided to capture and process data with internal recourses, first in the areas of topographic survey and aerial imagery. They complemented this later with aerial laser-scanning and mobile mapping systems based on laser and photogrammetric technologies.

Private companies in the geospatial field historically had their roots in land-surveying or aerial image capture. Analog and later analytical photogrammetric workstations for mapmaking from aerial imagery constituted considerable investments and required the intimate knowledge of the whole workflow, including the individual parameters of the aerial camera. This strong vertical integration of services within the companies led to strict protection of workflows and procedures as company-secrets. Nevertheless, the output was still limited.

With the advent of digital photogrammetry at the end of the 1990's, the industry started splitting up along the value-chain into more specialized service-providers. Technologists became able to digitize aerial imagery and transfer it across the globe via magnetic tapes, hard disk drives, or FTP-sites (Zhao et al., 2012). Leaders of Western companies, such as the U.S.-based Sanborn Inc., Danish Kampsax A/S, Norwegian Blom-ASA, German Hansa-Luftbild GmbH, and the Japanese Pasco Corporation established captive offshore-sites as geoprocessing facilities in emerging economies to reap the benefit of a reasonable technical education and low wages (Schroth et al., 2008).

Additionally, local companies without corporate ties to affiliates in industrial countries started operating and reached rapidly considerable head-counts. Examples

include the Indian-based InfoTech, IIC Technologies, Magnasoft, and Rolta, and Chinese-based Wuda-Geo, Beijing Eastdawn Information Technology Inc., and Heilongjiang Geographic Information Industrial Park (Schroth et al., 2008; Yan & Dehai, 2011). All providers—captive sites or external vendors—act within the frame of negotiated, often dynamic, service level agreements (SLAs), within which they assure delivering data according to certain quality of service (QoS) parameters. Brauner, Foerster, Schaeffer, and Baranski (2009) mentioned service availability, service accessibility, agreed production time, or acceptable quality level as some of them, identifying the need for further research within their proposal for a research agenda.

The Buyer-Vendor Relationship in the Geospatial Industry

In the geospatial industry, the outsourcing relationship between buyer, the geodata company in the primary market, and the vendor (the offshore production site), is more similar to an industrial process than to service provision. Geoinformation products include (a) digital terrain models, (b) digital maps, (c) rectified aerial and spatial images, and (d) a multitude of other sophisticated data products. Companies provide these products based on output from data capture equipment like airborne or spaceborne cameras and laserscanners, and terrestrial mobile or static systems (Schroth et al., 2008; Yan & Dehai, 2011). The typical constellation in this business is that managers of a geodata company in the primary market enter into a contractual relationship with a public or private customer in the same market. The geospatial service providers deliver the geospatial information product, usually as a finished digital dataset according to agreed

specifications of the end-client. Geospatial companies typically own or have access to local data capture equipment for use in projects.

After successful data collection, the technicians transfer datasets to the offshore-vendor, either in raw format or with a defined amount of preprocessing. The amount and type of preprocessing, which could be data cleaning or split into logical units, depends on the required local knowledge of the process and the level of technical equipment and expertise of the offshore vendor. Members of the technical department of the vendor company package and ship data by internet or data carriers to the offshore vendor, usually accompanied by technical specifications for the process and/or the final deliverables.

The offshore vendor processes the data, which typically require visual interpretation of elements in the data by a human operator (e.g., interpretation and drawing of features from digital imagery showing the surface of the Earth). A variable amount of interaction between buyer and vendor occurs during the process in order to adjust the understanding of the vendor for the specific project requirements (Schroth et al., 2008). The clarification could relate to the description of geographical features not commonly known in the offshore location (e.g., certain types of plants or specific infrastructure), specific requirements for process reporting, or elaboration of program-scripts for some processes. After termination of processing, the vendor delivers the data packages in the agreed form and format. The buyer applies further quality checks and integrates the data according to the specifications of the end-customer into the final deliverable.

One of the differences to manufacturing of hardware is that the specifications of the (data-) product may change rapidly from project to project and sometimes even during the project while the delivery times are short. Working environments are highly dynamic as the only goods to move are the data. The entire production and quality control process follows rather an industrial manufacturing rather than a service paradigm (Yan & Dehai, 2011). The final dataset or even data-related application is a product.

Managers on the vendor side discuss the required resources for any new project—software, hardware, specialists, and management. During the project-planning phase, the production manager of the vendor needs to consider the coordination of the resource usage with concurrent projects. The vendor internally elaborates a production plan depicting the allocation of resources and the virtual or physical mechanisms of the production line. The vendor may then include tools and processes for coordination and reporting with the remote representatives of the buyer. That process is part of the production system, comparable to the implementation of manufacturing lines.

Outsourcing

Smith (1776, as cited in Haetoenen & Eriksson, 2009), in his *An Inquiry into the Nature and Causes of the Wealth of Nations*, described the benefits of a division of labor, which forms the base for outsourcing. Haetoenen and Eriksson (2009) defined outsourcing as "the transfer of activities and processes previously conducted internally" (p. 143). Khan et al. (2011) provided a detailed distinction of outsourcing types in terms of vendor proximity to the geographical location of the buyer. The three outsourcing

types include (a) *onshore* or the same country, (b) *nearshore* or a group of countries or a region with a common border to the country of production or delivery of services, and (c) *offshore* or countries without a common land- or sea-border. Offshore outsourcing is part of the procurement process and the wider field of supply chain management (Tate & Ellram, 2009).

A first theoretical fundament of the phenomenon outsourcing is the transaction cost economy (TCE). Coase (1937, as cited in Coase, 1992) postulated in his TCE that managers of a company should consider abstaining from producing a product or service internally when the market offers the same at an inferior price level. Haetoenen and Eriksson (2009) defined the first phase of outsourcing—traditional outsourcing—in which company managers contract out any type of services or product manufacturing with the single criterion of lower cost.

Transaction costs remained in focus. Yang, Wacker, and Sheu (2012) clarified that companies seek to adapt a governance structure that minimizes transaction cost and the possibility of opportunistic behavior of business partners. Tate and Ellram (2009) elaborated on the transaction cost approach for offshore outsourcing and found that especially bounded rationality at vendor and buyer-side increases uncertainty and thus transaction costs play a larger role in an offshore-service environment.

More recent research indicated that cost alone, and thus the TCE, does not fully explain outsourcing. The access to specialized resources required to increase the value or flexibility of the value creation in a company and the need to seek outside workforce for satisfaction of consumer demand in peak times gives way to theoretical foundation called

the resource/competence-based view, relating to the phase strategic outsourcing (Haetoenen & Eriksson, 2009). Haetoenen and Eriksson (2009) further defined a third phase as *transformational outsourcing*, in which companies need to change strict hierarchical views in processes and organization to lose contractual relationships with providers to maintain flexibility, innovation, and cost-base for a sustainable competitive advantage. Authors identified key reasons for (offshore) outsourcing as (a) cost advantage, (b) lack of skilled resources in general or in a specific location, (c) lack of patents, (d) lack of capital equipment, and (e) lack of time for development of resources (Schoenherr, 2010). Other authors found considerable differences among the IT-industries of different continents for factors influencing the decision for outsourcing (Liu, Feils, & Scholnick, 2011).

It is worth mentioning that (offshore) outsourcing of services and product manufacturing creates different challenges for SMBs than for large, multinational companies. SMBs are usually not as structured as large enterprises and do not have access to dedicated staff for management of the offshore relationship. As a result, non-standard, complex or small, non-recurrent jobs often require more investment and more management time than the company would have had to spend for in-house production (Haetoenen & Eriksson, 2009). Furthermore, work orders from SMBs are smaller and less frequent so that the bargaining power against large offshore service provider is less (Haetoenen & Eriksson, 2009). The intimate connection of SMBs with their socio-cultural environment supports their access to local markets through trust. Thus, offshore outsourcing potentially poses a challenge to the SMBs' local business models. Different

governance models might be necessary, which might be difficult for them to implement (Hutzschenreuter, Lewin, & Dresel, 2011).

The Vendor Selection Problem

Any procurement process includes the phase of a vendor or supplier-selection. The market analyst Dickson (1966) published an early list of 23 parameters for vendor selection for purchase decisions by individuals, mainly in manufacturing businesses (see Table 2). Dickens had observed that the price alone might not be the only purchase criterion. He also found that criteria were changing their weights in different levels of the purchase process. In general, he doubted that there exists a universal list of criteria for every purchase decision (Cheraghi, 2011).

Table 2

Supplier Selection Criteria

Rank	Criteria	Main rating	Evaluation
1	Quality	3.508	Extreme importance
2	Delivery	3.147	
3	Performance history	2.998	
4	Warranties and claim policies	2.849	
5	Production facilities and capacity	2.775	Considerable importance
6	Price	2.758	
7	Technical capability	2.545	
8	Financial position	2.514	
9	Procedural compliance	2.488	
10	Communication system	2.426	
11	Reputation and position in industry	2.412	
12	Desire of business	2.256	
13	Management and organization	2.216	
14	Operating controls	2.211	
15	Repair service	2.187	Average importance
16	Attitude	2.120	
17	Impression	2.054	
18	Packaging ability	2.009	
19	Labor relations record	2.003	
20	Geographical location	1.872	
21	Amount of past business	1.597	
22	Training aids	1.537	
23	Reciprocal arrangements	0.610	Slight importance

Note. From "Simulation and prediction of vendor selective decisions," by G. W. Dickson, 1966, *Journal of Purchasing*, *2*, p. 32. Copyright 1966 by Academy of Management. Reprinted with permission.

According to the current literature, most of Dickson's criteria remain valid but considerations now include further enrichment (Agarwal et al., 2011; Ho et al., 2010; Khan et al., 2011; Nejadirani, Matin, & Farshad, 2011; Zhu, Dou, & Sarkis, 2010). Though the criteria themselves remain the same, the findings in the literature review indicate three factors influencing the relative importance of supplier selection criteria in the purchase process:

1. Type of industry
2. Geographical location of the buyer business
3. Nature of the purchase

Manufacturing of goods and provision of services differ by the nature of delivery. Just-in-time (JIT) delivery concepts have gained more importance in the last years so that reliability of the importance of logistics in both areas has become similar (Aksoy & Öztürk, 2011). Cheraghi and Dadashzadeh (2011) showed for the manufacturing industry that some factors already influenced by JIT and service purchasing such as geographical distance have lost importance in the period 1990-2001. However, geographical distance was a determining criterion in the previous period 1966-1990, a time with a focus on asynchronous manufacturing processes. Ishizaka and Blakiston (2012) developed their 18 C-Model from qualitative research in the facility management sector. They identified 18 factors that covered the four areas (a) client or buyer, (b) service provider or vendor, (c) contract, and (d) relationship.

Buyers have become more knowledgeable about the coordination of purchases, thus require faster reaction and better customer support than before. Cultural differences in the buyer country slightly influence the weight of several factors as Khan et al. (2011) found in their study about criteria in the software development outsourcing area. While in general terms all nationalities are focusing in the vendor selection on appropriate infrastructure, cost saving, and skilled human resources, European buyers seem to be more concerned about the risk and the contract management. Asian buyers, on the other hand, place the emphasis on an organization's track record of successful projects (Khan et al., 2011). Doh, Bunyaratavej, and Hahn (2009) found that factors determining the specific geographical location decision change by industry type. However, wages, education, infrastructure, common language, and political risk in the vendor-country

remain the most important, but have different weights for shared services, call centers, and IT service centers. The size of the business also seems to have an influence in the purchase decision. Shishank and Dekkers (2013) addressed the challenges related to uncertain and incomplete information as in fast developing environments not all information might be available in the moment of decision making.

S.-I. Chang et al. (2012) detected that managers in SMBs in Taiwan were more risk- and quality-conscious than managers in large companies, as they did not own the means to control and mold the outsourcing process from an early stage. For the present study, the following conditions describe the buyer-vendor relationship:

1. The purchase relates to a digital data-product (and not a service).
2. The vendors' location is an offshore-location.
3. The buyer-companies are commonly SMBs.
4. The buyers' location is in North America.
5. Quality and delivery-time seem to be traditionally the most prominent drivers for the formation of outsourcing relationships in the geospatial industry.

The above five conditions enhance a set of criteria for vendor selection that Bai and Sarkis (2010) provided and lead to an initial criteria list for the present study (see Appendix B).

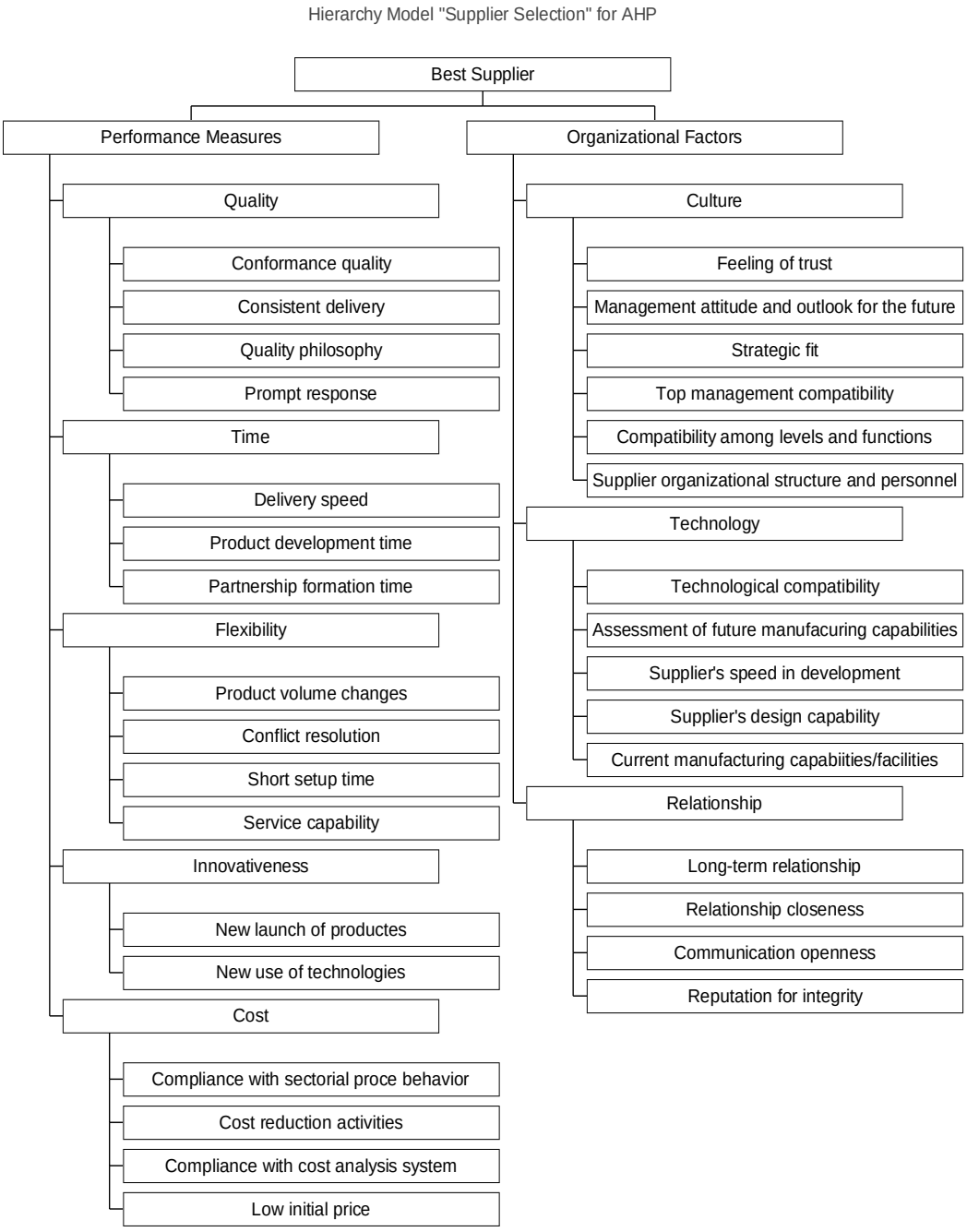


Figure 2. Hierarchical model for supplier selection. Adapted from "Integrating sustainability into supplier selection with grey system and roughset methodologies," by C. Bai and J. Sarkis, 2010, *International Journal of Production Economics*, *124*, p. 254. Copyright 2009 by Elsevier B.V. Reprinted with permission.

The order of the parameters in Figure 2 follows the form of an AHP-tree with three criteria levels. However, the parameters in Figure 2, based on the work of Bai and Sarkis (2010), are not specifically suitable for offshore outsourcing of geospatial data processing but seem to be more adapted to a local (onshore) supplier-selection process. Therefore, I have developed in Section 2, Instruments, the diagram in the form of an AHP-tree, closely reflecting the relevant parameters for offshore outsourcing relationships.

Multicriteria Decision Making (MCDM)

Decision sciences are part of the operational management field of science. In complex environments, the decision maker usually has to choose from a finite or infinite number of choices. Wallenius et al. (2008) described these choices in the two main fields of multiple-criteria discrete alternative problems for finite choices and multiple-criteria optimization problems for infinite choices. The author added the term multiple-criteria sorting problems for situations with a large number of choices.

Only the concept of multiple-criteria discrete alternative problems was relevant for the research, leaving design or optimization problems not within the scope of this study. The principal utility of all decision methods is to provide decision makers with a structured approach for choosing or ranking one or more alternatives according to a set of criteria. Decisions often need to be taken considering conflicting criteria and accepting trade-offs among them (Pirdashti et al., 2009). In the 19th century Pareto and others, using utility and welfare theory initially indicated the scientific approaches for decision making (Mockus, 2011). As optimality in a multicriteria environment cannot be achieved

over several criteria at one time the condition of non-domination or Pareto-optimality is the principal target of all methods (Mockus, 2011).

The main types of MCDM-methods used for supplier selection (Agarwal et al., 2011) are

- Data envelopment analysis
- Goal programming
- Analytic hierarchy process and analytical network process
- Case-based reasoning
- SMART
- Fuzzy set theory
- Genetic algorithms
- Criteria-based methods (ELECTRE, PROMETHEE)
- Mixed methods such as delphi

Agarwal et al. (2011) showed the frequency of mention of different methods in the literature. Many of these methods have been core tools in the field of supplier selection on which Chai, Liu, and Ngai (2013) provided a comprehensive overview.

Data envelopment analysis (DEA) is an advanced quantitative benchmarking technique based on the computation of the relative efficiency of various peer units. Efficiency of the unit is here a result of the comparison of the weighted sums of all inputs with the weighted sum of all outputs. The method works on non-commensurable inputs and outputs. At the core of the analytic hierarchy process or AHP is the determination of the relative importance among criteria by pairwise comparisons. The strength of AHP is

the possibility to use non-commensurable data and to mix quantitative and qualitative attributes. The analytical network process or ANP is a more general approach than AHP and allows additionally for feedback loops. The chapter AHP comprises a detailed description of the AHP.

Case-based reasoning (CBR) is a technique in which the decision maker tries to match similar cases from the past to the present problem. CBR requires a considerable upfront effort to collect and classify data to make it usable for comparison (Chattopadhyay, Banerjee, Rabhi, & Acharya, 2013). With the simple multiattribute rating technique (SMART), a direct weighting procedure, the decision maker elaborates a set of weights for relevant criteria and compares them to the available options (Jahan, Mustapha, Sapuan, Ismail, & Bahraminasab, 2011). In a subsequent sensitivity analysis, the decision maker then tests the results against their applicability. Though the results may be similar to AHP, the approach is less structured and highly interactive, which reduces the validity of the results.

Fuzzy set theory circumscribes the handling of uncertainty in the data, and criteria can be quantitative or qualitative. Rodriguez, Martinez, and Herrera (2012) noted that fuzzy sets work well when the data are vague and imprecise (e.g., data from qualitative verbal statements). Genetic algorithms or evolutionary algorithms arose based on the natural principle of the survival of the fittest, which in this context means that a specific combination of scores on all decision criteria may be better adapted to the problem than others do. Wallenius et al. (2008) the alternative possessing the strongest combination of attributes compared to the required target parameters as optimal.

Criteria-based methods include outranking methods like ELECTRE and TOPSIS. The input data are similar to MAUT or AHP and consist of weights for different factors. With a pairwise comparison of the weighted factors for each alternative and supporting discordance and concordance indices the decision maker determines the most promising alternatives (Greco, Kadziński, Mousseau, & Słowiński, 2011).

One well known mixed method is the delphi technique, a nonparametric group-decision method with feedback cycles after each interview round (Davidson, 2013). All participants receive compiled results of the former round until the experts reach a consensus. I describe the delphi method in the following subsection.

The standard decision process in multicriteria decision problems according to Pirdashti et al.(2009) includes the following:

1. Defining the problem
2. Knowing all relevant information
3. Identifying all criteria
4. Accurately weighting the criteria according to the goals
5. Assessing each alternative on each criterion
6. Chosing the alternative with the highest value

Most of the given methods require the measurement of attributes in a quantitative manner and along a common scale in order to compare the performance according to one or many attributes. Both conditions constitute a serious limitation for problems in which mere comparison can indicate qualification (e.g., “A is better than B”) or qualitative judgments (“A is very important”). Supplier-selection problems with sets of qualitative

and quantitative criteria would consequently require either pure qualitative methods or mixed approaches. In such instances, qualitative and heterogeneous judgments require a previous step of normalization to a comparable numeric scale (Ho et al., 2010).

Ho et al. (2010) found in a systematic literature review covering the period 2000-2008 that authors described AHP-GP as the most prevalent integrated approach and DEA as the favored individual approach. Chai et al. (2013) discovered AHP as the preferred methodology in the period 2008–2012 after review of 123 international journal articles on decision science. Agarwal et al. (2011) conducted a literature review on vendor selection from articles covering the period 2000–2011 and confirmed that DEA and AHP/ANP were the most common methodologies.

Some authors described combinations of DEA and AHP in a sequential process in which evaluators derived the weights for the AHP-process from a preceding data envelopment analysis (Mirhedayat, Jafarian, & Saen, 2011). Combinations of AHP with delphi and other methods are common, as Mousavi, Tavakkoli-Moghaddam, Heydar, and Ebrahimnejad (2012) showed for plant location selection, Hsueh, Lee, and Chen (2013) for construction risk assessment, and Bilişik, Erdoğan, Kaya, and Baraçlı (2013) for customer satisfaction in public transport. As a prelude to the AHP discussion, the present study contains a detailed discussion of the delphi method. Though being a similar approach to AHP, the delphi method did not provide an appropriate solution for the study, as the time required to apply the feedback loops with SMEs from the industry was unpredictable, and there was a residual probability of not reaching a consensus.

Delphi method. Specialists of the U.S. Air Force developed the delphi method and researchers of the RAND Corporation later used and refined it further (Avandi & Fazli, 2011). The scope of this method's use is to obtain an opinion of a group of expert on the most probable future timeline of technological development using an interview technique with controlled feedback mechanisms (Davidson, 2013). The structured communication largely allows reaching an agreement of the expert group on issues for which history or precedents do not exist. Subramanian and Ramanathan (2012) coined the term *judgmental forecasting* (p. 6).

In the first phase of the study, the coordination group chose an expert panel and developed the first questionnaire, which consists of open- or closed-ended questions. However, the open-ended variant is more useful for the setup. Questions seemed to evolve naturally during the process from open ones covering a wide field to more focused ones in further rounds. The process ended when the coordination-group noted saturation, indicated by the moment in which the moderator team did not expect any more new information from further rounds. Delphi studies commonly reach that status after latest three rounds (Seuring & Mueller, 2008).

Critical issues in a delphi process are the form of feedback to and responsiveness and response times from the expert group. Delphi processes often include feedback sessions in the form of panel discussions and focus groups. However, Seuring and Mueller (2008) commented that these setups bear the probability that the strong presentation of an individual opinion might dominate the discussion, affecting the results. Though the delphi method is applicable in supplier selection processes, authors have

described that this occurs mostly in connection with other techniques, such as AHP and DEA (Subramanian & Ramanathan, 2012). S.-I. Chang et al. (2012) used the delphi method to identify supplier-selection criteria for IT-services among SMBs in Taiwan using an expert group of 25 and achieved a response-rate of 50% in two rounds. Y.-J. Chen (2011) integrated the delphi method with SWOT, DEA, Fuzzy Sets, and TOPSIS, but limited the questionnaire to a small Likert scale for the assessment of factors (cost, quality, and delivery) on their influence on the supply chain performance. C.-M. Wu, Hsieh, and Chang (2013) combined a multiple criteria decision making model with a delphi study to prepare the parameters for a combined ANP/TOPSIS study of a multisourcing vendor selection problem. Authors favored the delphi method as a useful tool for complex environments with uncertain information. However, they noted time availability and responsiveness of experts after remote administration of questionnaires as a significant constraint (S.-I. Chang et al., 2012).

AHP. Saaty originally developed analytical hierarchy process in the year 1977 during his function as head of a think tank in the nuclear arms reduction talks (Saaty & Shang, 2011). The scope of the process is to rank alternatives against each other using a set of criteria or factors with predefined weights. The evaluator orders factors in two or more groups or clusters in which each factor consists of one or more of subfactors. Pairwise comparison within groups or clusters would result in the relative weight or importance among the factors on each level (of the hierarchy). The final hierarchical factor tree constitutes the framework for ranking of different alternatives. Alternatives receive scores on the factors on the lowest level of the hierarchy, and their combination

into a total score makes alternatives comparable (Janicki & Zhai, 2011). For the principle of an AHP-tree, see Figure 3.

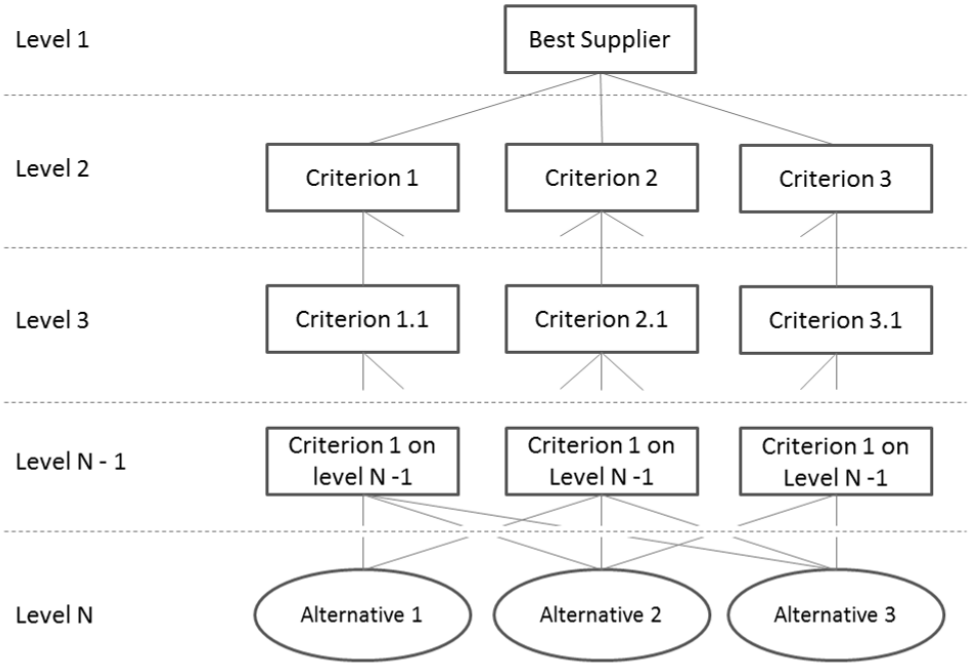


Figure 3. The AHP framework.

A decision maker compares pairwise all subcriteria (subfactors) to one criterion (factor) among each other, applying intensity values from a scale of 1 to 9. For example, if *A* is *strongly more important* than *B*, then *A* would receive a value of 6, while *B*'s result would be the reciprocal value of 1/6. The numerical expression linked to this comparison logic would later populate the comparison matrix. The vector of eigenvalues of the comparison matrix contains the absolute importance of each factor in a cluster. Saaty recommended limiting the number of factor per level to seven, and the number of levels to three to maintain the process manageable (Saaty & Shang, 2011).

AHP is in its pure form or combined with other techniques an important tool to solve the supplier selection problem. A critical point and positive argument for the use of AHP is the ability of the framework to handle quantitative and qualitative inputs at the same time (Saaty & Shang, 2011). Labib (2011) compared the performance of AHP against fuzzy logic in a supplier selection process using an identical dataset without detecting a significant difference. Hruška, Průša, and Babić (2014) emphasized in the introduction to their study that AHP additionally enables the researcher decompose complex decision problems into simplified elements and to accelerate the natural flow of decision making.

J. Peng (2012) defined a supplier selector framework with AHP for logistics outsourcing using two levels and 12 factors on the lowest level. S.-I. Chang et al. (2012) identified two levels and 19 factors for IT-services outsourcing of SMB in Taiwan. Alvandi and Fazli (2011) identified 27 criteria on the lowest level necessary and used a two-level hierarchy in a fuzzy-AHP for e-procurement of an Iranian automobile supplier. The same aforementioned authors found in a combined delphi and fuzzy-AHP study 13 decision criteria for the SCM processes, out of which four factors (product quality, quality of online information, online order tracking, and lag time) are the most important (Alvandi, 2011). Zeydan, Çolpan, and Çobanoğlu (2011) identified six factors in a single-level approach using a combination of fuzzy-AHP and fuzzy-TOPSIS sufficient. All authors agreed that AHP is an excellent tool to support the decision maker in handling complex situations with a large number of criteria (see Table 3).

Table 3

Other Applications of AHP in the Literature

Area of application	Methodology	Author
Banking Sectors	Fuzzy AHP	Haghighi, Divandari, & Keimasi, 2010
	AHP	Yin, Pu, Liu, Yu, & Zhou, 2014
Construction	Fuzzy AHP	Hosny, Nassar, & Esmail, 2013
Drugs selection	AHP	Vidal, Sahin, Martelli, Berhoune, & Bonan, 2010
Energy selection	Fuzzy AHP	Kahraman & Kaya, 2010
	MACBETH, Fuzzy AHP	Ertay, Kahraman, & Kaya, 2013)
GIS applications	AHP	Sener & Davraz, 2012
Manufacturing systems	AHP, GREY	A.-Y. Chang, 2012
	Fuzzy AHP, PROMETHEE	Taha & Rostam, 2011
	AHP	Jain & Raj, 2013
Marketing	AHP	Y.-L. Li, Tang, & Luo, 2010
	AHP, fuzzy integral method	C.-L. Lin, Chen, & Tzeng, 2010
Mining	AHP, Leopold matrix	Sobczyk, Kowalska, & Sobczyk, 2014
	AHP, fuzzy sets	Su, Yu, & Zhang, 2010
Operators evaluation	Fuzzy AHP, max-min	Şen & Çınar, 2010
Organizational performance	AHP, BSC	Bentes, Carneiro, da Silva, & Kimura, 2012
Projects oil industry	AHP, fuzzy TOPSIS	Amiri, 2010
Recruitment	Fuzzy TOPSIS, fuzzy AHP	Coombs, Arnold, Loan-Clarke, Bosley, & Martin, 2010
	Fuzzy AHP	Faliagka, Tsakalidis, & Tzimas, 2012
Recycling technology	Fuzzy delphi, fuzzy AHP	Hsu, Lee, & Kreng, 2010
Site selection	Fuzzy TOPSIS, fuzzy AHP	Onüt, Efendigil, & Soner Kara, 2010
	Fuzzy AHP	Donevska, Gorsevski, Jovanovski, & Peševski, 2011
Software selection	Fuzzy AHP	Ayağ, 2010
	Fuzzy AHP	Benlian, 2011
Strategy selection	AHP	M. K. Chen & Wang, 2010
	AHP, TOPSIS	Fouladgar, Yazdani-Chamzini, Lashgari, Zavadskas, & Turskis, 2012
	AHP	W. Wu, Kou, Peng, & Ergu, 2012
Supplier selection	Fuzzy AHP	Chamodrakas, Batis, & Martakos, 2010
	Fuzzy AHP	Che, 2010
	AHP, DEA, LP	Falsini, Fondi, & Schiraldi, 2012
University evaluation	Fuzzy AHP	S.-H. Lee, 2010
Warehouse selection	AHP	Oezcan, Çelebi, & Esnaf, 2011
Weapon selection	AHP, GP	J. Lee, Kang, Rosenberger, & Kim, 2010
Website performance	Fuzzy AHP	Ip, Law, & Lee, 2012

Summary and Transition

The growing complexity of today's global supply chain operations has become the focus of intensified interest within the academic and practitioner community in resolving the supplier selection problem for a number of specialized application domains. Geodata processing is one of the application domains in which leaders of SMBs in North America have to deal with the selection, establishment, and evaluation of offshore vendor relationships to maintain their competitiveness in a market with JIT-characteristics.

The results of the literature review indicated that the general supplier selection problem is a multiple criteria decision making problem of high complexity. At the same time, I found a lack of application of MCDM to the specific domain of geospatial vendor selection, which motivated this research. Furthermore, after a thorough exploration of the field of multicriteria decision sciences and other methodologies, the AHP in its pure form (not combined with other methods) is a candidate for examining the geospatial vendor selection problem.

In Section 2, I discuss the details of the research design, methodology, and application of AHP to the geospatial vendor selection problem. Section 3 contains the results of the data collection and analysis with their possible effect on positive social change, and concluded the study with recommendations for action and further research.

Section 2: The Project

Section 2 begins with the purpose of the study and an explanation of my role as the researcher. Section 2 continues with (a) the steps to access the participant pool to obtain the required data and (b) the chosen research method and design for the study. An elaboration on the various elements of the sampling plan includes details on the sampling unit, population, and sampling frame as well as the sample design and size. After the description of the data plan, the verification of the data collection plan follows, enacted through a pilot study and the detailed follow-up survey that resulted. The first part of Section 2 concludes with an introduction to the instruments for both the pilot study and the detailed survey, together with the data collection and organization technique.

Section 2 continues with an outline of the analytic procedure in the same linear sequence of steps as applied for activities in Section 3. An explanation of the model variables and the implementation of the model in Excel precedes a description of the analysis of the relevant outputs in relation with the research questions and associated working hypotheses. During the design process in Section 2, no actual data came to application in the crafted model since this followed only the proposal and consequently IRB approval process.

The last topics covered in Section 2 are validity and reliability. After addressing the three key validity areas—content validity, empirical validity, and the more difficult construct validity—I discuss the process for estimating the reliability of the Thurstone-scale instrument using Saaty's *consistency index* of the analytic hierarchy process (Ergu, Kou, Peng, & Shi, 2011).

Purpose Statement

In this quantitative, descriptive, nonexperimental research, I used the AHP-method to generate a model for offshore vendor evaluation in the geospatial industry. The purpose of the study stems from the problem that, for various reasons, buyers terminate more than 40% of their offshore business relationships every year (Manning et al., 2011). In the North American geospatial industry, SMBs generate most of the business; a considerable amount of services are executed by overseas vendors, which makes their evaluation a critical exercise (Geospatial Today & FICCI, 2009). Managers in the U.S. and Canada could use the resulting vendor selection model to increase the likelihood for sustainable business-relationships with offshore-vendors. Specifically, during the due diligence processes before starting a distance business-relationship an application of the structured model may reduce future risks.

Role of the Researcher

The motivation for the application of AHP is rooted in my own business environment where samples and data are readily accessible. Consequently, this connection with my business gave me the opportunity to develop and test the model operationally to allow for an evaluation of subproviders in India.

The role of the researcher included the decision about the research design, review, and evaluation of the professional literature with relation to the research topic, decision on the instrument, collection of data, analysis and interpretation of the data, and scholarly description of the results. The study involved the collection of primary data; thus, one of the primary roles as researcher was to design, plan, and administer a survey to the

interviewees participating in the research. Furthermore, ensuring a high level of ethics during planning and execution of the survey, the subsequent analysis, and interpretation was tantamount. After preparation of the survey by choosing an instrument and programming the Excel tool for collection, organization, analysis, and evaluation of the data, in the interpretation phase, I had to make conclusions about generalizability of the results and gave recommendations about the future use of the results.

Participants

The population frame for this research consisted of SMEs, who are all contacts from my own professional and social network, and most are members of the American Society for Photogrammetry and Remote Sensing (ASPRS). After IRB approval #02-28-14-0192835, a small group of five SMEs constituted a sample for a pilot survey to validate the instrument and refine the initial list of then potential factors. For the follow-up survey, an expert panel of 15 North America-based SMEs comprised the sample for the detailed survey to evaluate the refined list of factors, resulting from the pilot study. The participant list for the final survey included participants from the pilot-study as objective and questions in both surveys are different. The survey results may have even improved through communication among the participants, as a possible agreement on assessment may enhance the validity of the results. All participants were managers with outsourcing experience in charge of procurement or relationships. The majority of experts had reached the level of international business development managers, technical directors, or managing directors. The selection criteria included (a) level of exposure of

the person to the outsourcing process, (b) being part of a North American organization, and (c) willingness to participate in the process.

All participants received assurance that data from the surveys would be handled anonymously and exclusively for the purpose of the present study. The surveys started only after obtaining a letter of consent from the participants and the due permission from Walden's Institutional Review Board (IRB). An Internet-based questionnaire through https://www.surveymonkey.com was the preferred platform of obtaining the results during the pilot survey. An Excel spreadsheet with integrated consistency checks was the choice for the follow-up survey as distance and time differences precluded face-to-face interviews. I will store the data for 5 years in CD-ROM with password-protected folders and then destroy it physically.

Research Method and Design

The objective of this quantitative descriptive, nonexperimental study was to examine the efficacy of AHP for determination of weights of different factors leading North-American companies in the geospatial sector to select a specific partner outside their own country for a business relationship. The business relationship would have at its core the purchase of data processing services from the offshore vendor. As no sources of secondary data for the specific question were in existence, this study benefited from a survey among representatives of the geospatial industry in North America. I sent an initial list of factors identified from literature and own experience and knowledge to five randomly selected SMEs (from my contract list) who satisfy all other selection criteria.

During this pilot study, the SMEs were able to validate, change, or extend the list of factors. In a follow-up survey, I administered the validated list to approximately 120 SMEs from North American companies for ranking of the factors. A response rate of 10% or better for consistent and complete results seemed to be reasonable, to obtain the planned number of 15 valid evaluations (S.-I. Chang et al., 2012). The instrument would contained a Thurstone-type questionnaire allowing pairwise comparisons for AHP (S.-I. Chang et al., 2012). The analytic hierarchy process enabled a detailed determination of weights of factors through pairwise comparisons, and the resulting model can further be of benefit for ranking vendors following the same method.

Method

The scope of the research was an examination of the relative importance of parameters for decision making, a scope for which Saaty (2013) proposed AHP as appropriate. Although Saaty related decisions to human behavior, which might point to the use of qualitative methodology, I considered a quantitative descriptive study. Previously, researchers have applied qualitative methods for the identification of vendor selection criteria (Y. Li, Liu, & Chen, 2012). Therefore, a complete redetermination of the criteria list would not have been efficient (Bilsel & Ravindran, 2011; Ho et al., 2010; Khan et al., 2011). However, the calculation of priorities based on numerical weights for the individual factors requires quantitative methodology. As a qualitative element would not have contributed efficiently to the study and the time available was rather limited, neither a mixed methodology nor a delphi study appeared applicable. Examining the

efficacy of AHP requires comparison of importance for different factors, which may or may not be directly measurable with a given metric. During the AHP-process, the evaluator expresses in the pairwise comparison the degree of preference for one factor over another using a 17-point Thurstone scale, 2-9 for the preferred factor, 1/2 to 1/9 for the lower evaluated factor, and 1/1 for equality. This technique did not require commensurability among factors; therefore, AHP was an appropriate method to integrate qualitative and quantitative attributes into one framework (Ishizaka, Balkenborg, & Kaplan, 2010).

I derived the initial list of vendor selection criteria from a systematic literature review. The list consisted of 45 factors in three levels of the AHP tree in Appendix B. The pilot survey contained the initial list of factors on the lowest level for review by various SMEs who dealt with geospatial data processing vendor contracts. After removing identified inconsistencies, the resultant modification formed the final validated instrument for administration to SMEs in the follow-up survey. The results of the follow-up survey completed a matrix with the criteria as rows and SMEs as columns. Through AHP, I then generated an overall weighting estimate for each factor. The research was analytic in nature and its objective was the examination of the importance of parameters for decision making, that is, within the application domain for which Saaty proposed AHP (Saaty, 2013). The study was not exploratory in nature, as complete redetermination of parameters of vendor selection was unnecessary.

Research Design

Based on a review of the current literature, I found a strong indication that the analytic hierarchy process is appropriate (Saaty & Shang, 2011; Saaty, 2013). Literature on research covering the process of supplier selection contributed to the review (Agarwal et al., 2011; Y.-J. Chen, 2011; Zhu et al., 2010).

For this study, I used a quantitative descriptive, single group, nonexperimental research design. A quantitative AHP design appeared to be a good choice, as researchers and practitioners developed it into the most preferred for determination of vendor selection criteria with their relative weights (Agarwal et al., 2011; Chakraborty & Ghosh, 2011; Sipahi & Timor, 2010). The purpose of the study was the examination of the efficacy of AHP for determination of offshore vendor selection criteria with their relative importance. I foresaw a two-phase sampling plan for data collection as follows: In a pilot phase a group of five SMEs validated the initial list of factors, while in the second phase, a larger group conducted a pairwise comparison of factors on the validated list.

An experimental design did not seem adequate, as the participants did not receive any intervention. A longitudinal design was not necessary, as changing variables over time were not subject of the study. A quantitative descriptive design without a control group was sufficient as individual experts would contribute with the data. As examination of neither causal relationships nor correlation among variables was of interest for the study, I decided against a correlational design.

Population and Sampling

The purpose of this study was to examine the efficacy of AHP for determination of criteria in the offshore supplier selection process in the geospatial industry of North America. The research population consisted of representatives of buyer companies (SMBs) in the North American industry, senior managers with experience in the process of establishing offshore relationships. The participants in this study were subject matter experts or SMEs. From my activity in the industry as a leader of an Indian offshore facility in one of the largest mapping companies in Europe, most of the contacts were from my personal contact list. Other contacts arose from a general market-study during the 2010-2012 conferences in the U.S. and Europe or from members of the ASPRS.

Companies constituting the sampling frame all operated in the U.S. or Canada and represent a mix of different sizes, economic strengths, and intensities of international involvement. The sampling process was purposeful as it related to a specific industry, and companies identified stemmed from my personal market study and membership lists from various organizations. The group of SMEs, chosen for validation of the initial list in the pilot study, constituted a purposeful sample of close acquaintances and business partners who were open and willing to support the study.

To avoid scarcity of valid and consistent answers through a low response rate, all identified SMEs received the questionnaire for the detailed survey. The questionnaire for the detailed follow-up survey was available in an Excel spreadsheet and contained a 17-point Thurstone scale to realize the pairwise comparisons among factors.

It was not possible to determine the sample size using power analysis as the AHP does

not include a statistical hypothesis like ANOVA or regression. Data for AHP stemmed from evaluations by an expert group, and statistical randomness was not relevant, as no errors need to be distributed. AHP should already render a satisfactory result with the answer of one single SME, but the use of an expert panel would help to create a reliable base. Goepel (2012) recommended the following for AHP:

> There is no recommendation for the sample size, selection depends more on the background and experience of the people you ask, or whether they are stakeholder in your project. If you have 5 of them, ask them all, if you have many more, make a selection to get inputs from people with different background and viewpoints. (Goepel, 2012, p.1)

Salmeron and Lopez (2012) in their article about fuzzy cognitive maps method (FCMM) discussed the validity of results in function of the expert panel. As an expert analysis is the source of data for the AHP in this study, it should be valid to assume similarity with the FCMM in terms of sample size. Salmeron and Lopez (2012) postulated "the greater the heterogeneity of the group, the lower the recommended number of experts. Between 10 and 20 seems to be a good group size." (p. 444). Thus, I did not assume a minimum sample size required for the study. In order to obtain about 15 valid and consistent results, I planned to send the survey to 120 experts from my contact list, considering that former studies achieved response rates of about 10-50% (S.-I. Chang et al., 2012). Furthermore, I analyzed the variation among the SMEs' answers showing different weights for the factors by using the variance of the arithmetic means.

Ethical Research

After IRB approval, I sent to all participants of pilot and follow-up surveys an invitation by email containing the survey questionnaire. The body of the email included a letter of consent for both pilot survey and follow-up survey. Participants received the information that they would give their consent to the content of the letter by participating in the survey. Participation was voluntary, and participants could withdraw or refuse to proceed at any time by email or any other documented communication. As an incentive, I committed to sharing the results of the study in a summary and to offer all participants an Excel spreadsheet for application of the AHP. To protect rights of participants, all data will remain for 3 years in my password-protected computer and on password-protected backup media and then destroyed. No names of individuals or individual organizations are used.

Data Collection

Instruments

The data collection process consisted of two phases: (a) pilot study for validation of the initial list of factors and (b) detailed survey for pairwise comparison of the factors. The factors for the initial list in Table 4 were the result of a literature review of 19 articles; several of these factors stemming from literature studies on the importance of factors for vendor selection based (see Appendix A). In Table 4, the value for *score* indicates the frequency of use of the individual factor in scientific articles from the field of vendor selection. The list contains factors except those which appear with a score "1" after literature review and do not overlap with any other (see Table 4). The one

exception is the factor *technical and managerial competences of project managers*, which from my professional experience appeared to be indispensable for geospatial data processing outsourcing.

Table 4

Initial List of Factors: Results of a Systematic Literature Review Showing the Vendor Selection Criteria from 19 Articles Published After 2008

Factor	Score
Performance Measures	
Product quality	12
International quality certifications	6
Reputation and positive track record	8
Consistency of quality over time	11
Timeliness of delivery/lead time	10
Timeliness and quality of reporting/responsiveness	5
Technical and managerial competence of project managers	1
R&D advantage	13
Use of new technologies and future capabilities	3
Product volume changes and peak load capacity	15
Short setup time/flexibility in schedules	2
Compliance with sectorial price behavior and with cost analysis of the buyer	10
Low initial price	14
Organizational factors	
Sufficient and quality management resources	3
Management attitude and compatibility	12
Strategic fit of businesses	2
Compatibility among levels and functions	9
Environmental and social sensitivity	7
Compatibility of technical platforms	4
Technical specialization and educational level of staff	14
Existing communication and online systems	7
Present technological capacity	11
Relationship closeness and feeling of trust	13
Knowledge exchange and reciprocal arrangements	2

	(table continues)
Communication openness	7
Reputation for integrity	4
Conflict resolution mechanisms	2
Common language	4
Geographical distance	3
Currency stability/economical risk	5
Legal stability/protection of intellectual property/political risk	2
Size of vendor business/financial stability and position	9

All factors in Table 4 pertain to Level 4 of an AHP tree. A grouping on Level 2 resulted in a distinction of (a) performance measures and (b) organizational factors, and thus the base structure from Bai and Sarkis (2010) was applicable. On Level 3 under performance measures reside the groups (a) quality, (b) delivery, (c) project management, (d) innovativeness, (e) flexibility, and (f) cost. Organizational measures could contain (a) culture, (b) technology, (c) relationship and communication, (d) geographical location, and (e) business. Appendix B contains the resulting AHP tree.

The main differences between the original model of Bai and Sarkis (2010) and the adapted model in Appendix B include the exchange, abolishment, and addition of various subfactors. Bai and Sarkis (2010) had not included factors like *geographical location* and *business* but both seemed potentially relevant to offshore relationships.

The list and structure of parameters might still not be conclusive, and further elements could have expanded both at a later stage. The expansion followed the first phase of list validation by five SMEs in the pilot survey. The AHP process is flexible enough for adjustment at any time. The model provided the potential for the addition of

new levels and sublevels, as ranking takes place only relatively in pairwise comparison with a later consolidation of the priorities at the highest level. The following list contains the considerations leading to the AHP-tree in Appendix B.

Level 1. Results of the literature review supported the two main categories (a) performance measures and (b) organizational factors, which originated from Bai and Sarkis (2010).

Level 2/3. The lower levels in the hierarchy referred to standard groups found in the literature (S.-I. Chang et al., 2012; Cheraghi, 2011; Doh et al., 2009; Khan et al., 2011). Appendix A contains the results of the literature survey. Personal discussions with various SMEs for outsourcing operations of my own company often emphasized some aspects, such as quality of processes and cost. To visualize the relative importance of factors from the literature review, I used the scores for frequency of mention as relative weights and developed the pareto chart in Appendix C.

Quality of processes. Quality of processes is a standard quality criterion used to assure that the vendor has proven to adhere to an acceptable quality-system. In this group, the identified elements were (a) product quality, (b) existence of international quality certifications like ISO 9001, and (c) reputation and positive track record.

***Delivery*.** Adherence to deadlines and the ability to adjust the processes to the required speed in the super-processes is a relevant group of parameters. Required parameters in this group were (a) consistency of quality over time and (b) timeliness of delivery.

Project management. This sub-group refers to the ability of the vendor to collaborate in the daily business on a project level. Identified factors in this field were (a) the quality of reporting, which relates to timeliness, completeness and correctness, and (b) the observed professional competence of the project managers.

Innovativeness. Factors in this cluster refer to vendor's ability to offer independently innovative solutions by (a) quality and magnitude of current R&D facilities and (b) continuous use of innovative technology and observed potential.

Flexibility. Flexibility refers to the ability to adjust to changes in procedures or volumes due to emerging constraints. Here, the identified factors were (a) product volume changes, which staff from buyer companies could initiate by an increased complexity of specifications or increase of input-data to be processed, and (b) set-up time for new projects, which includes the capacity to react to varying service requirements.

Cost. Even though it was possible dividing the elements *benefit* and *cost* in the decision process, it seemed valuable to introduce at this point some evaluation of cost-related behavior. This was only one parameter of the low initial price. The final price itself would be subject to introduction into the decision process at a later stage.

Culture. An initial set of factors was (a) quality of existing management resources; (b) management attitude and compatibility, a factor which offers a second dimension on the ability of management to interact with the buyer; (c) strategic fit, which also might be a point of interest if the vendor is part of a competing organization; (d) compatibility amongst levels, evaluating the fit of buyer's staff to vendor's staff below the management; and (e) environmental and social sensitivity.

Technology. The most important points under this aspect were (a) compatibility of the technological platform, mainly related to used software for production and as databases; (b) technical specialization and education, which reflects the quality of the technical staff; (c) communication and online systems dealing with dynamic websites for real-time reporting and online payment facilities; and (d) technological capacity relating to the existence of the latest software, hardware, and interfaces.

Relationship and communication. Generally, partners evaluate the relationship over time according to stability, openness, and trust. Under this heading, I took into consideration (a) relationship closeness, one's ability to establish a long-term relationship; (b) knowledge exchange, a person's ability to trustfully interact and share information on a technological level; (c) communication openness, transparency of daily collaboration, especially dealing with challenging situations that affect the buyer; (d) integrity, a factor describing the use of confidential information obtained in the relationship in nonrelated business activities and ethical behavior; and (e) the ability to resolve conflicts.

Geographical location. In an offshore-outsource relationship the spatial elements might play a pivotal role for a fruitful relationship. Here, determining factors indicated in the literature were (a) common language, (b) geographical distance and time zone, (c) currency stability and predictability of price-levels, and (d) legal and political stability. The last factor (d) is particularly important when vendors incur investments and transfer intellectual property.

***Business*.** Various authors mentioned controllability, dependence on the buyer, ability to perform over time, financial stability, and political influence. These factors relate to the size of the vendor business, which formed one single consolidated factor for all business.

A custom survey instrument, presented later in this study, served for the collection of the pairwise comparisons or preferences of individual SMEs across the various vendor selection criteria (factors). The factors for use in the detailed survey were subject to calibration in a pilot survey with a small group of SMEs prior to proceeding. I then administered the detailed follow-up survey using a 17-point Thurstone-based electronic questionnaire to the participants over the Internet. Specifics are a part of the sample and instrument subsections. The instrument contained the structure of the AHP and required the interviewee to declare the magnitude of preference of one factor over a second one, until all factors within their hierarchical level in the branch of the decision tree had received a value. Figure 4 is an example of a cluster named *Performance Measures* with the pairwise comparison among three factors: (a) quality of processes, (b) time of delivery, and (c) flexibility.

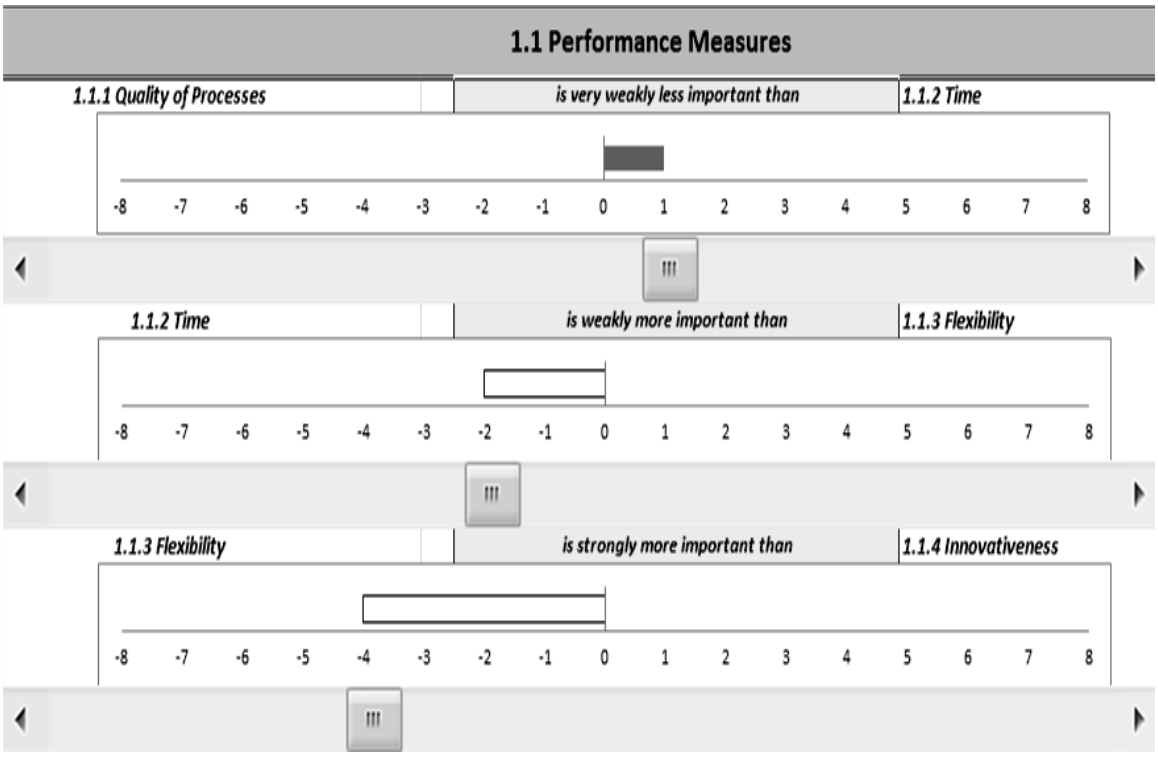


Figure 4. Example for pairwise evaluation of factors in AHP.

Chan and Chan (2010) described various uses of the process and the Likert-based instrument. AHP trees, as described in Section 2, contain three or more levels, with the description of the goal in the first and alternatives in the last level. Level 2 represents the factors or criteria and may subdivide in as many subcriteria in further intermediate levels as required. In the present study, the AHP tree comprehended three factor levels with two criteria in the highest level and a maximum of six sub criteria in a next lower level. Each subcriterion itself again contained a maximum of further six subcriteria on one next lower level. The maximum, total number of pairwise comparisons *N* for the five-level AHP tree of this study was as follows

$$N = c_{L2}\,(c_{L2}-1)/2 + c_{L2}\,c_{L3}\,(c_{L3}-1)/2 + c_{L3}\,c_{L4}(c_{L4}-1)/2. \qquad (1)$$

where c_{Li} is the number of factors in level i for an n-level AHP-tree and $i = \{2,. . . , n\text{-}1\}$.

Equation 1 results in a potential maximum of 211 pairwise comparisons among factors. The research-population consisted of SMEs from North American geospatial companies with experience in offshore relationships.

Data Collection Technique

Data collection followed a two-step process. In the first step, five SMEs received through https://www.surveymonkey.com the initial list of factors for validation and possible minor adjustments (see Figure 5). Specifically, for validation of the instrument it was necessary to capture expert judgments in the pilot survey with the expectation to reveal if the initial list of factors was complete, relevant, understandable, and sufficiently precise. Since IRB required disclosure of the sample and survey in the application, to obtain IRB approval, the initial list in Figure 5 was preliminary and was subject to verification and modification, together with the instrument.

1. Please give your opinion to the relevance of the following criteria in a selection process for an offshore-outsourcing vendor.

	Relevant	Not relevant	Do not understand
Product quality	○	○	○
International quality certifications	○	○	○
Reputation and positive track-record	○	○	○
Consistency of quality over time	○	○	○
Timeliness of delivery/Lead time	○	○	○
Timeliness and quality of reporting/responsiveness	○	○	○
Technical and managerial competence of Project Managers	○	○	○
R&D advantage	○	○	○
Use of new technologies and future capabilities	○	○	○
Product volume changes and peakload capacity	○	○	○
Short setup time/flexibility in schedules	○	○	○
Compliance with sectorial price behavior and with cost analysis of the buyer	○	○	○
Low initial price	○	○	○
Sufficient and quality management resources	○	○	○
Management attitude and compatibility	○	○	○
Strategic fit of businesses	○	○	○
Compatibility among levels and functions	○	○	○
Environmental and social sensitivity	○	○	○
Compatibility of technical platforms	○	○	○
Technical specialization and educational level of staff	○	○	○
Existing communication and online systems	○	○	○
Present technological capacity	○	○	○
Relationship closeness and feeling of trust	○	○	○
Knowledge exchange and reciprocal arrangements	○	○	○
Communication openness	○	○	○
Reputation for integrity	○	○	○
Conflict resolution mechanisms	○	○	○
Common language	○	○	○
Geographical distance	○	○	○
Currency stability/economical risk	○	○	○
Legal stability/protection of intellectual property/political risk	○	○	○
Size of vendor business/financial stability and position	○	○	○

Other (please specify)

Figure 5. Initial list of factors for the pilot-study.

An important element of the plan for the study was the follow-up survey, as a second step, with the full participant group. Approximately 120 SMEs in the U.S. and Canada received an Excel questionnaire by e-mail. As it was important to maintain consistency in the pairwise comparisons, the Excel spreadsheet provided a function to flag inconsistent responses, and the participants had the opportunity to correct their own input concurrently. Consistency measurement was not available in Internet questionnaires, such as https://www.surveymonkey.com.

Appendix D contains the list of the survey questions. As it was crucial to maintain anonymity, the questionnaire did not contain questions about personal information that could reveal the identity of the participants. Participants compared the factors pairwise, thereby refining the magnitude and stating the degree of preference for one or the other factor. (See Table 5 for the translation of statements into numerical values.)

Table 5

Expression of Values in Pairwise Comparison

PAIR-WISE COMPARISON SCALE FOR AHP PREFERENCE

Numerical rating	Verbal judgments of preferences
9	Extremely preferred
8	Very strongly to extremely
7	Very strongly preferred
6	Strongly to Very strongly
5	Strongly preferred
4	Moderately to strongly
3	Moderately preferred
2	Equally to moderately
1	Equally preferred

Note. From "Multi-criteria decision making selection model with application to chemical engineering management decisions", by M. Pirdashti, A. Ghadi, M. Mohammadi, and G. Shojatalab, 2009, *International Journal of Human and Social Sciences, 4,* p. 1151. Copyright 2009 by World Academy of Science, Engineering & Technology (WASET). Reprinted with permission.

Following are examples reflecting the usage of the above comparison logic. In a comparison of factor A to factor B, then the value of preference would be

- 6 in favor of A when A is between strongly and very strongly preferred to B
- 1 when A is equally preferred as B
- 4 in favor of B when B is between moderately and strongly preferred to B

Refer to Figure 6 for an example of pairwise comparison of all factors in a cluster with a Thurstone scale.

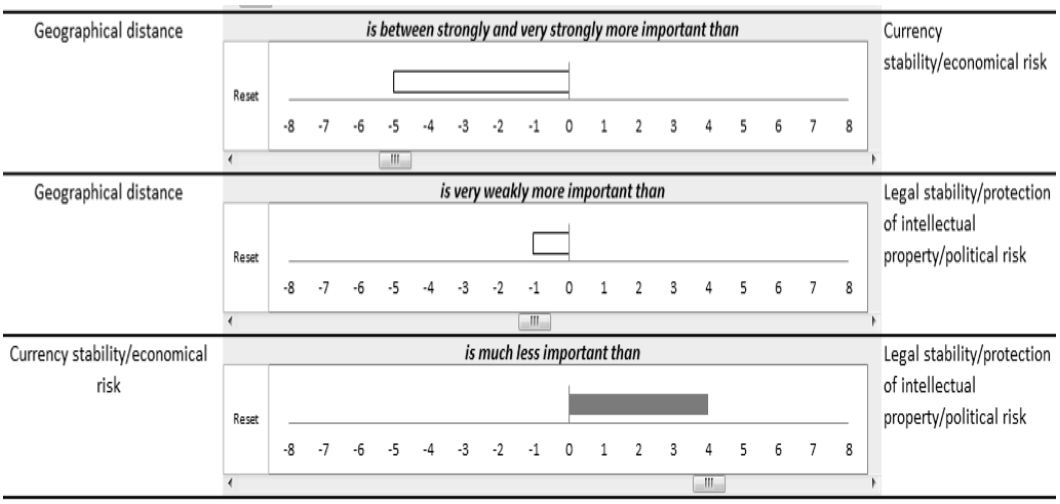


Figure 6. Example for pairwise comparison of factors in the Excel questionnaire.

After finishing the questionnaire without remaining inconsistencies over 10%, the SME could upload the Excel questionnaire to an open FTP-server under an anonymous login. As described in the analysis chapter, I later transferred the resultant data for each participant into a consolidated Excel-sheet.

Data Organization Techniques

For the pilot-survey, https://www.surveymonkey.com became the interface for data collection, and data remains for six months on the Internet account, only accessible to me as the researcher. For the follow-up survey, the Excel questionnaires only remained on the anonymous FTP-site for the duration of the survey. Since the closure of the survey, all data remains on password-protected locations (a) on CD-ROM and (b) on a password protected computer. I will delete all data after 6 months and destroy the CD-ROM after 5 years in compliance with Walden University's IRB guidelines. Only I shall have access to the collected data at any time before the end of the 3-year retention period.

Data Analysis Technique

AHP contains a ranking method based on pairwise comparisons of factors in thematic clusters. After the model completion, the technique is not complex, but the results require thorough interpretation. Although various professional programs do exist for application of AHP, in this study a self-designed Excel spreadsheet served for obtaining a thorough understanding of the processes and for maintaining the freedom to test different approaches for aggregating of results. The self-designed, macro-enabled MS-Excel workbook *Musaeus_S_AHP_Excel for Vendor Selection Outsourcing_mac* (in following chapters simply referred to as "workbook") contained all required functions and presentation options introduced later in this chapter. Excel offers a wide range of functions, which supported the analysis of the results. The remainder of this chapter contains a description of the process of data analysis in detail.

Step 1: Establishment of the AHP-Model in the Excel-Sheet

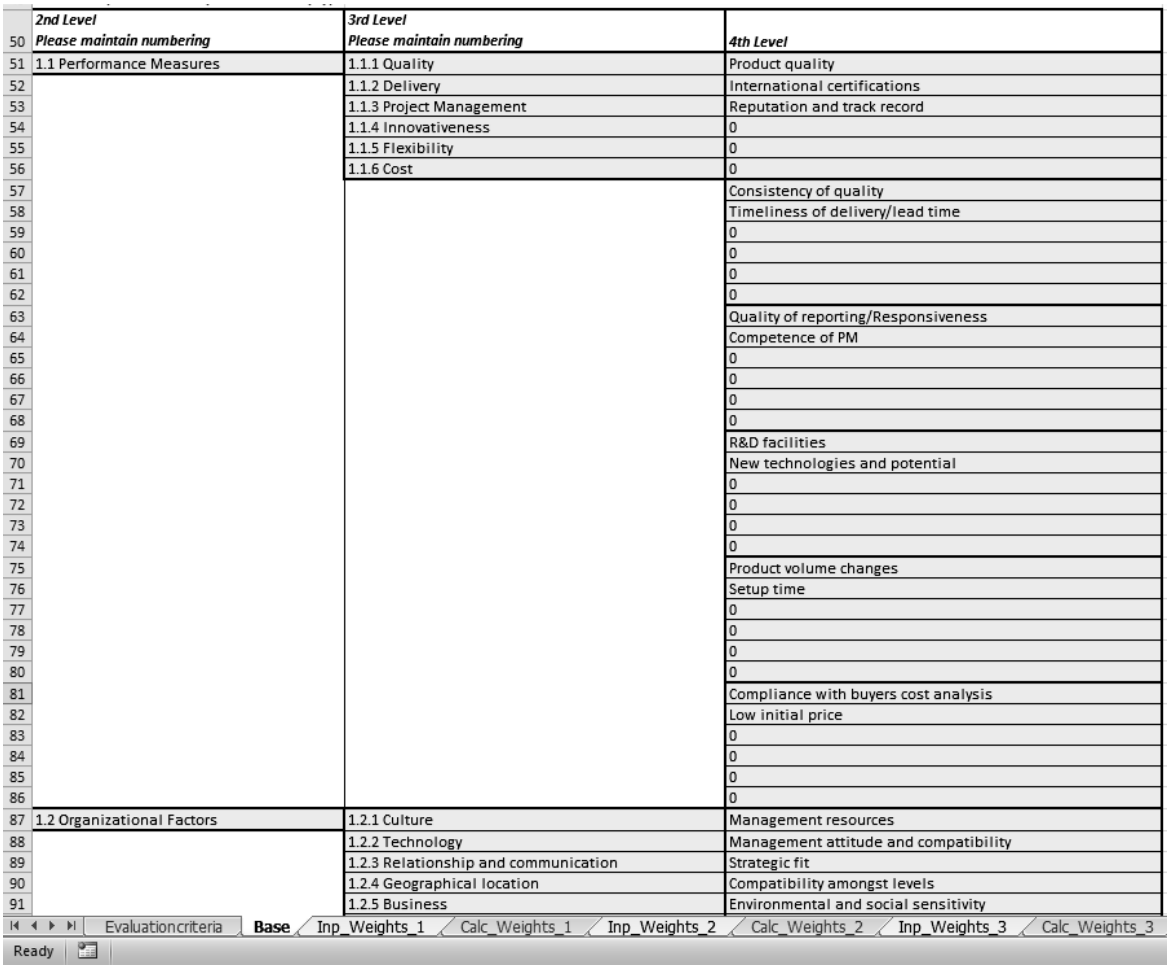
The Excel workbook had a limitation to five-level AHP trees with two factors on Level 2, six factors per cluster on Level 3, and six factors per cluster on Level 4. Using the macros (underlying to buttons in a number of sheets) was the only option that enabled any modification outside the yellow fields in the workbook. The first step was opening the sheet *Base* wherein the user would start filling in only the yellow fields, by identifying the *Evaluation problem.* The next relevant field was the *Allowed consistency in PC* (pairwise comparison). Saaty introduced the *consistency ratio* (CR) as a measure of internal consistency of the pairwise comparisons, and various authors have noted that a maximum *CR* of 10% is acceptable (S.-I. Chang et al., 2012; J. Peng, 2012). This setting

for the *CR* in the workbook did not influence any calculation process.

However, CR values served in later sheets for identifying and flagging values exceeding the threshold. The worksheet *Base* (see Figure 7) comprised all factors that resulted from the validation in the pilot survey. It was not necessary to inscribe the full name of the factor as long as it was recognizable and understandable.

Step 2: Transcribe the Results from the Survey Excel Sheets

I transferred every evaluator's results from the Excel questionnaire into a sheet *Inp_Weights_<number>*, where every number indicated a different evaluator (See the lower area of the screenshot in Figure 7).



	2nd Level Please maintain numbering	3rd Level Please maintain numbering	4th Level
50			
51	1.1 Performance Measures	1.1.1 Quality	Product quality
52		1.1.2 Delivery	International certifications
53		1.1.3 Project Management	Reputation and track record
54		1.1.4 Innovativeness	0
55		1.1.5 Flexibility	0
56		1.1.6 Cost	0
57			Consistency of quality
58			Timeliness of delivery/lead time
59			0
60			0
61			0
62			0
63			Quality of reporting/Responsiveness
64			Competence of PM
65			0
66			0
67			0
68			0
69			R&D facilities
70			New technologies and potential
71			0
72			0
73			0
74			0
75			Product volume changes
76			Setup time
77			0
78			0
79			0
80			0
81			Compliance with buyers cost analysis
82			Low initial price
83			0
84			0
85			0
86			0
87	1.2 Organizational Factors	1.2.1 Culture	Management resources
88		1.2.2 Technology	Management attitude and compatibility
89		1.2.3 Relationship and communication	Strategic fit
90		1.2.4 Geographical location	Compatibility amongst levels
91		1.2.5 Business	Environmental and social sensitivity

Figure 7. Setting up the AHP tree for factor levels 2 to 4.

In a second step, all pairwise comparisons from all evaluators were the input (see Figure 8). Due to technical considerations in Excel, the center point was 0 instead of 1 and the extremes -8 and 8 were equivalent to the values 1/9 and 9 on the AHP Thurstone scale. Thus, all values from the survey required an automatic recalculation to adjust from the Excel to the AHP scale according to the magnitude of preference they represented.

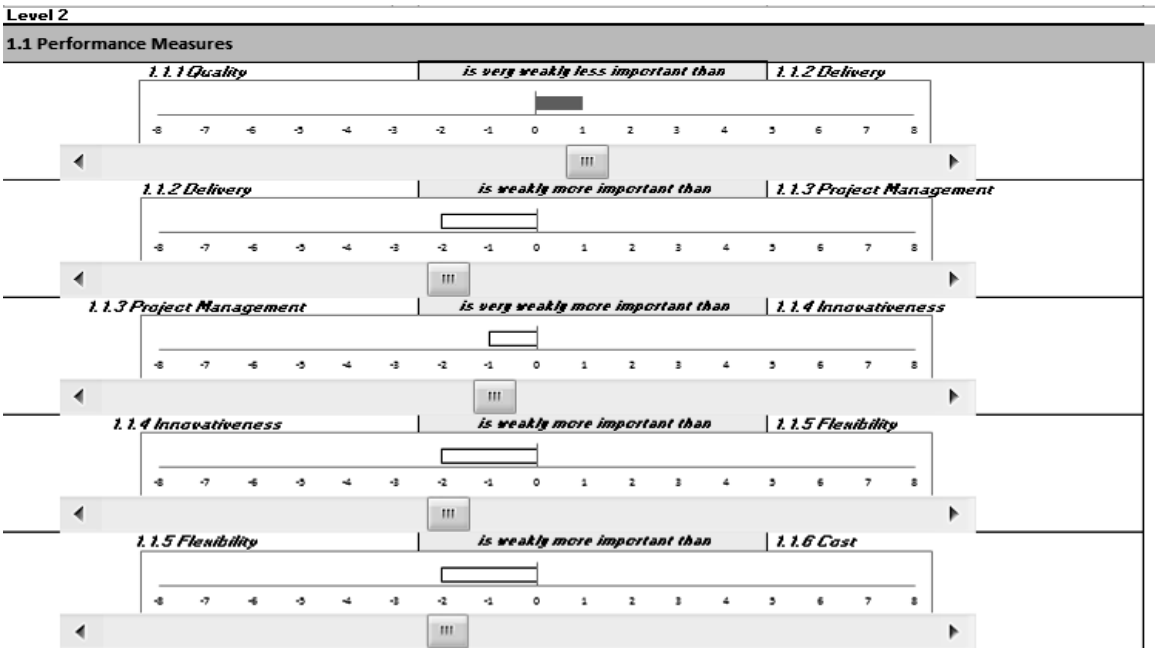


Figure 8. Adjustment of pairwise comparisons in *part two* of the sheet *Inp_Weights_1* to refine the magnitude of differences by importance of each factor compared to other factors in the cluster.

Step 3: Filling in the Comparison Matrix

Any value of the pairwise comparison automatically appeared in the pairwise comparison matrix in the adjunct work sheet *calc_weights_<number>*, where *number* indicated the same evaluator's number as in the connected sheet *Inp_weights_<number>*.

Given that the comparison included all *n* elements from a set *w* with each other, the results $a_{ij} = w_i/w_j$ of the pairwise evaluations translated into an n-by-n matrix $A = (a_{ij})$ with $i,j = 1, 2, \ldots, n$. Further rules were (a) $a_{ij} = 1/a_{ji}$ and (b) $a_{ij} = 1$ for all $i=j$. The fully filled matrix *A* had the following form

$$A = \begin{array}{c} \\ A_1 \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{ccc} A_1 & \cdots & A_n \end{array} \\ \begin{bmatrix} w_1/w_1 & \cdots & w_1/w_n \\ \vdots & \cdots & \vdots \\ w_n/w_1 & \cdots & w_n/w_n \end{bmatrix} \end{array}$$

or with $a_{ij} = w_i/w_j$ *and* $i,j = (1,\ldots, n)$

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix}$$

Each matrix element a_{ij} represented the relative importance assigned to the individual comparison of factor w_i and w_j by an SME. Due to the transitivity rules, matrix A was positive reciprocal. For special cases, some authors have described solutions for non-reciprocal matrices (Fueloep, Koczkodaj, & Szarek, 2011). In applying AHP, Saaty and Shang (2011) postulated that the comparison matrix in a single thematic cluster of factors should —for reasons of manageability and channel capacity of the evaluator—not exceed the dimension 6*6 or six subfactors per factor, which I followed in this study.

Table 6 contains the results of the final pairwise comparison for the cluster "Performance Measures" in form of a comparison matrix with all factors and the relative weights among them. The values in Table 6 indicate the numerical evaluation according to metric explanation in chapter Instrument. The main diagonal of the matrix shows necessarily the value one, as the factor here compares with itself. Once the evaluator had

filled in the upper semimatrix, the lower semimatrix below the main diagonal automatically demonstrated the reciprocal values.

Table 6

Pairwise Comparison for the Cluster "Performance Measures" on Level 3

Pairwise comparison for Level 2

You have **6** factors in this cluster.

1.1 Performance Measures	1.1.1 Quality	1.1.2 Delivery	1.1.3 Project Management	1.1.4 Innovativeness
1.1.1 Quality	1.0	0.5	2.0	3.0
1.1.2 Delivery	2.0	1.0	3.0	3.0
1.1.3 Project Management	0.5	0.3	1.0	2.0
1.1.4 Innovativeness	0.3	0.3	0.5	1.0

For example, in Table 6 the value at the crossing point of row *1.1.1 Quality* ($i = 1$) and column *1.1.2 Delivery* ($j = 2$) is $a_{12} = 0.5$. This means that the evaluator considered quality as *very weakly less important* than delivery. Automatically the field below the main diagonal, with the comparison score of *1.1.2 Delivery* ($i = 2$) and *1.1.1 Quality* ($j = 1$), changes to value $a_{12} = 1/a_{21} = 2.0$, indicating that the evaluator had given delivery a score of *very weakly more important than* quality.

Step 4: Calculation of Weights and Consistency Ratio with the Eigenvalue Approach

For the determination of the priorities, many authors have described different methods. Bajwa, Choo, and Wedley (2008) compared seven different methodologies: geometric mean method, normalized column mean, simple column mean method, weighted least square method, logarithmic least absolute error method, the chainwise geometric mean method, and principal eigenvector method. The authors did conclude that none of the methods is generally superior to the others. Although there was no clear

judgment, I followed in this study the recommendations of Tavana, Sodenkamp, and Pirdashti (2010) and other authors who confirmed the use of the principal eigenvector method for slightly inconsistent matrices, which Dong, Zhang, Hong, and Xu (2010) proposed.

Even though there did exist different measures for consistency, I used Saaty's definitions for the study (Kéri, 2010). Consistency can have the forms: (a) ordinal and (b) cardinal consistency. An example for ordinal consistency is that if *A* is preferred to *B* and *B* is preferred to *C*, then *A* is preferred to *C*. Cardinal consistency exists when *A* is two times preferred to *B; B* is three times preferred to *C*; and *A* is six times preferred to *C*. While evaluators usually achieve ordinal consistency in their decisions, they rarely reach cardinal consistency (Saaty & Vargas, 2011; Saaty, 2013). As a measure for cardinal consistency, Saaty introduced the consistency ratio (CR*;* L. Lin, 2012). To obtain the vector of priorities *p* for the different factors *w*, I used of the method of principal eigenvector determination. The vector *p* would result from the solution of the linear system

$$Ap = \lambda p,\ e^T = 1 \qquad (2)$$

with λ being the principal eigenvalue of *A*.

The Excel spreadsheet *calc_weights_<number>* contains the solution for all comparison matrices. In this computation, I applied an approximation for the normalized eigenvector calculation as Teknomo (2006) suggested. Compared to the numerical calculation the error of a calculation according to Teknomo's method would be less than 1%. The process consists of the following steps

1. Divide each value a_{ij} of A by the sum of all elements a_{ij} in its related column j to create the normalized comparison matrix A_{norm}
2. Generate vector r with n elements, with r_i containing the sum of each row i of the normalized matrix as shown in Table 7

Table 7

Example For A Normalized Comparison Matrix A_{norm} and Vector r

Normalized C-Matrix							*Vector r*
1.1.1 Quality	*0,44*	*0,60*	*0,37*	*0,33*	*0,32*	*0,26*	*2,33*
1.1.2 Delivery	*0,15*	*0,20*	*0,37*	*0,42*	*0,24*	*0,26*	*1,64*
1.1.3 Project Management	*0,11*	*0,05*	*0,09*	*0,08*	*0,16*	*0,16*	*0,66*
1.1.4 Flexibility	*0,11*	*0,04*	*0,09*	*0,08*	*0,16*	*0,11*	*0,59*
1.1.5 Use of new technologies and future capabilities	*0,11*	*0,07*	*0,05*	*0,04*	*0,08*	*0,16*	*0,50*
1.1.6 Low initial price	*0,09*	*0,04*	*0,03*	*0,04*	*0,03*	*0,05*	*0,28*

3. Divide every element r_i of r by the number of factors n to obtain the priority vector p or normalized eigenvector
4. Calculate the consistency index CI as

   $$CI = (\lambda_{max} - n) / (n - 1). \quad (3)$$

   Equation 3 illustrates n as the number of pairwise compared factors in the cluster or the size of matrix A; λmax is the principal eigenvalue of A.

Table 8

Priority Vector with Individual Weights, Principal Eigenvalue λ_{max}, and Consistency Values CI and CR.

1.1 Performance Measures	*Priority Vector*
1.1.1 Quality	*25.33%*
1.1.2 Delivery	*35.52%*
1.1.3 Project Management	*16.45%*
1.1.4 Innovativeness	*12.23%*
1.1.5 Flexibility	*6.99%*
1.1.6 Cost	*3.50%*

lambda max	*6.294*
consistency index (CI)	*5.89%*
consistency ratio (CR)	*4.75%*

5. For calculating the relevant *CR*, a comparison of *CI* with the random consistency index *RI* is necessary. *CR* = *CI* / *RI* with *RI* from Table 9 in the column indicating the number *n* of factors in the pairwise comparison matrix (Pirdashti et al., 2009). Consistency ratios of CR < 10%, such as the one in Table 8, are acceptable.

Table 9

Average Random Consistency of Comparison Matrices

AVERAGE RANDOM CONSISTENCY

Size of Matrix	1	2	3	4	5	6	7	8	9	10
Random Consistency	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Note: From "Multi-criteria decision making selection model with application to chemical engineering management decisions", by M. Pirdashti, A. Ghadi, M. Mohammadi, and G. Shojatalab, 2009, *International Journal of Human and Social Sciences, 4,* p. 1151. Copyright 2009 by World Academy of Science, Engineering & Technology (WASET). Reprinted with permission.

The consistency ratio CR was the measure for the cardinal consistency of the answers within a cluster (Benítez, Delgado-Galván, Gutiérrez, & Izquierdo, 2011). The

degree to which the matrix fulfilled the following relationship $a_{ij}a_{jk} = a_{ik}$ for any evaluation indicated cardinal consistency for the pairwise comparison. As human judgments are normally not perfectly cardinally consistent, consistency ratios of up to 10% among the values of one cluster are usually acceptable in the analytic hierarchy process (Saaty, 2013).

The calculation resulted in CRs for all clusters and SMEs. Theoretically, it was possible that the survey results showed larger inconsistencies than 10%. Various authors have developed techniques to discover contradictory judgments and to correct them (Ergu et al., 2011; W. Wu et al., 2012). However, I did not expect to find a large percentage of extraordinary inconsistencies because (a) the group of participants consisted of experts in the fields and (b) every participant of the follow-up survey had received instant feedback on the consistency of their answers.

Should the analysis have resulted in a CR > 10%, there were two possibilities:

(1) Mild violations of CR > 10% (but below 15%): As in statistical analysis that involves assumption violations, such as, for example, a sample that is not being highly normal, the analysis would have still proceeded but somewhat jeopardizing the strength (power) of the sample.

(2) Severe violations of CR > 15%: In that case, the dataset would not have contributed to further calculations.

If due to the number of inconsistent answers the number of usable datasets had fallen below 15, I would have sought more SMEs to participate in the survey.

Step 5: Aggregation of the Results.

In order to obtain a result reflecting the opinion of all experts, it was necessary to aggregate results. Ishizaka and Labib (2011) recommended for distant experts a mathematical aggregation, while for group settings in companies other methods of consensus building should be preferred. Various authors have presented views on when to use aggregation of individual judgments (AIJ) or aggregation of individual priorities (AIP; Ishizaka & Labib, 2011; Pirdashti et al., 2009). In AIJ, the combination of judgments of all evaluators populate aggregated comparison matrices by applying element-wise the geometric mean to the individual a_{ij}. The resulting aggregated set of comparison matrices is then the input to calculate the global priorities of the factors. On the other hand, the aggregation of priorities for each level in AIP would take place for every SME individually. In a second step, the priorities from all SMEs of each factor form in their aggregation through arithmetic mean an aggregated priority. In the literature, researchers followed mainly Saaty by proposing AIJ if the group of decision makers acts as members of a unit (e.g., a company) and decides as a single individual. AIP, on the other hand, would be the preferred method when no connection exists among the participants in the process, and every SME would evaluate only on his own behalf (Dong et al., 2010; Pirdashti et al., 2009).

In the present study, the group consisted of experts united just by pertinence to the same industry, which implicated the aggregation of individual priorities (AIP) with the arithmetic mean method. Consequently, the final priority of any factor resulted from an aggregation of the arithmetic means of all evaluators' priorities for the factor. Given

that the arithmetic mean is an additive measure, the sum of all arithmetic means within one cluster is 100%. Therefore, the results did not require further normalization, as they would have by using the geometric mean.

There was no further concern about the internal consistency of the aggregated results. Grošelj and Zadnik Stirn (2012) showed that the aggregated matrices of consistent source matrices are also consistent. Table 10 contains the results of the cluster "performance measures."

Table 10

Result of Aggregation of Evaluations from Four SMEs by Arithmetic Means of Individual Priorities for Cluster "Performance Measures"

	Evaluator 1	*Evaluator 2*	*Evaluator 3*	*Evaluator 4*	*Arithmetic mean all valid*	*Variance all valid*
1.1.1 Quality	25.3%	21.9%	23.8%	6.9%	19.5%	0.7%
1.1.2 Delivery	35.5%	12.6%	28.6%	6.2%	20.7%	1.9%
1.1.3 Project Management	16.4%	9.4%	19.0%	21.1%	16.5%	0.3%
1.1.4 Innovativeness	12.2%	4.7%	14.3%	15.7%	11.7%	0.2%
1.1.5 Flexibility	7.0%	23.4%	9.5%	22.7%	15.7%	0.7%
1.1.6 Cost	3.5%	28.1%	4.8%	27.3%	15.9%	1.9%

Step 6: Calculation of Global Priorities

The values of the normalized eigenvector of the comparison matrix represented the priorities within one thematic cluster. These priorities always add up to 100% within one cluster and do not on their own shed light on the global priority of the factor in the AHP tree. The global priority of a factor determines which weight the factor has against all other factors in the same level and, thus, how the factors contributes to the overall decision. Within this final step, combining local priorities into global priorities takes

place. The integration process consists of a multiplication of the local weight of the factor with the one of parent factors on all higher levels according to the following concepts.

There are *n* priorities for every factor *w* on every level, where *n* is the number of evaluating SMEs. In the evaluation from SME *i*, p_2^i is the local priority of factor w_2 on level 2, p_3^i is the local priority of factor w_3 on Level 3, and p_4^i is the local priority of factor w_4 on Level 4. Furthermore, w_2 is the parent to w_3, and w_3 *is* the parent to w_4. Then the aggregated global priorities g_2, g_3, and g_4 for the factors are

$$g_2 = \Sigma (p_2^i) / n \qquad , for\ i = 1 \ldots n \tag{4}$$

$$g_3 = \Sigma (p_2^i \times p_3^i) / n \qquad , for\ i = 1 \ldots n \tag{5}$$

$$g_4 = \Sigma (p_2^i \times p_3^i \times p_4^i) / n \qquad , for\ i = 1 \ldots n \tag{6}$$

Table 11 contains the results for Level 2 and 3 in the existing AHP tree.

Table 11

Local and Global Priorities of Factors in Level 2 and 3 after Aggregation

	Evaluator 1	*Evaluator 2*	Local priorities		**Global Priorities**	
	1	**1**	*Arithmetic mean activated*	*Variance activated*	***Global priorities activated***	***Variance activated***
1.1 Performance Measures	80,0%	87,5%	83,8%	0,3%	**83,75%**	**0,28%**
1.2 Organizational Factors	20,0%	12,5%	16,3%	0,3%	**16,25%**	**0,28%**
Pairwise comparison for Level 2						
1.1 Performance Measures						
1.1.1 Quality	38,8%	46,2%	42,5%	0,3%	**35,59%**	**0,22%**
1.1.2 Delivery	27,3%	15,3%	21,3%	0,7%	**17,85%**	**0,51%**
1.1.3 Project Management	10,9%	5,3%	8,1%	0,2%	**6,81%**	**0,11%**
1.1.4 Flexibility	9,9%	10,0%	9,9%	0,0%	**8,33%**	**0,00%**
1.1.5 Use of new technologies and future capab	8,4%	3,6%	6,0%	0,1%	**5,01%**	**0,08%**
1.1.6 Low initial price	4,7%	19,6%	12,1%	1,1%	**10,16%**	**0,78%**

Priorities' empirical variance s^2 and standard deviation s result from the standard formula for variance and standard deviation of the arithmetic mean from

$$s^2_i = (\Sigma (m_i - p^j{}_i)^2) / (n\text{-}1) \quad (7)$$

where

$$s_i = \sqrt{s^2_i} \quad (8)$$

with

m_i: Arithmetic mean of the priorities of factor w_i and

$p^j{}_i$: Individual priority of factor w_i by SME_j.

Calculation of variance and standard deviation of the global priorities occurred individually by factor and level.

Reliability and Validity

Reliability

For the purpose of this study, reliability referred to the ability of a measuring instrument to facilitate for data collection with a high degree of consistency in achieving the same conclusions. It is common practice to assess the reliability of a survey using Likert-type scales by applying (a) split half reliability (uses the Spearman-Brown coefficient; Thompson, Green, & Yang, 2010), (b) test-retest method (Schatz, 2010), or (c) Cronbach's alpha (Tavakol & Dennick, 2011). In the study, none of these analyses was applicable (unlike other types of instrument reliability studies) since AHP provided an instrument to measure directly the consistency of the answers of participants.

Saaty (2013) suggested the consistency ratio CR to visualize in a mathematical form the degree of consistency of the answers in a pairwise comparison of factors.

Consistency ratios of more than 0.1 are critical, which would lead to review or exclusion of the judgment. The participants of the follow-up survey had the possibility to measure their own consistency index or ratio during the survey. Every evaluator first ranked all factors in one cluster and used the pairwise comparisons later, for further expressing the magnitude of the differences. The visualization of the consistency ratio facilitated participants maintaining consistency even within a large set of pairwise comparisons. Saaty and Shang (2011) posited that the human ability of information processing does not allow for more than six to seven synchronous evaluations. Ishizaka (2012) presented a model using pivots for matrices with more elements, which is even suitable for incomplete matrices. However, I maintained the limitation to six elements, as incomplete judgments were not possible due to restrictions in the electronic questionnaire.

Validity

There are three kinds of measurement validity: content validity, empirical validity and construct validity (Trochim, 2006). All refer to the degree to which actual measurements of an instrument comply with the purpose of its design. Content validity consists of two distinct types: (a) face validity and (b) sampling validity (Trochim, 2006). Determining the face validity the scientist may receive an indicator on the relevance of an instrument to measure characteristics of the variable he designed to measure. Sampling validity describes the degree to which statement, questions, or indicators in the instrument adequately measure the qualities we intend to measure.

There are also two forms of sampling validity: external and internal validity (Trochim, 2006). External validity relates to the ability to generalize the results to other populations (Allcott & Mullainathan, 2012). Internal validity relates to the correctness of causal reasoning and causal conclusions within the study (Bleijenbergh, Korzilius, & Verschuren, 2011).

Empirical or criterion-related validity exists when there is a strong relationship between the results the instrument predicts and obtains when measuring related variables. Empirical validity consists of predictive validity, concurrent validity, convergent validity, and discriminant validity (Trochim, 2006). One can assure construct validity by relating the measuring instrument to a general theoretical framework and the theories fitting the instrument.

The researcher may assume sufficient face validity or construct coverage when the measurement scales contained in the instrument adequately discriminate the observations (Farrell, 2010). The purpose of Thurstone scales for pairwise comparisons in the AHP methodology is to capture relative judgments in the form of verbal statements of preference. The results of the pilot study (in which the group of 5 SMEs stated if the instrument was appropriate for measuring criteria and their relevance for vendor selection in the geospatial industry) also further supported face validity.

To increase the potential for external validity of the results, only experts with relevant offshore outsourcing expertise from the geospatial industry participated in the study. According to the results of the pilot study, the participants in the follow-up study received only reviewed and adjusted questions and explanatory introductions. AHP

provides an instrument which has proven its applicability for vendor selection problems (Pirdashti et al., 2009).

Given that no predictions on the behavior of a variable were within the study's purpose, empirical validity was not relevant for the study. Empirical validity in the study could only relate to the two questions: (a) "If factor *A* is preferred to factor *B*, would factor *A* also receive a higher weight in the decision model?" and (b) "If factor *A* has a higher weight than other factors in the decision model, would a vendor who scores higher on factor *A* also receive an evaluation as the preferred vendor?"

Saaty (2013) suggested that the design of AHP using the eigenvector approach ensures that the results render constantly consistent rankings. Predictive validity had no relevance to the study. However, the investigation if vendors, who have scored highest according to the final weighted factor list, actually received the award for the jobs and performed better than lower scoring vendors, could be subject to future studies.

Convergent validity of the results exists if the final weighted factor list of the geospatial industry is similar to the factor lists of previous studies in similar industries (e.g., IT and construction). A second approach could be to compare the results of vendor selection with AHP with vendor selection results by means of other methodologies in the same industry. However, both aforementioned options were only theoretical, as no other studies on vendor selection in the geospatial industry existed. Discriminant validity is the degree of correlation among independent variables accounting for a variance in the dependent variables (Farrell, 2010). A statistical method to support discriminant validity is to compare the shared variance with the average variance extracted (AVE) as Farrell

(2010) described. As AHP is not a statistical method, these tests were inapplicable. The objective of the present study was to achieve a high degree of agreement among the experts and discriminant validity remained irrelevant.

In re construct validity, AHP is a mathematically sound and adequate methodology for deriving factor weights used for subsequent ranking of alternatives from pairwise comparison (Saaty, 2013). Practitioners and scientists have used AHP extensively in the field of vendor selection problems (e.g. in IT industry, fashion retail, aeronautical industry, construction); thus, AHP provided an adequate framework for the given problem also for the geospatial industry.

Summary and Transition

In Section 2, I described the details of the vision for the study in detail, addressing research method and design, participants, population and sampling, data collection, data analysis, and finally validity and reliability. Section 2 furthermore comprises a detailed description of the AHP model to assure the model's constituent elements were available within this study. The actual pilot and final surveys followed only upon Walden University IRB approval. Section 3 contains the results of the data collection and analysis with their possible impact on positive social change, and closure of the study with recommendations for action and further research.

Section 3: Application to Professional Practice and Implications for Change

The purpose of this quantitative, descriptive study was to identify the factors underlying how a U.S. or Canadian geospatial service company selects an offshore, outsource vendor. The goal was to collect original data on individual preferences for evaluation factors from a panel of industry experts, to apply the analytic hierarchy process (AHP), and to find a quantitative representation of the weights of the decision parameters (factors). Identifying the factors with the respective weights may lead to financial benefit for both buyer and vendor companies and social benefit for employees and consumers. The application of the findings to professional practice follows the detailed description of the study's results. The additional topics are implications for social change, recommendations for action and further study. My reflections as the researcher and a final summary conclude the section.

Overview of Study

The purpose of this quantitative, descriptive study was to determine the usability of the AHP in selecting an offshore outsourcing vendor in the U.S. and Canadian geospatial industry. The target population consisted of procurement experts in the North American geospatial industry with experience in establishing offshore outsourcing partnerships for data processing. I executed a pilot study and a follow-up study and then applied the AHP on the resulting data.

The main research questions was, How can practitioners apply the AHP multifactor decision process to develop a set of prioritized factors for the selection of offshore geospatial data processing vendors? The subquestions were as follows:

SQ1: What are the top five critical factors in the vendor selection for an offshore-outsourcing relationship in the geospatial industry?

SQ2: How do social responsibility-related factors rank when compared to delivery, quality, and cost-related factors?

SQ3: How do cost-related factors rank compared to any other factor?

SQ4: How large is the variance of the aggregated factor weights?

The working hypotheses (WHs) for the study were as follows:

WH1: US/Canadian business leaders decide to establish an offshore-relationship for data processing based on a process evaluating multiple criteria; thus, a multicriteria decision problem exists.

WH2: Decision makers give social responsibility related criteria a measurable weight in the decision process.

WH3: Low cost alone is not the most influential decision criterion in the vendor selection.

WH4: The aggregated weights for all factors derived from pairwise comparisons by the SMEs have low variance. Low variance would indicate that the results could become the base for a generalized decision system for offshore vendor selection in the geospatial industry.

For the pilot study, a group of six SMEs evaluated a set of 32 factors for relevance and had the opportunity to identify and possibly add missing factors. The participants considered 26 factors relevant and none of the SMEs identified a new factor.

Thus, the 26 factors formed the base for an AHP hierarchy, which I transferred into the survey Excel spreadsheet in Appendix D.

Preceded by IRB approval, 128 procurement managers, managing directors, and technical directors in the U.S. and Canadian geospatial industry received an invitation to participate. After giving consent, a 15 experts agreed to participate. After completing an anonymous survey, they uploaded it to the study's Internet site. Because the consistency ratio (CR) for all 15 surveys was below 10%, neither the period for the survey was extended nor were more invitations send to SMEs.

Summarizing the findings, the answers to the survey questions were that the top five critical factors in the vendor selection for an offshore-outsourcing relationship in the geospatial industry are (a) product quality, (b) consistency of quality over time, (c) low initial price, (d) reputation and positive track record of the vendor, and (e) short setup time/flexibility in schedules. These top five factors account together for 54.5% of the importance for the vendor selection. Already during the pilot study, five out of six participants did not consider *social and environmental sensitivity* relevant and, consequently, the factor did not form part of the list for the follow-up survey.

Low initial price ranked third place and is, thus, a major contributor to the decision on selection of a specific vendor; however, *quality* and *consistency of quality over time* attained a higher score. The results show that standard deviations of the arithmetic means of any factor are smaller than the value of the arithmetic mean itself. Practitioners, both from vendors' and buyers' side, would be able to use the results as guidance for determining candidate vendors for successful partnerships. Managers in

buyer companies could use the factor weights for documenting the performance of vendor companies formally during the selection process and during ongoing partnerships. Managers at vendor companies would therefore have guidance to shape their companies' structure and services according to the weights of the decision factors.

Presentation of the Findings

The Pilot Study

The data acquisition started with a pilot study to verify potentially important factors from the literature review that might influence the decision of managers to start an offshore outsourcing relationship (see Figure 5). As the initial list of factors represented only a consolidated view from experts of different industries, I invited nine SMEs from the geospatial industry in US/Canada, as a purposeful sample, to participate in a pilot study to evaluate all factors for relevance or to identify and add missing factors.

I conducted the web survey after IRB approval from February 24 to March 18, 2014. Nine SMEs, three from Canada and six from the US, received an invitation for the pilot survey based on my professional assessment of their involvement in the outsourcing decisions and their previously expressed openness for participation. The intention was to identify factors non-relevant for the geospatial industry and to identify potentially missing ones. Six SMEs responded to the research by filling in the web survey sheet at *https://www.surveymonkey.com* (see Figure 5). Six factors out of 32 received less than three votes for relevance and consequently did not form part of the final factor list. Table 12 depicts the results and decisions for inclusion or exclusion from the follow-up survey.

Table 12

Results of the Pilot Study

Factor	Relevant–	Not relevant–	Do not understand–	Decision for Follow-up survey
Product volume changes and peakload capacity	5	1	0	included
Technical specialization and educational level of staff	6	0	0	included
Low initial price	6	0	0	included
R&D advantage	0	6	0	excluded
Relationship closeness and feeling of trust	6	0	0	included
Consistency of quality over time	6	0	0	included
Product quality	6	0	0	included
Management attitude and compatibility	6	0	0	included
Timeliness of delivery/lead time	6	0	0	included
Present technological capacity	6	0	0	included
Compliance with sectorial price behavior and with cost analysis of the buyer	2	2	2	excluded
Size of vendor business/financial stability and position	2	4	0	excluded
Compatibility among levels and functions	4	1	1	included
Reputation and positive track-record	6	0	0	included
Communication openness	6	0	0	included
Existing communication and online systems	5	1	0	included
Environmental and social sensitivity	1	4	1	excluded
Timeliness and quality of reporting/responsiveness	6	0	0	included
International quality certifications	4	1	1	included
Currency stability/economical risk	2	4	0	excluded
Compatibility of technical platforms	6	0	0	included
Common language	5	1	0	included
Reputation for integrity	6	0	0	included
Use of new technologies and future capabilities	5	1	0	included
Sufficient and quality management resources	6	0	0	included
Geographical distance	0	5	1	excluded
Short setup time/flexibility in schedules	5	1	0	included
Strategic fit of businesses	3	3	0	included
Legal stability/protection of intellectual property/political risk	3	3	0	included
Knowledge exchange and reciprocal arrangements	3	3	0	included
Conflict resolution mechanisms	6	0	0	included
Technical and managerial competence of Project Managers	6	0	0	included

As preparation for the follow-up survey, it was necessary to model the refined list of factors after the pilot study in an AHP hierarchy. The final AHP-tree in Figure 9 is an adaptation of the original hierarchy, which had emerged from the literature review (see Appendix C).

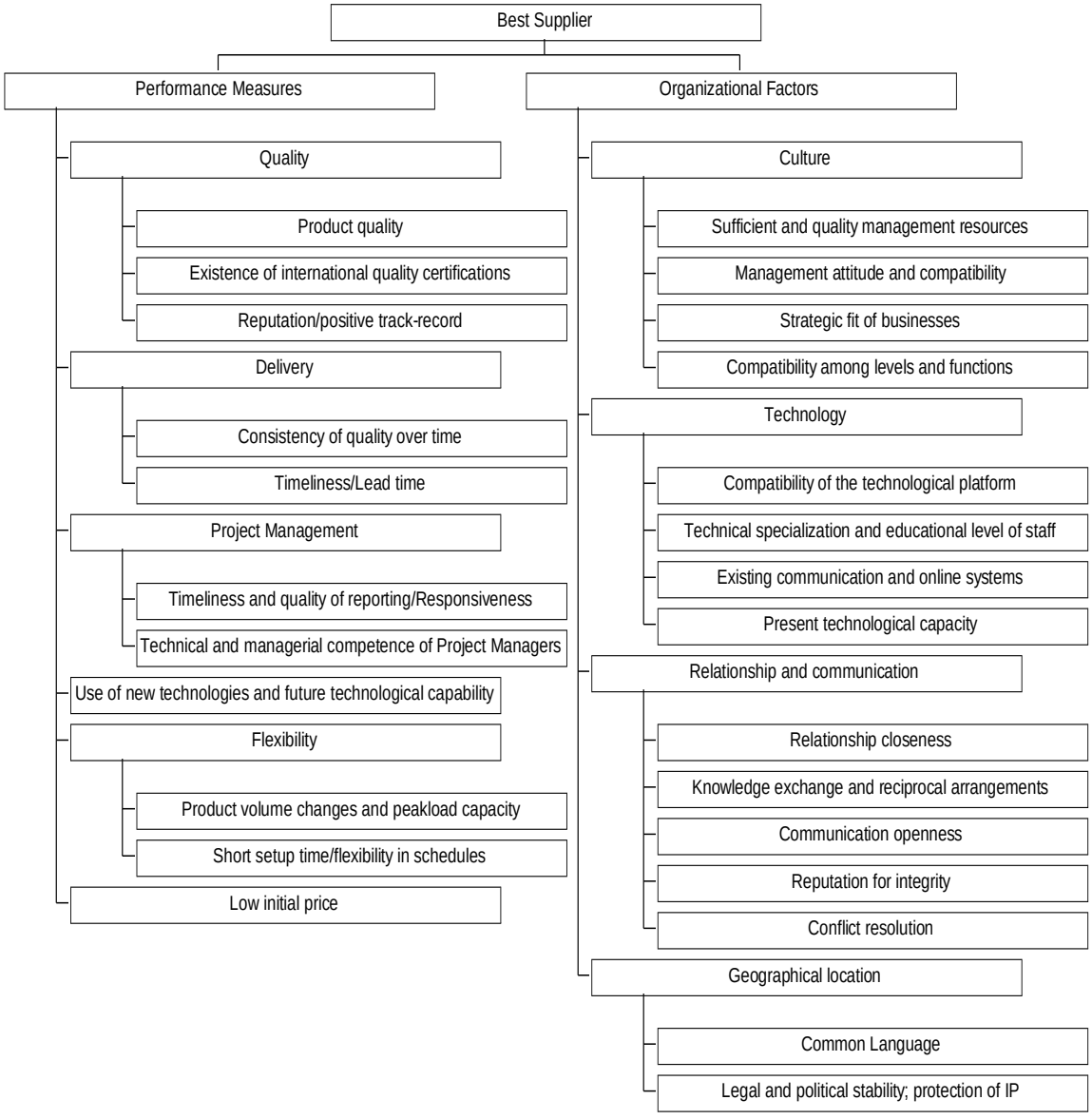


Figure 9. Final AHP-tree after the pilot survey.

The Follow-up Survey

The resulting refined factor list served as input for the follow-up survey with a larger number of SMEs from the geospatial industry. For the follow-up survey, it was necessary to map the AHP hierarchy from Figure 9 into survey questions for pairwise comparisons among the factors (see Appendix D). The follow-up survey took place between April 2 and April 30, 2014. A total of 58 SMEs from the geospatial industry from my own contact list and further 60 from the participant list of two major geospatial conferences received invitations to the expert panel and a personalized email containing the consent letter and a survey Excel spreadsheet (see appendix E). Within the first six days, six SMEs responded. I sent in total three reminders to the entire group; however, the response rate remained low so that I decided to close the survey after reception of the minimum number of fifteen consistent survey results. Three participants indicated Canada and 10 indicated the United States as the country of their company, while two did not answer this initial question. The total response rate was 11.7%. The low response rate might relate to the perception of the survey as complex and/or seeking access to business sensitive data, the latter being email statements of some SMEs, who also directly refused to participate.

Fifteen SMEs compared all factors within each level and branch of the AHP tree pairwise, starting from the highest factor level. The participants marked on a Thurstone-type scale their preference for one of the factors over the other, with "*-9*" indicating *dominating preference* for the left factor, "*9*" *dominating preference* for the right factor, and "*1*" indicating *no preference at all*.

To maintain anonymity of the survey, it was crucial to offer the participants in real time an indicator about the achieved consistency. The survey Excel spreadsheet included one example page to familiarize the participants with the use of the voting tools and the consistency indicator (see Appendix D). Thus, every participant could express their preferences in the pairwise comparisons and, at the same time, observe the development of the CR to keep it below 10%. An algorithm in the Excel spreadsheet contained results for the consistency ratio so that the participants could ascertain the usefulness of their results before submission. None of the surveys resulted in any cluster with a CR beyond 10% (see Appendix F). The calculation of the CR followed Section 2, Step 4: Calculation of Weights and Consistency Ratio with the Eigenvalue Approach.

Data Analysis

The data analysis followed the six steps described in Section 2, Chapter Data Analysis Technique.

Step 1: Establishment of the AHP-model in the Excel spreadsheet. This step consisted of the transcription of the AHP tree into the analysis Excel spreadsheet (see Figure 9). In addition, the allowable consistency ratio was now set to a maximum of 10%.

Step 2: Transcribe the results from the survey Excel sheets. I transferred the results of all received survey Excel sheets. During this process, it was important to check the completeness and consistency of all pairwise comparison. For a complete

transcription, it was necessary to place the markers in the analysis sheet to the same position as the participant had indicated in the survey sheet.

Step 3: Filling in the comparison matrix. An integrated automatic algorithm in the Excel spreadsheet transferred the judgments from the input mask into the comparison matrices. This action occurred concurrently while completing Step 2.

Step 4: Calculation of weights and consistency ratio with the eigenvalue approach. At the same time as Step 2 and 3, another algorithm calculated in the background from the pairwise comparison matrices the eigenvectors and the consistency ratios. The elements of the eigenvectors of the comparison matrices are equivalent to the relative priorities of the factors underlying the pairwise comparisons (Tavana et al., 2010). Appendix E contains the individual priority vectors from all participants. Appendix F contains the consistency ratios of every cluster by survey participant. None of the clusters' CRs exceeded 10%, therefore, all surveys were acceptable. After completing the transcript, I checked all resulting priority vectors (principal eigenvectors) for every participant from the analysis Excel spreadsheet against the priority vectors from the individual survey sheets for coincidence. This checking process ensured the correctness of the manual data transfer.

Step 5: Aggregation of the results. The chosen method for aggregation of the results was the aggregation by individual priorities (AIP), following the description in Section 2, Data Analysis Technique, Step 5. In Step 5, all relative priorities of each factor from every participant contribute to the arithmetic mean of the aggregated relative priority of each factor in its cluster. All arithmetic means of factors in one cluster must

add up to 100%. The aggregation process occurred cluster wise starting from the highest Level 2. Tables 13 through 23 contain the aggregated results for every cluster, with minimum value, maximum value, mean value, and standard deviation of the mean referring to the relative priorities for the respective cluster.

Level 2. The first comparison was at Level 2 between organizational factors and performance measures with

- Performance factors: Any measurable managers of an organization use to evaluate performance
- Organizational measures: Inherent capabilities and capacities of the partner organization

Results in Figure 10 indicate that the majority of SMEs preferred performance measures over the organizational factors of the vendor company.

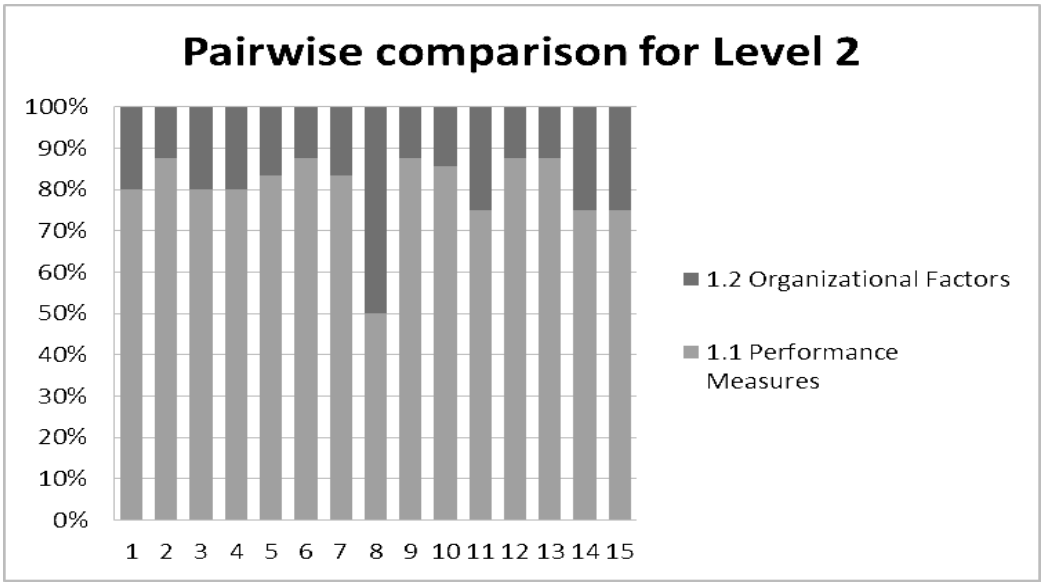


Figure 10. Individual relative priorities for Level 2 - cluster performance measures.

Table 13

Descriptive Statistics: Aggregated Relative Priorities for Level 2

Level 2[a]	Min	Max	Mean	Std.Dev
Performance measures	50.0%	87.5%	80.3%	9.7%
Organizational factors	12.5%	50.0%	19.7%	9.7%

[a]*n* = 15

Level 3. The first cluster *performance measures* contained the elements (a) *quality*, (b) *delivery*, (c) *project management*, (d) *flexibility*, (e) *use of new technologies and future capabilities*, and (f) *low initial price*. Figure 11 depicts the results.

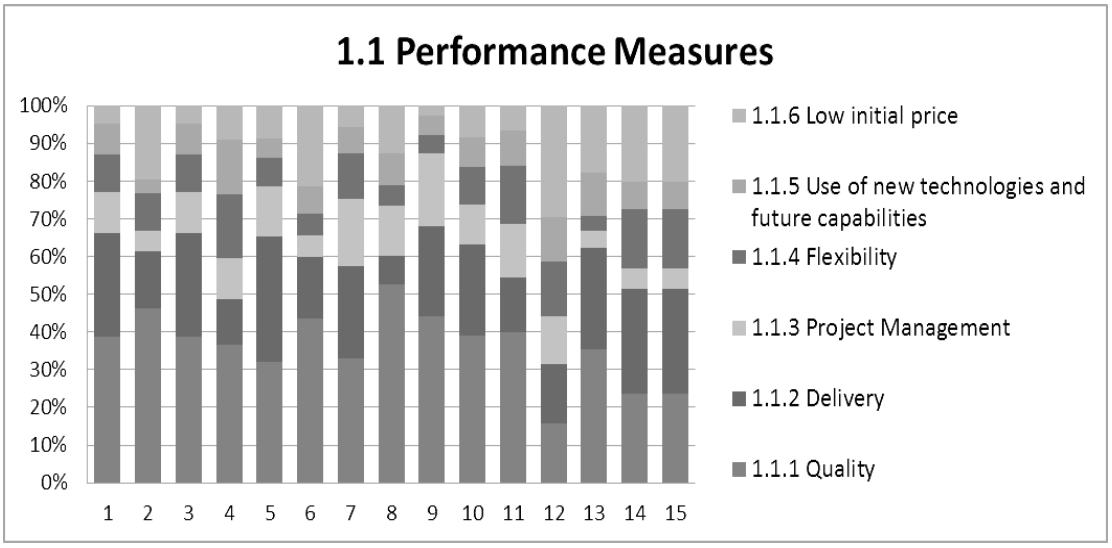


Figure 11. Individual relative priorities for Level 3 - cluster performance measures.

Table 14

Descriptive Statistics: Aggregated Relative Priorities for Level 3 Cluster Performance Measures

Level 3-Cluster performance measures[a]	Min	Max	Mean	Std.Dev
Quality	15.7%	52.8%	36.2%	9.6%
Delivery	7.4%	33.1%	21.6%	7.4%
Project management	4.6%	19.2%	10.7%	4.6%
Flexibility	3.9%	16.9%	10.5%	4.4%
Use of new technologies and future capabilities	3.6%	14.5%	8.2%	2.8%
Low initial price	2.7%	29.4%	12.8%	8.0%

[a]$n = 15$

The results for the cluster *performance measures* indicate a strong preference for *quality* and *delivery* related factors with only one participant, number 12, rating *low initial price* highest. For the second cluster on Level 3, *organizational factors*, the results reflect a rather heterogeneous pattern.

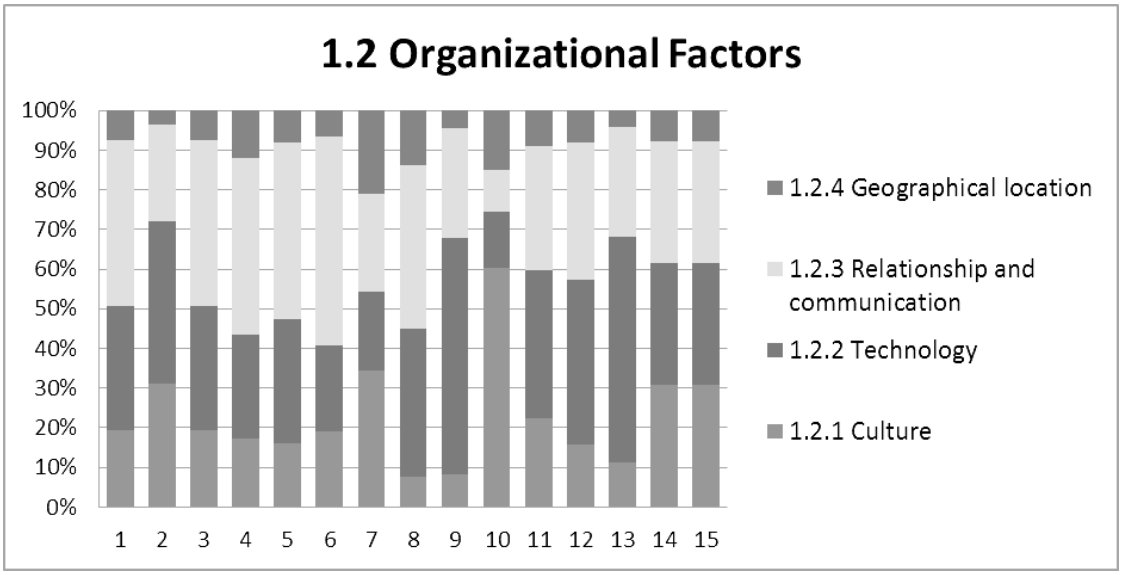


Figure 12. Individual relative priorities for Level 3 – cluster organizational factors.

Table 15

Descriptive Statistics: Aggregated Relative Priorities for Level 3 Cluster Organizational Factors

Level 3-Cluster 1.2 Organizational Factors[n]	Min	Max	Mean	Std.Dev
Culture	7.7%	60.3%	18.5%	11.7%
Technology	14.2%	59.5%	47.3%	10.6%
Relationship and communication	10.5%	52.8%	28.9%	5.2%
Geographical location	3.5%	21.1%	5.4%	2.5%

[a]*n* = 15

In the aggregated results, *technology*, followed by *relationship and communication* rank highest.

Level 4. Level 4 is the most detailed level and comprises the primary factors that a manager would apply to evaluate a company for an offshore outsourcing partnership. From Level 3 (a) *quality*, (b) *delivery*, (c) *project management*, (d) *flexibility*, (e) *use of technology and future capabilities*, and (f) l*ow initial price* in the branch *performance measures* only the first four contain clusters with further subfactors on Level 4. Thus, in the final aggregation the factors *use of technology and future capabilities* and *low initial price* contribute also as factors on Level 4. In the branch *organizational factors* the four clusters (a) *culture*, (b) *technology*, (c) *relationship and communication*, and (d) *geographical location* include subfactors on Level 4 and, thus, contribute as clusters.

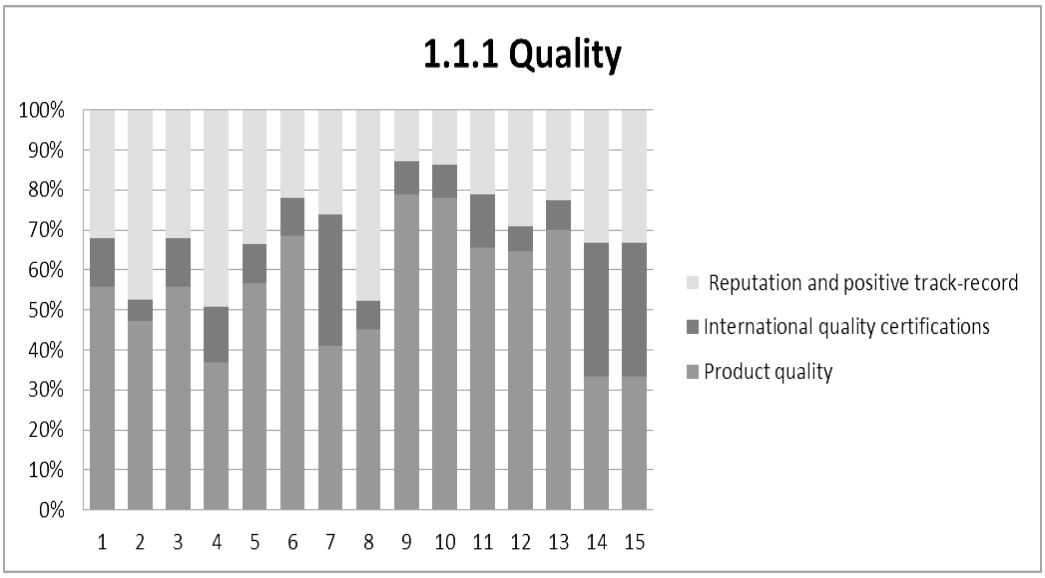


Figure 13. Individual relative priorities for Level 4 – cluster quality.

Table 16

Descriptive Statistics: Aggregated Relative Priorities for Level 4 Cluster Quality

Level 4-Cluster 1.1.1 Quality[n]	Min	Max	Mean	Std.Dev
Product quality	33.3%	79.0%	55.4%	15.4%
International quality certifications	5.3%	33.3%	14.2%	10.1%
Reputation and positive track-record	12.9%	49.3%	30.4%	11.3%

[a]*n* = 15

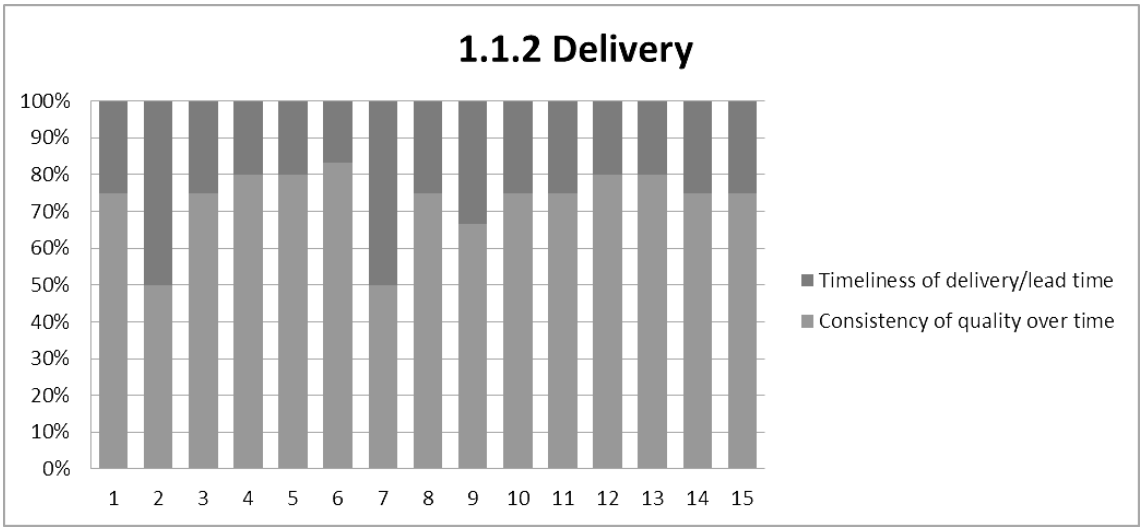


Figure 14. Individual relative priorities for Level 4 – cluster delivery.

Table 17

Descriptive Statistics: Aggregated Relative Priorities for Level 4 Cluster Quality

Level 4-Cluster 1.1.2 Delivery[n]	Min	Max	Mean	Std.Dev
Consistency of quality over time	50.0%	83.3%	73.0%	10.1%
Timeliness of delivery/lead time	16.7%	50.0%	27.0%	10.1%

[a]*n* = 15

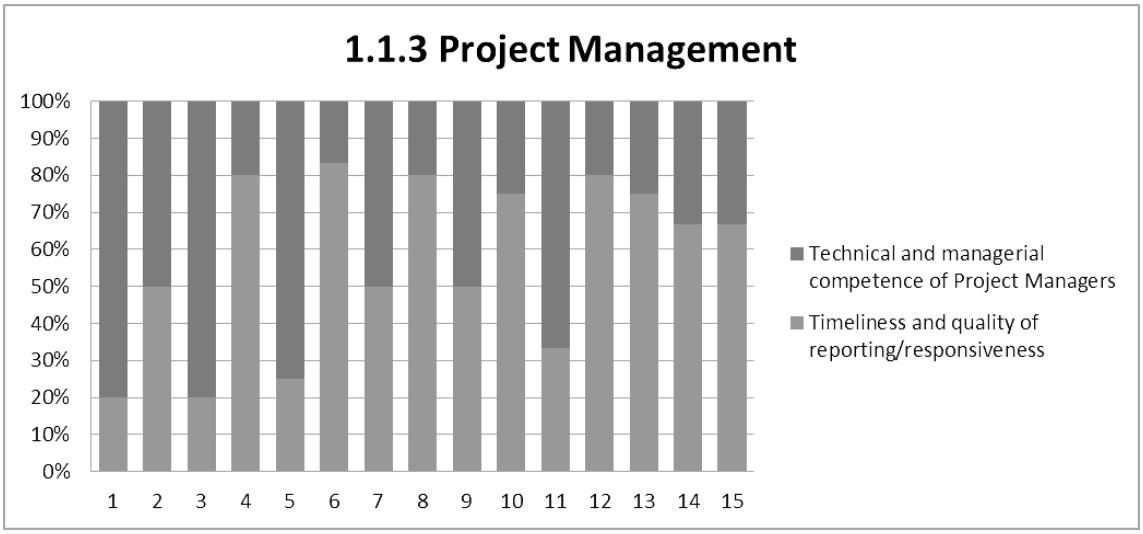


Figure 15. Individual relative priorities for Level 4 – cluster project management.

Table 18

Descriptive Statistics: Aggregated Relative Priorities for Level 4 Cluster Project Management

Level 4-Cluster 1.1.3 Project Management[n]	Min	Max	Mean	Std.Dev
Timeliness and quality of reporting/responsiveness	20.0%	83.3%	57.0%	23.3%
Technical and managerial competence of project managers	16.7%	80.0%	43.0%	23.3%

[a]*n* = 15

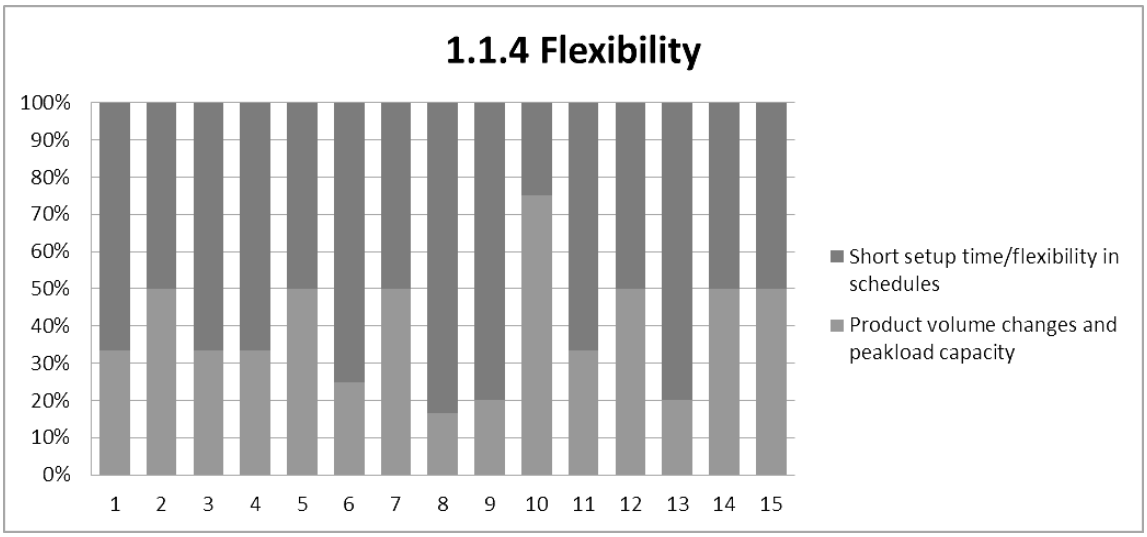


Figure 16. Individual relative priorities for Level 4 – cluster flexibility.

Table 19

Descriptive Statistics: Aggregated Relative Priorities for Level 4 Cluster Flexibility

Level 4-Cluster 1.1.4 Flexibility[n]	Min	Max	Mean	Std.Dev
Product volume changes and peakload capacity	16.7%	75.0%	39.3%	16.0%
Short setup time/flexibility in schedules	25.0%	83.3%	60.7%	16.0%

[a]*n* = 15

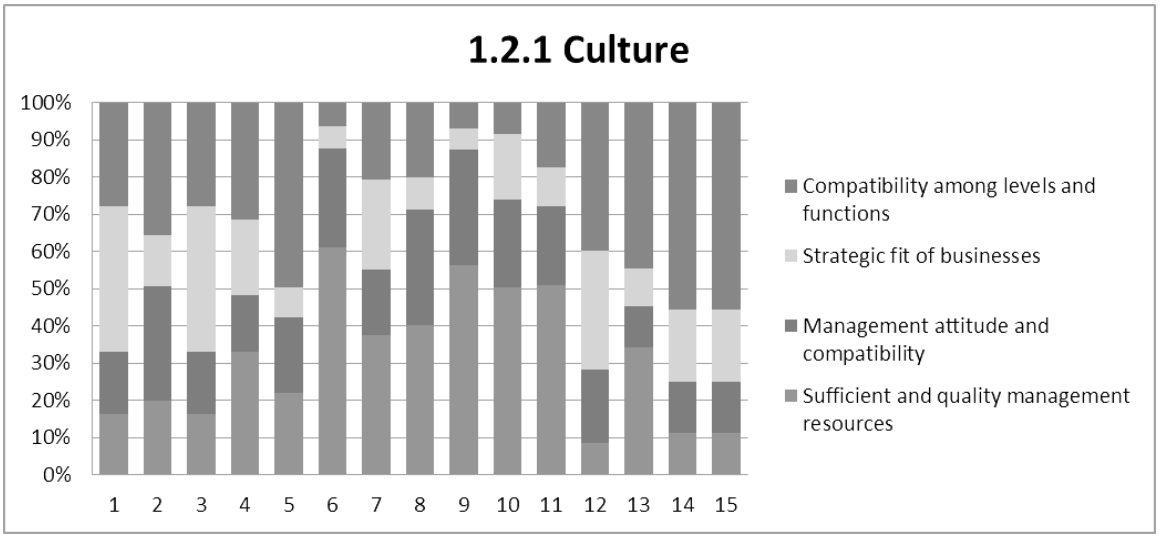


Figure 17. Individual relative priorities for Level 4 – cluster culture.

Table 20

Descriptive Statistics: Aggregated Relative Priorities for Level 4 Cluster Culture

Level 4-Cluster 1.2.1 Culture[n]	Min	Max	Mean	Std.Dev
Sufficient and quality management resources	8.6%	61.1%	31.3%	17.6%
Management attitude and compatibility	11.1%	31.1%	20.6%	6.6%
Strategic fit of businesses	5.7%	39.2%	18.3%	11.2%
Compatibility among levels and functions	6.2%	55.5%	29.9%	16.8%

[a]$n = 15$

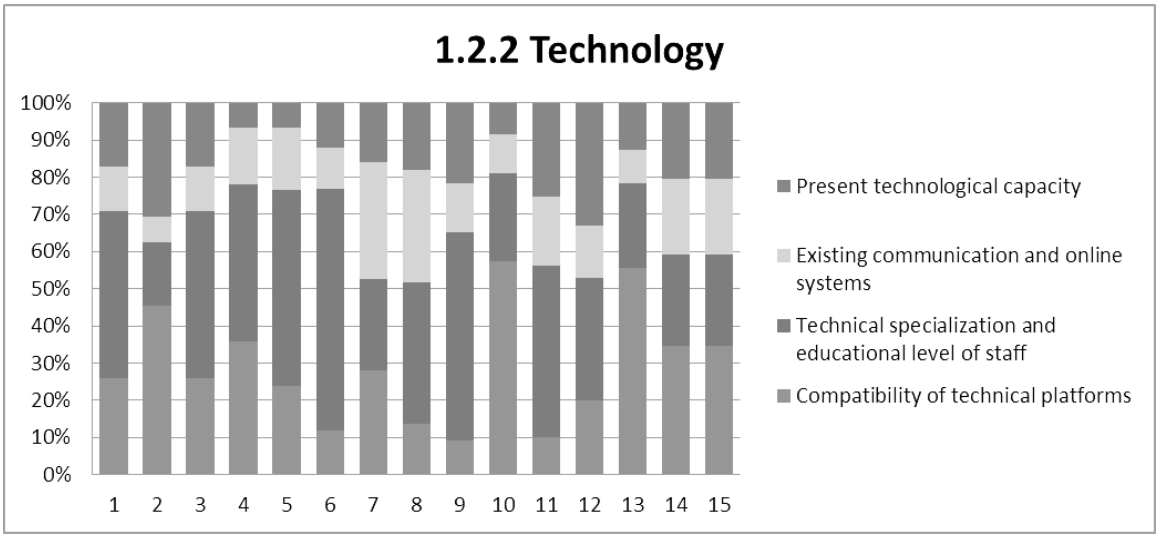


Figure 18. Individual relative priorities for Level 4 – cluster technology.

Table 21

Descriptive Statistics: Aggregated Relative Priorities for Level 4 Cluster Technology

Level 4-Cluster 1.2.2 Technology[n]	Min	Max	Mean	Std.Dev
Compatibility of technical platforms	9.1%	57.5%	28.8%	15.4%
Technical specialization and educational level of staff	17.0%	65.0%	37.3%	14.4%
Existing communication and online systems	6.9%	31.6%	16.2%	7.2%
Present technological capacity	6.6%	32.9%	17.7%	7.9%

[a]*n* = 15

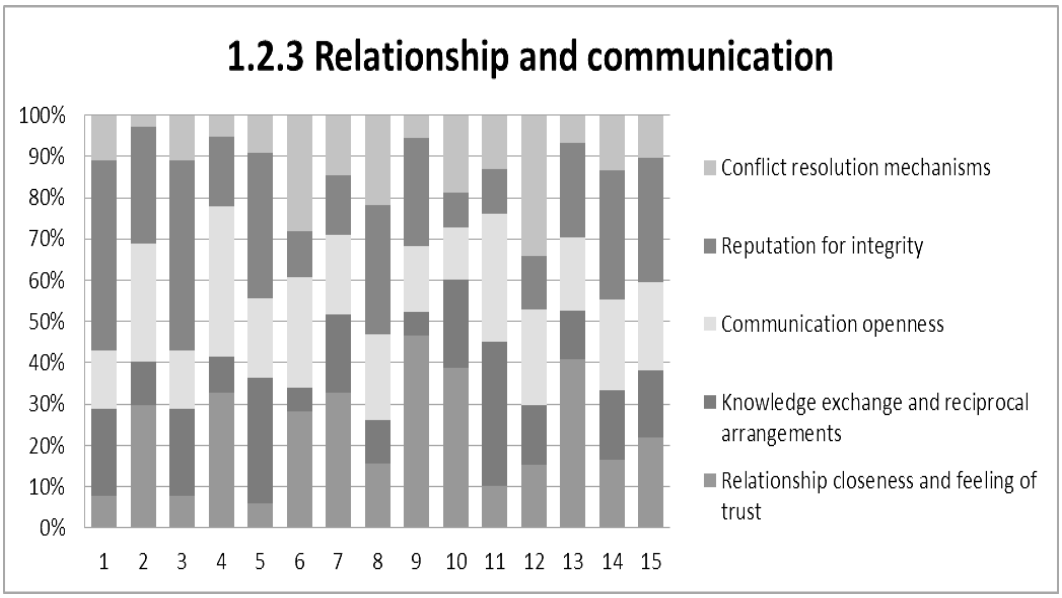


Figure 19. Individual relative priorities for Level 4 – cluster relationship and communication.

Table 22

Descriptive Statistics: Aggregated Relative Priorities for Level 4 Cluster Relationship and Communication

Level 4-Cluster 1.2.3 Relationship and communication[n]	Min	Max	Mean	Std.Dev
Relationship closeness and feeling of trust	6.0%	46.6%	23.4%	13.3%
Knowledge exchange and reciprocal arrangements	5.7%	34.9%	16.6%	8.4%
Communication openness	12.7%	36.4%	21.6%	6.7%
Reputation for integrity	8.3%	45.9%	24.8%	12.2%
Conflict resolution mechanisms	2.7%	34.0%	13.7%	8.8%

[a]*n* = 15

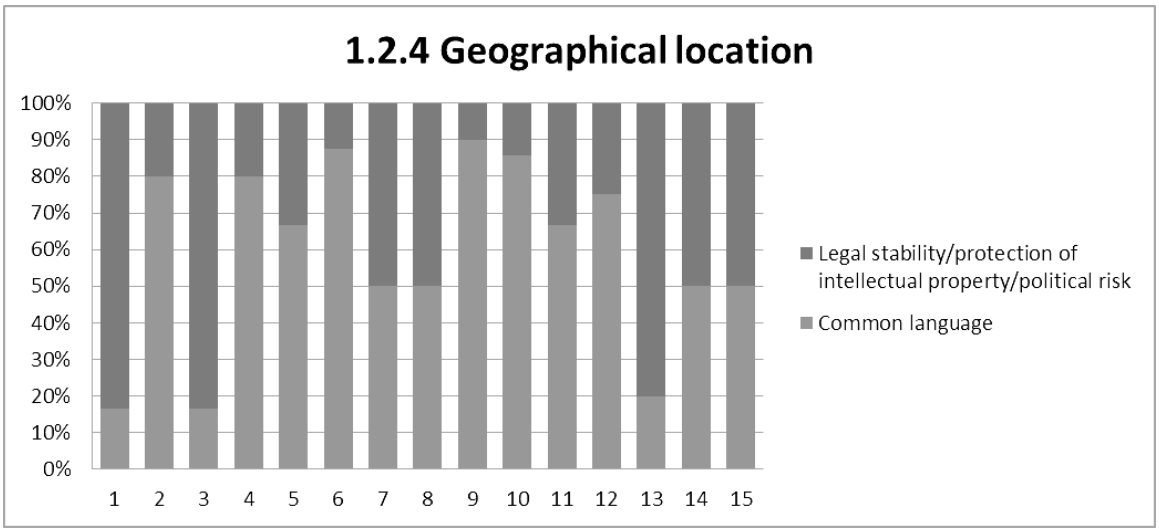


Figure 20. Individual relative priorities for Level 4 – cluster geographical location.

Table 23

Descriptive Statistics: Aggregated Relative Priorities for Level 4 Cluster Geographical Location

Level 4-Cluster 1.2.4 Geographical location[n]	Min	Max	Mean	Std.Dev
Common language	16.7%	90.0%	59.0%	25.6%
Legal stability/protection of intellectual property/political risk	10.0%	83.3%	41.0%	25.6%

[a]*n* = 15

It is noticeable that only the clusters *project management* and *geographical location* indicate major differences in evaluation. In both clusters, standard deviations of the mean are higher than 20% for some factors.

Step 6: Calculation of global priorities. In the sixth and final step, all complete lists of global, relative priorities from all participants contributed to the concluding aggregation process, the aggregation by individual properties. The aggregation

proceeded by application of the arithmetic mean on all global relative priorities for each factor across SMEs. The global priority *g* of any factor represents its weight in the decision process compared to all other factors.

The aggregation by individual priorities (AIP) proceeded by using the formulas (4), (5) and (6) in *Section 2, Data Analysis Technique, Step 6*. Table 24 is a representation of the results for Level 3 and Table 25 of the results for Level 4. The calculation of the standard deviations in Table 24 and 25 utilized formulas (7) and (8) in *Section 2, Data Analysis Technique, Step 6.*

Table 24

Descriptive Statistics: Aggregated Global Priorities for Level 3

Level 3 - Global Priorities[a]	Min	Max	Mean	Std.Dev
Quality	13.77%	40.40%	28.86%	7.74%
Delivery	3.70%	27.59%	17.62%	6.34%
Low initial price	2.34%	25.76%	10.34%	6.99%
Project Management	4.00%	16.78%	8.52%	3.95%
Flexibility	2.71%	13.55%	8.43%	3.51%
Relationship and communication	1.50%	20.61%	6.89%	4.48%
Technology	2.03%	18.68%	6.62%	3.89%
Use of new technologies and future capabilities	3.13%	11.57%	6.55%	2.42%
Culture	1.03%	8.62%	4.25%	2.36%
Geographical location	0.43%	6.87%	1.91%	1.61%

[a]$n = 15$

Table 25 contains the results for Level 4, while Appendices H-K contain the graphical representations.

Table 25

Descriptive Statistics: Global Priorities for Level 4

Level 4 - Global Priorities[a]	Min	Max	Mean	Std.Dev
Product quality	5.92%	30.56%	16.52%	7.52%
Consistency of quality over time	2.77%	22.07%	12.86%	5.12%
Low initial price	2.34%	25.76%	10.34%	6.99%
Reputation and positive track-record	3.99%	19.14%	8.62%	4.13%
Use of new technologies and future capabilities	3.13%	11.57%	6.55%	2.42%
Short setup time/flexibility in schedules	2.15%	9.03%	4.82%	1.98%
Timeliness of delivery/lead time	0.92%	10.25%	4.76%	2.35%
Timeliness and quality of reporting/responsiveness	1.75%	8.78%	4.55%	2.49%
Technical and managerial competence of project managers	0.82%	8.39%	3.97%	3.06%
International quality certifications	0.88%	8.99%	3.72%	2.01%
Product volume changes and peakload capacity	0.45%	6.45%	3.61%	2.13%
Technical specialization and educational level of staff	0.48%	7.08%	2.48%	1.68%
Reputation for integrity	0.12%	6.46%	1.89%	1.72%
Compatibility of technical platforms	0.33%	3.95%	1.71%	0.97%
Communication openness	0.19%	4.25%	1.52%	1.08%
Relationship closeness and feeling of trust	0.45%	3.19%	1.33%	0.83%
Compatibility among levels and functions	0.07%	4.27%	1.32%	1.25%
Sufficient and quality management resources	0.17%	4.35%	1.27%	1.10%
Present technological capacity	0.17%	3.39%	1.23%	0.88%
Existing communication and online systems	0.21%	5.64%	1.20%	1.31%
Knowledge exchange and reciprocal arrangements	0.20%	2.74%	1.14%	0.83%
Common language	0.10%	3.43%	1.08%	0.88%
Conflict resolution mechanisms	0.08%	4.51%	1.00%	1.09%
Management attitude and compatibility	0.16%	2.02%	0.84%	0.47%
Legal stability/protection of intellectual property/political risk	0.06%	3.43%	0.84%	0.88%
Strategic fit of businesses	0.06%	1.52%	0.82%	0.60%

[a]$n = 15$

Discussion of the Results

The results from the research confirmed that SMEs use factors specified on Level 4 during the evaluation process of offshore outsourcing relationships. The comparison of factor ranks resulting from the literature review and ranks resulting from the survey reveals further information as specified in Table 26 below. While ranks from the literature review stem from counting the frequency of mention of a specific factor in the publications (Appendix A), the ranks from the current survey are a result of the application of the AHP on pairwise comparisons of the factors by SMEs from the geospatial industry in North America. The difference in ranks might have various reasons, such as (a) the literature covering a much broader range of industries and geographies, (b) many of the publications did not contain a relative priority among the factors, and (c) some of the publications are based on survey results before the economic downturn in 2007-2009.

To maintain focus on the research questions and working hypotheses and to reduce complexity, I chose only to compare ranks instead of relative priorities. The emphasis on the highest-ranking factors in the current follow-up survey indicates a performance oriented *arm's-length* relationship, as none of these highest-ranking ten factors requires further integration of the buyer with the vendor. Communication and relationship related factors, which might show emphasis of the vendor on integration and concern for a partnership, only rank 13 and lower. Exclusion of the factors *size of vendor business/financial stability and position*, *currency stability/economical risk*, and *geographical distance* already in the pilot study, might be a further indicator for the

limited concern of the managers at the buyer companies for integration. Especially the exclusion of the factor *R/D advantage* already in the pilot study, a factor that during the literature review ranked fourth, supports the view that managers from geospatial buyer companies in the US and Canada have little interest in a closer collaboration. This possible preference for an arms-length relationship further might indicate less desire for integration and might, at least partially, explain the relatively low ranking of knowledge exchange and reciprocal arrangements.

Table 26

Comparison of Factor Ranks from Survey and From Literature Review

Factor	*Survey*	*Literature*
Product quality	1	7
Consistency of quality over time	2	6
Low initial price	3	3
Reputation and positive track-record	4	14
Use of new technologies and future capabilities	5	24
Short setup time/flexibility in schedules	6	27
Timeliness and quality of reporting/responsiveness	7	18
Timeliness of delivery/lead time	8	9
International quality certifications	9	19
Technical and managerial competence of project managers	10	32
Product volume changes and peakload capacity	11	1
Technical specialization and educational level of staff	12	2
Compatibility of technical platforms	13	21
Reputation for integrity	14	23
Relationship closeness and feeling of trust	15	5
Communication openness	16	15
Sufficient and quality management resources	17	25
Compatibility among levels and functions	18	13
Present technological capacity	19	10
Knowledge exchange and reciprocal arrangements	20	30
Existing communication and online systems	21	16
Common language	22	22
Management attitude and compatibility	23	8
Conflict resolution mechanisms	24	31
Strategic fit of businesses	25	28
Legal stability/protection of intellectual property/political risk	26	29
R&D advantage[a]		4
Compliance with sectorial price behavior and with cost analysis of the buyer[a]		11
Size of vendor business/financial stability and position[a]		12
Environmental and social sensitivity[a]		17
Currency stability/economical risk[a]		20
Geographical distance[a]		26

[a]factor excluded after pilot survey

SQ1: What are the top five critical factors in the vendor selection for an offshore-outsourcing relationship in the geospatial industry?/ WH1: US/Canadian business leaders decide to establish an offshore-relationship for data processing based on a process evaluating multiple criteria; thus, a multicriteria decision problem exists. All SMEs participating in the study confirmed the usefulness of the research and could relate to the existence of a list of factors that affect their decision making. Business leaders in the North American geospatial industry take outsourcing decisions based on a process evaluating multiple criteria, and thus a multicriteria decision problem exists, which supports WH1. Answering SQ1, the top five critical factors are (a) product quality, (b) consistency of quality over time, (c) low initial price, (d) reputation and positive track record, and (e) use of new technologies and future capabilities. The accumulated weight of the top ranking five factors is 54.51%, which means that a buyer would normally prefer the provider scoring highest on all of these factors to all other providers.

SQ2: How do social responsibility-related factors rank when compared to delivery, quality, and cost-related factors? / WH2: Decision makers give social responsibility related criteria a measurable weight in the decision process. With reference to SQ2, the answer results already from the pilot study. The SMEs considered social responsibility-related factors as irrelevant, which indicates that these factors would attain a weight of less than 0.73%, which is below the lowest scoring factor. Some authors postulate that social responsibility has major importance for vendor selection in other industries (Kanagaraj, Ponnambalam, & Jawahar, 2014; Kumar, Palaniappan,

Kannan, & Shankar, 2014; Xu, Kumar, Shankar, Kannan, & Chen, 2013); however, the results of the present study indicate that WH2 is not valid for the chosen geographic location and population.

SQ3: How do cost-related factors rank compared to any other factor? / WH3: Low cost alone is not the most influential decision criterion in the vendor selection. The only cost-related factor was low initial price, with a relative priority of 10.28% the third highest-ranking factor. Thus, cost-related factors remain very important compared to other factors, but do not score highest. The comparison of ranks from literature and the survey in Table 26 shows an unchanged rank for low initial price. Already during the pilot-study, a majority of SMEs voted for exclusion of the factor compliance with sectorial price behavior and with cost analysis of the buyer. This exclusion indicates that evaluators appreciate low initial offers as important factor in the vendor selection, but do not tend to apply further cost-related analysis. WH3 apparently remains valid, as low cost alone is not the most influential decision criterion in the vendor selection. Recent research by Y.-H. Chen, Wang, and Wu (2011), and Low and Chen (2012) confirmed the trend also for other industries. Sonmez and Moorhouse (2010) applied factor analysis for determination of vendor selection criteria for outsourcing of professional services and came to the conclusion that cost ranked lowest among 36 factors.

SQ4: How large is the variance of the aggregated factor weights? / WH4: The aggregated weights for all factors derived from pairwise comparisons by the SMEs have a low variance. SQ4 relates to the uniformity of the answers across evaluators. All evaluations should be reliable, which the low consistency ratio confirms; however, this

does not relate to uniformity. All evaluations originated from an expert panel and all experts received the same weight; thus, weight of all evaluations was equal and the aggregated global priorities form the unweighted arithmetic mean from evaluations by 15 SMEs. Due to the low *n*, statistical tests for determination of similarity to a normal distribution, like Kolmogorov-Smirnov with Lilliefors significance correction or Shapiro-Wilk would not deliver meaningful results. However, the observed standard deviations of the arithmetic mean indicate for some factors high consensus, as for low initial price, and for others low consensus, as for international quality certifications. López-Ortega and Rosales (2011) noted that the known aggregation methods AIP and AIJ do not provide specific measures for the degree of agreement among the decision makers. S.-W. Lin and Lu (2012) proposed the use of the Sammons map for a visual interpretation of dispersion and expanded the solution with a regression based on a linear mixed model. However, S.-W. Lin and Lu (2012) also concluded that their method had limitations due to the assumption of a specific distribution of errors, and, more important, noted that the methods also did not provide an indication for a specific cut-off point when the results indicated unacceptable disagreement.

Conclusion

Numeric results in Table 25 and in the visualization in Appendix I and L show that the four highest-ranking factors receive much more weight than the following 22. The visual interpretation gives the impression that there are three main groups of evaluation parameters:

- "Must-have" or primary factors, which are the five highest ranking factors determining more than 50% of the evaluation outcome.
- "Help-to-win" or secondary factors with individual weights between 2.5 and 5%, which somehow have an influence on the total score and could collectively substitute one or two of the primary factors.
- "Decorative" or tertiary factors, which practically do not affect the decision.

However, within these groups, there does not seem a clear agreement on the actual sequence of importance. As the number of contributing SMEs was relatively small, the only option to reach further clarity would be the execution of a survey with a larger sample.

Applications to Professional Practice

In the present study, I conducted two surveys with SMEs in the North-American geospatial industry to identify all the relevant factors for the evaluation of an offshore outsourcing partner and to determine the relative priority of the factor weights. While there is an agreement on a certain set of factors, the results of the study indicate only coarsely the relative priorities in the decision process. The uncertainty may have different reasons such as the use of separate factor lists by project type or size, extreme past experience with specific offshore relationships, or orientation on products with different degree of complexity. However, by virtue of the simple application in the multiplicative AHP model, managers can use the parameters to examine past decisions and pre-select new partners. MCDM models do not necessarily fit all specific decision

problems, but represent an option to orientate the decision maker based on a scientific methodology, aggregating general knowledge in a structured way.

Specifically, procurement managers in the North American geospatial industry would be able to apply the model to increase the consistency and transparency of the selection process, which would accelerate decisions. The weighted factor list could evolve into a fundamental training document for knowledge management and decision documentation to enable responsible managers to improve their decisions for establishing professional partnerships. Furthermore, managers could reexamine and reevaluate existing provider relationships or adjust the weighted factor list to specific product lines or projects. The distinction of the "*must-have*", "*help-to-win*", and "*decorative"* factors additionally provides managers in offshore outsourcing service provider companies with a guidance for reviewing their business practices, and could help the vendors to be more competitive in the market.

Implications for Social Change

The findings from this study indicated that the application of AHP renders a useful and robust methodology for ranking a set of key geospatial vendor selection criteria. In turn, the research renders a significant potential for social change. Consequent application of the AHP-based process would increase professionalism and transparency in the vendor selection process. In addition, vendor selection decisions would be improved and increase the stability of business relationships with concomitant level and/or increases in employment and predictable budgets. Next, the reduced risk for geospatial companies would positively affect the ability of the managers to stabilize the

number of employees and increase profits. Furthermore, managers in North America who apply the structured approach would potentially increase the effectiveness of their decision procedures and traceability of decisions, by documenting the processes. In addition, managers in vendor companies would gain the ability to train their staff to increase staff efficiency and effectiveness in the required fields and improve their level of education. Lastly, consumers might benefit through derivative increased product quality and reduced and stable prices.

Recommendations for Action

To the readers of this study and specifically those involved in geospatial vendor procurement processes, the recommendation is to verify the mapping of their procurement processes and to identify the right person and time for application of the formal evaluation in their vendor selection processes. The implementation of a structured vendor selection process and the clear definition of the relevant parameters for their own company are both crucial. I suggest defining a limited number of use-cases, for major projects or product types, and then assessing the weight of the evaluation factors by applying the structured AHP-process. Second, it is important to agree on the methodology and unit of measurement for the different factors to be considered for ranking by AHP as some factors may have a base in quantitative data (low initial price) while others might require rather a qualitative pairwise comparison among the vendors (reputation and positive track-record). Once the team has agreed on decisive factors and their relative weights, the procurement managers would be able to complete the vendor evaluation Excel sheet, which I will distribute to all SMEs invited for the survey as part

of the publication of this study. In this Excel sheet, the managers would either accept the relative weights for factors from this study, or overwrite with their own estimates. Vendors would receive in this Excel spreadsheet a score on any of the factors and calculation would result in a comprehensive report on the ranking, including a sensitivity analysis. Both results would support the procurement manager in the final decision for establishing an offshore relationship. The same process is valid for evaluation of already existing relationships. I would apply the results of this study in my own company. Furthermore, the research should serve as a motivation and content for presentation at major geospatial conferences and the ISAHP, a conference dedicated to decision making with the analytic hierarchy process.

Recommendations for Further Study

The results presented in this study stem from the survey of an expert panel in the North American geospatial industry. Although surveys of expert opinions do not require statistical analysis, results indicated that the level of agreement on the factor weights varied considerably across the expert participants. There might be many reasons for this disagreement, such as (a) company size, (b) type and complexity of projects, (c) recent extreme experience with specific vendors, or (d) personal relationship to specific vendors. In addition, the depth and breadth of experience with the topic might have affected the answers. Tsyganok, Kadenko, and Andriichuk (2012) conducted a modeling study to simulate different statistical distributions of expert responses in AHP and discovered, that differences in expertise is not negligible in groups of 50 or fewer experts. Future studies with less than 50 experts might include a more detailed data collection on

control parameters, like specific expertise of the SME, which would then allow the researcher to visualize potentially existing correlations among evaluation results and the control parameters.

Second, there is considerable discussion about the determination and interpretation of dispersion in the results. The question, if experts agree and if it is possible to develop threshold values for disagreement, would provide a wide and open field to research. Third, as requirements for geodata change with available user technology, and interconnectedness between vendors and buyers increases, the factors themselves or their relative weights may change. Consequently, a further recommendation is to repeat the same study periodically. Fourth, the same type of study provides the possibility for future research in other geographies like Europe. Finally, application of other MCDM methods like MAUT, Delphi study, DEA, or hybrid methods on the same topic might provide additional insights into the relative importance of factors.

Reflections

This study had its genesis in my professional field. As a leader of a European owned offshore outsourcing company for geospatial data services in India, there was an intimate connection with my business life. The missing transparency on the side of North American managers in the selection process for an outsourcing partner considerably influenced my decision for the topic of the study. Furthermore, as a manager I had also been responsible for finding other outsourcing providers from the perspective of a Danish geospatial company. As the decisions depended largely on the implicit knowledge of the

responsible procurement managers, a solution in the field of decision sciences seemed a desirable solution. The AHP process offered important characteristics as (a) traceability of the decision, (b) robust mathematical algorithms, (c) possibility to quantify inherently qualitative criteria, and (c) the option to involve multiple stakeholders in the determination of factors and relative weights. The nature and design of the study allowed all SMEs to participate in determining the important factors and to vote objectively without interference by me, and thereby being independent of my personal possible biases. However, the design of the AHP hierarchy remains amenable for improvement, as its structure influences the calculation of relative weights. Designing and implementing the study gave me the opportunity to expand my knowledge in the field of structured decision methodologies in the complex field of MCDM. Consequently, my perspective on structuring decision processes has changed, and, in the future, this knowledge should allow me to choose among a large tool-set for most situations in my business.

Summary and Study Conclusions

The present study followed a quantitative descriptive methodology to determine relevant decision factors and their relative weights in the offshore outsourcing partnership decisions of procurement managers in the North American geospatial industry. During this study I (a) extracted relevant decision factors for outsourcing from a systematic literature review, (b) presented the factors in a pilot survey to SMEs in the industry to vote for relative importance, and after a follow-up survey (c) applied the AHP to the pairwise comparison of the factors to estimate their relative weights for the decision

process. While the resulting list of 26 decision factors seems generally accepted among the SMEs in the industry, there appears to be no clear agreement on the factors' sequence and relative importance. Low initial price is not the highest-ranking factor, but is among the top *must-have* five factors, which with an aggregated weight of more than 50% would primarily influence the partnership decisions. Only seven more *nice-to-have* factors seem to have partial influence, and the remaining *decorative* 14 factors contribute only in a negligible manner. Social and environmental conscious behavior of the vendor has no apparent relevance. The results from this study and the structured approach, offer valuable and readily applicable tools for managers making outsourcing partnership decisions.

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Appendix A: Factors for Vendor Selection from the Literature

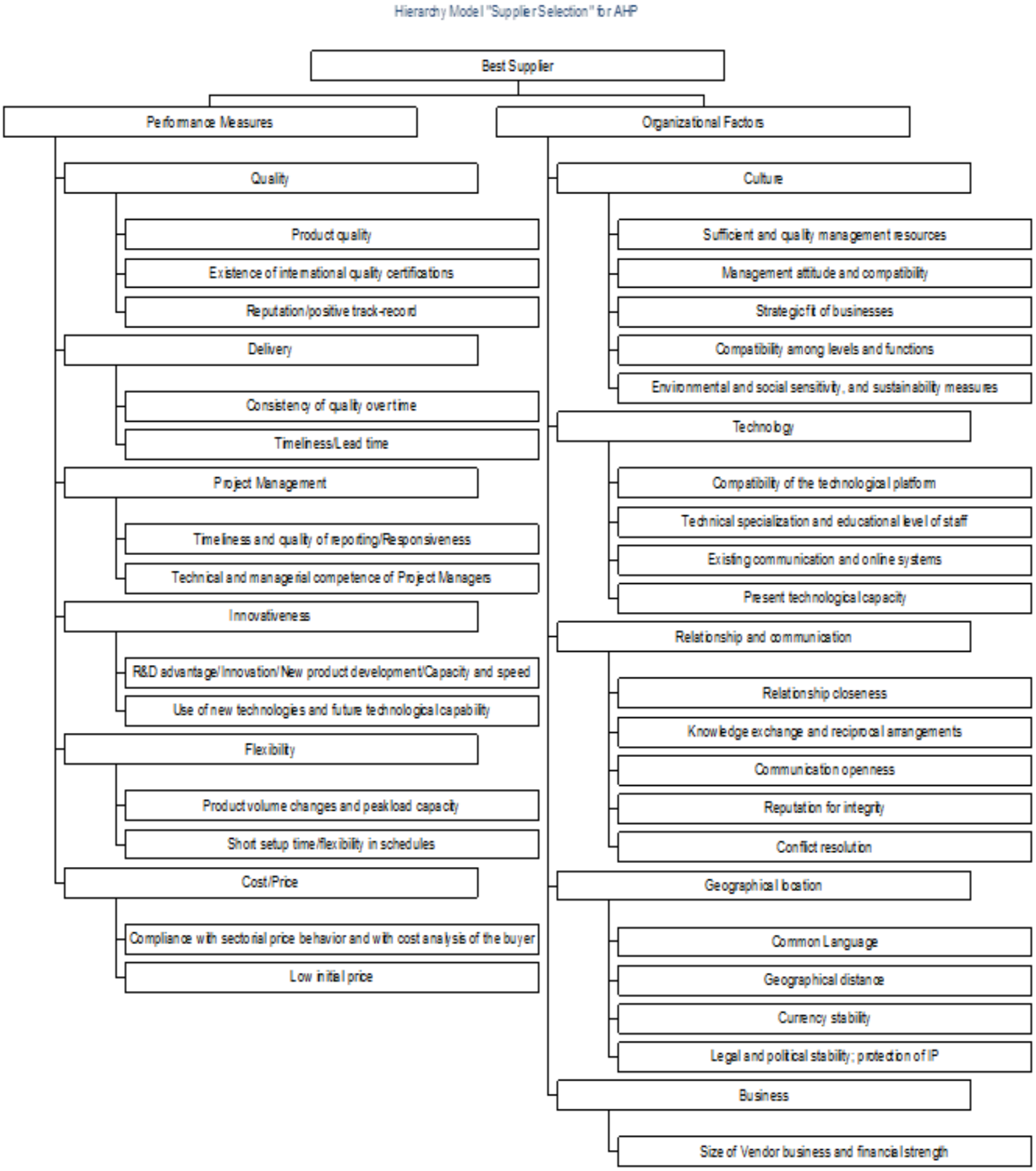
	Quality			Delivery		Project Management		Innovativeness		Flexibility		Cost		Culture					Technology				Relationship					location				Business
	Compliance with agreed product quality/performance on pilot	Existence of international quality certifications	Track record of successful projects/Reputation/Performance history	Consistent quality	Timeliness of delivery/Lead time	Timeliness and quality of reporting/Responsiveness	Technical and managerial competence of Project Managers	R&D advantage/Innovation/New product development/Capacity and speed	Use of new technologies	Product volume changes and peak/load capacity, access to skilled resources	Short setup time/flexibility in schedules	Compliance with sectorial price behavior and with cost analysis of the vendor	Low initial price	Sufficient and quality management resources	management attitude and compatibility, professionalism and amount of supervision required, contract management	Strategic fit of businesses	Compatibility among levels and functions: organizational structure and personnel	Environmental and social sensitivity, and sustainability measures; Environmental responsibility & Environmental management systems, certification of ISO 14000	Compatibility of technical platforms	Technical specialization and educational level	Online systems (reporting, payment)	Access to capital equipment/advanced production facilities/power backup	Reputation for integrity	Conflict resolution	Relationship closeness and feeling of trust, long-term relationship	Knowledge exchange and reciprocal arrangements	Communication openness; ability to establish personal relationships; time of relationship establishment	common language	Geographical distance	currency stability/economical risk	legal stability/protection of intellectual property/political risk	size of vendor business/financial stability and position
Scores	*13*	*6*	*6*	*12*	*11*	*6*	*1*	*13*	*5*	*15*	*7*	*16*	*14*	*3*	*12*	*7*	*9*	*7*	*4*	*14*	*7*	*11*	*4*	*7*	*13*	*7*	*6*	*4*	*3*	*5*	*7*	*5*
Journals																																
Aksoy, A., & Öztürk, N. (2011). Supplier selection and performance evaluation in just-in-time production environments. *Expert Systems with Applications* , *38* (5), 6351–6359. doi:10.1016/j.eswa.2010.11.104	1			1	1								1																1			
Alvandi, M., & Fazli, S. (2011). E-Supplier Selection using Delphi, Fuzzy AHP and SIR. *European Journal of Scientific Research* , *66* (4), 491–509. Retrieved from http://www.europeanjournalofscientificresearch.com/ISSUES/EJSR_66_4_02.pdf	1		1	1	1	1				2	1		1								2	1	1		1		1					
Bai, C., & Sarkis, J. (2010). Integrating sustainability into supplier selection with grey system and rough set methodologies. *International Journal of Production Economics* , *124* (1), 252–264.	1	1		1	1	1		3	2	3	1	2	2	1	2	1	2		1	3	1	2	1	1	3		2					
Büyüközkan, G., & Çifçi, G. (2011). A novel fuzzy multi-criteria decision framework for sustainable supplier selection with incomplete information. *Computers in Industry* , *62* (2), 164–174. doi:10.1016/j.compind.2010.10.009	1	1		1	1	1		1				1					1	3		1					2				1			1
Calvi, R., Le Dain, M. A., Fendt, T. C., & Herrmann, C. J. (2010). Supplier selection for strategic supplier development. *Industrial Engineering* . Retrieved from http://hal.archives-ouvertes.fr/halshs-	1			1	1			1	1	1			1	1	2		1			1		1				1						
Chang, S.-I., Yen, D. C., Ng, C. S.-P., & Chang, W.-T. (2012). An Analysis of IT/IS Outsourcing Provider Selection for Small- and Medium-sized Enterprises in Taiwan. *Information & Management* . doi:10.1016/j.im.2012.03.001	1	1	1	1				1		2				1			1		1	1		1	1	1			1			2			
Cheraghi, S., & Dadashzadeh, M. (2011). Critical success factors for supplier selection: an update. *Journal of Applied Business Research* , *28* (2), 91-108. Retrieved from http://www.journals.cluteonline.com/index.php/JABR/article/view/2209 - Systematic Literature review	2	1	1	1	1			2		2			1		2		2	1		1	1	1	1		2	1			1				1
Cheraghi, S., & Dadashzadeh, M. (2011). Critical success factors for supplier selection: an update. *Journal of Applied Business Research* , *28* (2), 91-108. Retrieved from http://www.journals.cluteonline.com/index.php/JABR/article/view/2209 - Internet Survey	1	1	1		1								1					1	1	1					2		1					2
DeHondt II, G. R., & Leidig, P. M. (2010). The Impact of Transition Costs on Offshore Systems Development. *Journal of Information Systems Applied Research* , *3* (1), 1-11. Retrieved from http://jisar.org/3/1/JISAR.3(1).DeHondt.pdf												2	1																				

(table continues)

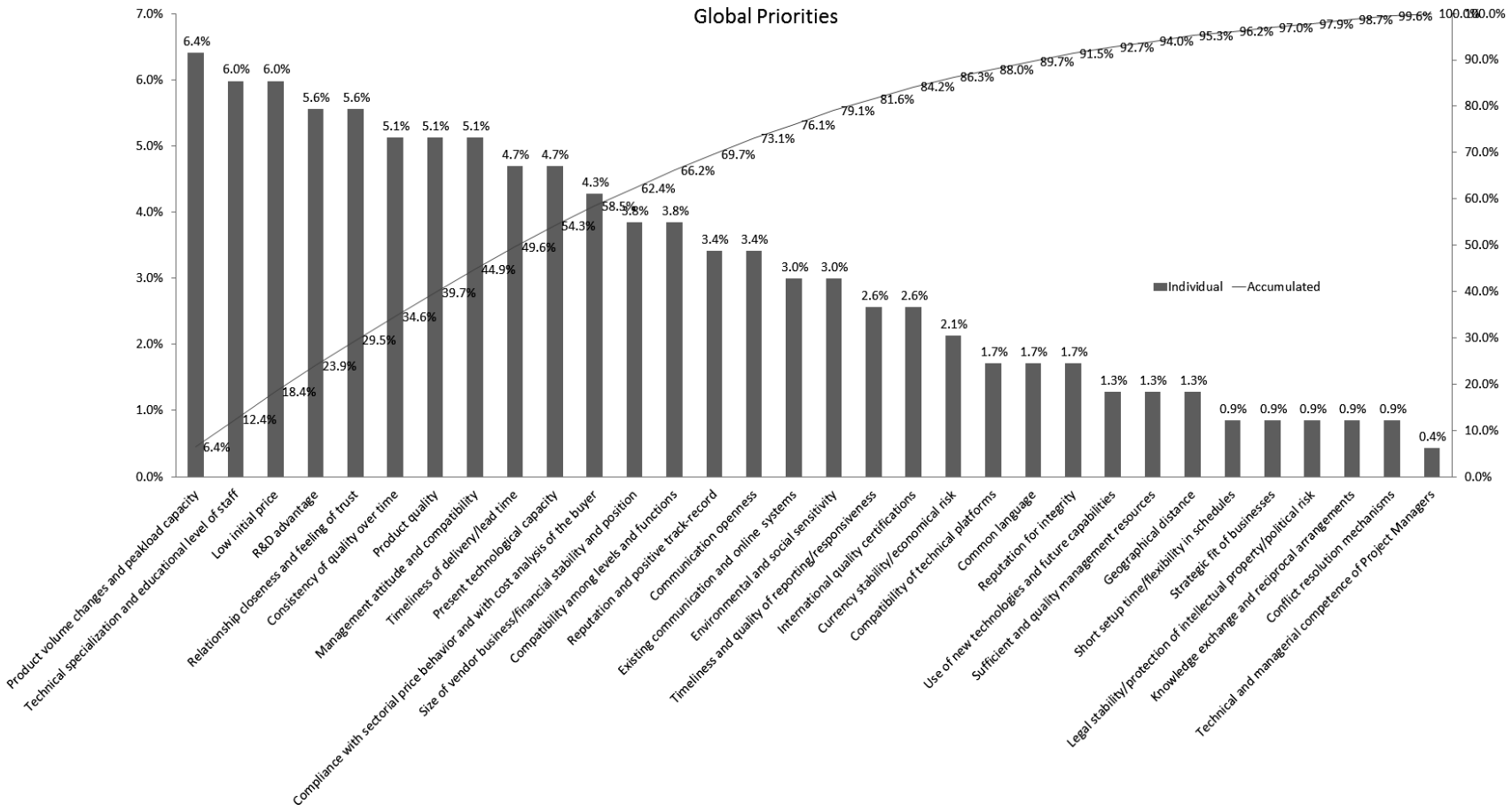
	Quality			Delivery		Project Management		Innovativeness		Flexibility		Cost		Culture					Technology				Relationship					location				Business
	Compliance with agreed product quality/performance on pilot	Existence of international quality certifications	Track record of successful projects/Reputation/Performance history	Consistent quality	Timeliness of delivery/Lead time	Timeliness and quality of reporting/Responsiveness	Technical and managerial competence of Project Managers	R&D advantage/Innovation/New product development/Capacity and speed	Use of new technologies	Product volume changes and peakload capacity; access to skilled resources	Short setup time/flexibility in schedules	Compliance with sectorial price behavior and with cost analysis of the vendor	Low initial price	Sufficient and quality management resources	management attitude and compatibility; professionalism and amount of supervision required; contract management	Strategic fit of businesses	Compatibility among levels and functions; organizational structure and personnel	Environmental and social sensitivity and sustainability measures: Environmental responsibility & Environmental management systems: certification of ISO 14000	Compatibility of technical platforms	Technical specialization and educational level	Online systems (reporting, payment)	Access to capital equipment/advanced production facilities/power backup	Reputation for integrity	Conflict resolution	Relationship closeness and feeling of trust; long-term relationship	Knowledge exchange and reciprocal arrangements	Communication openness; ability to establish personal relationships; time of relationship establishment	common language	Geographical distance	currency stability/economical risk	legal stability/protection of intellectual property/political risk	size of vendor business/financial stability and position
Scores	*13*	*6*	*6*	*12*	*11*	*6*	*1*	*13*	*3*	*15*	*2*	*16*	*14*	*3*	*12*	*2*	*5*	*7*	*4*	*14*	*7*	*11*	*4*	*2*	*13*	*2*	*8*	*4*	*3*	*5*	*2*	*5*
Journals																																
Doh, J. P., Bungaratavej, K., & Hahn, E. D. (2009). Separable but not equal: The location determinants of discrete services offshoring activities. *Journal of International Business Studies* , *41* (6), 926-943. doi:10.1057/jibs.2008.89												2	1							1								1	1			1
Hätönen, J., & Eriksson, T. (2009). 30+ years of research and practice of outsourcing – Exploring the past and anticipating the future. *Journal of International Management* , *15* (2), 142-155. Elsevier Inc. doi:10.1016/j.intman.2008.07.002								1		1										1												
Ho, W., Xu, X., & Dey, P. K. (2010). Multi-criteria decision making approaches for supplier evaluation and selection: A literature review. *European Journal of Operational Research* , *202* (1), 16–24. doi:10.1016/j.ejor.2009.05.009	1		1	1				1					1		2			2	1	1		1					1					1
Khan, S. U., Niazi, M., & Ahmad, R. (2011). Factors influencing clients in the selection of offshore software outsourcing vendors: An exploratory study using a systematic literature review. *Journal of Systems and Software* , *84* (4), 686–699. doi:10.1016/j.jss.2010.12.010	1	1	1	1	1	1	1			1			1		1		1				1	2			1	1	1	1			1	2
Khan, S. U., Niazi, M., & Ahmad, R. (2011). Factors influencing clients in the selection of offshore software outsourcing vendors: An exploratory study using a systematic literature review. *Journal of Systems and Software* , *84* (4), 686-693. Elsevier Inc.			1												2		1															
Kumar, J., & Roy, N. (2011). Analytic Hierarchy Process (AHP) for a Power Transmission Industry to Vendor Selection Decisions. *International Journal of Computer Applications* , *15* (11), 26–30.				1	1								1												1							
Liu, L. B., Berger, P., Zeng, A., & Gerstenfeld, A. (2008). Applying the analytic hierarchy process to the offshore outsourcing location decision. *Supply Chain Management: An International Journal* , *13* (6), 435–449. doi:10.1108/13598540810905697			1							1		1			1					2	1	1						2		2	1	
Mondello, C., Hepner, G., & Medina, R. (2008). ASPRS Ten-Year Remote Sensing Industry Forecast Phase V. *Photogrammetric Engineering & Remote Sensing* , 1297-1305. Retrieved from http://www.asprs.org/a/publications/pers/2008journal/november/highlight2.pdf												2	1																			
Ravindran, A. R., Ufuk Bilsel, R., Wadhwa, V., & Yang, T. (2010). Risk adjusted multicriteria supplier selection models with applications. *International Journal of Production Research* , *48* (2), 405–424. doi:10.1080/00207540903174940	1			1	1	1		2		1			1			1						1										1
Schoenherr, T., Rao Tummala, V., & Harrison, T. P. (2008). Assessing supply chain risks with the analytic hierarchy process: Providing decision support for the offshoring decision by a US manufacturing company. *Journal of Purchasing and Supply Management* , *14* (2), 100–111. Elsevier. Retrieved from http://www.sciencedirect.com/science/article/pii/S1478409208000091										1												1										
Yan, L., & Dehai, Z. (2011). The Study on Sub-sectors of Small and Medium-sized Enterprises Engaging in Service Outsourcing in Heilongjiang. *ASSE* , 889-893.								1												1												

Note: The numbers indicate the frequency of mention of the factors. Numbers higher than one indicate an amalgamation of various factors due to similarity. If the table is not readable, then please ask the author for a digital copy.

Appendix B: Initial AHP-Tree from Literature Review



Appendix C: Presentation of Global Priorities from Scores in Appendix A for the Factors



Note: If the details are not readable, then please ask the author for a digital copy.

Appendix D: Excel Spreadsheet for the Follow-up Survey Pairwise Comparison of the Factors

Dear Survey Participant!

First of all ***"Thank You!"*** *that you have chosen to support my studies with your participation in this survey. The geospatial community is small and you are one of the few experts in the US and Canadian area.*
Offshore outsourcing has been common in the last years and I am investigating in my Doctoral Stduy the relevance of specific parameters for chosing an offshore vendor.
I will ask you to rate your degree of preference in the ***Offshore Vendor Selection*** *of one deciding factor over another. That process is called "pairwise comparison" and is the base for the "Analytic Hierarchy Process".*

During the pairwise comparison, you will express your degree of preference on a rating scale according to the following scheme (see also the ***"EXAMPLE"****- sheet)*
On the scale you mark your preference moving the marker on the scrollbar to your degree of preference.
This means that if you feel that factor (A) is demonstrably MORE important than factor (B), you will move the marker to the "-6" on the left side.
If you feel that factor (A) is demonstrably LESS important than factor (B), you will mark the "7" on the RIGHT side of the "0".
If you feel that factor (A) and (B) are equally important, you mark the "0".

The preference will be visually clear. The closer the mark is to the LEFT, the higher is your preference of (A) over (B), the closer it is to the RIGHT, the higher is your preference of (B) over (A).
Please take your time and have a second look on all answers, to avoid possible inconsistencies you might have overlooked.

Thank you for your attendance and attention!

I will maintain anonymity for the survey, but I would need for statistical reasons the country of your company.

Your headquarters are in (please mark with a cross (X))

Canada	
US	

Please continue to the ***EXAMPLE.***

Figure D1. Introduction and general questions.

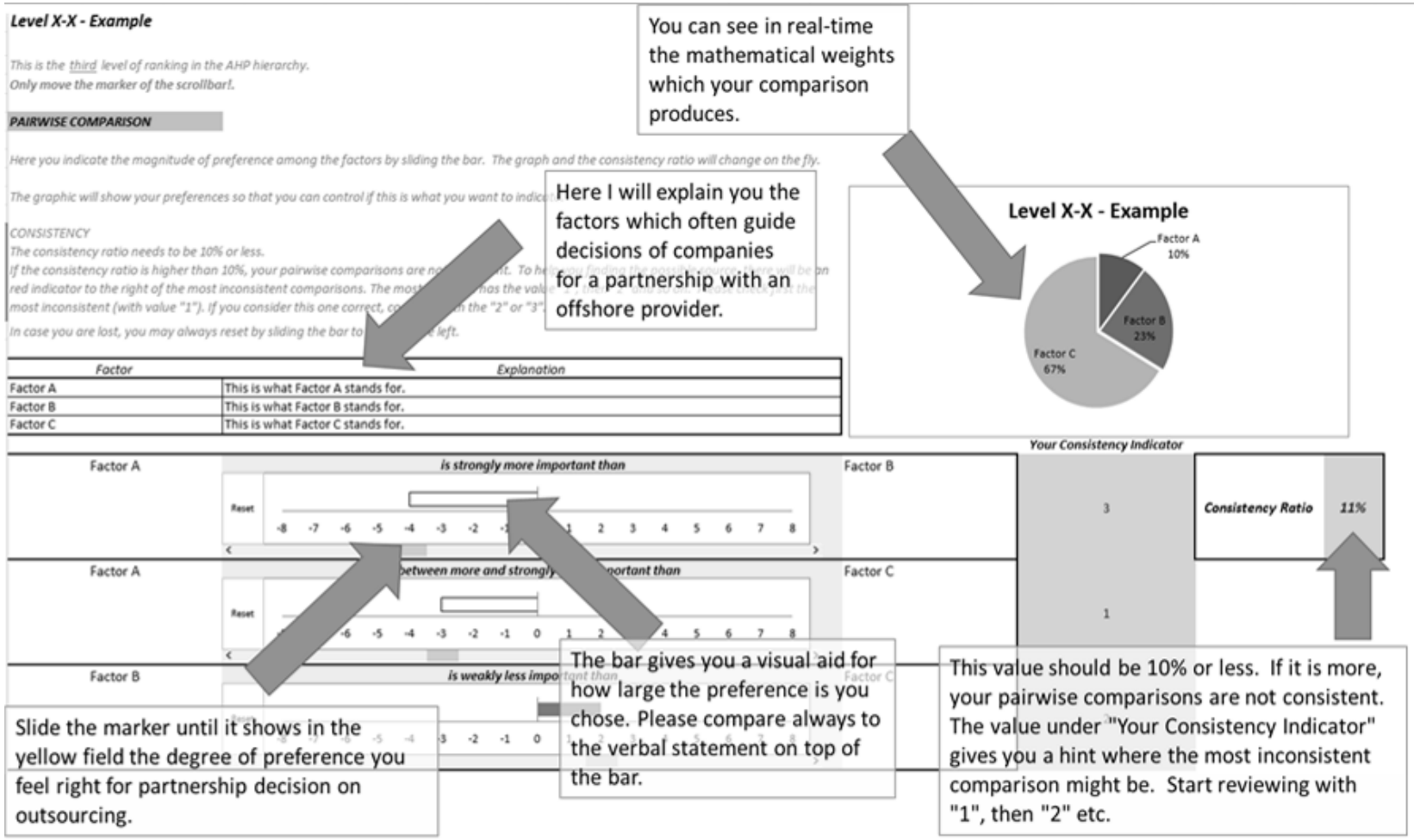


Figure D2. Example with comments as guidance for the survey participant.

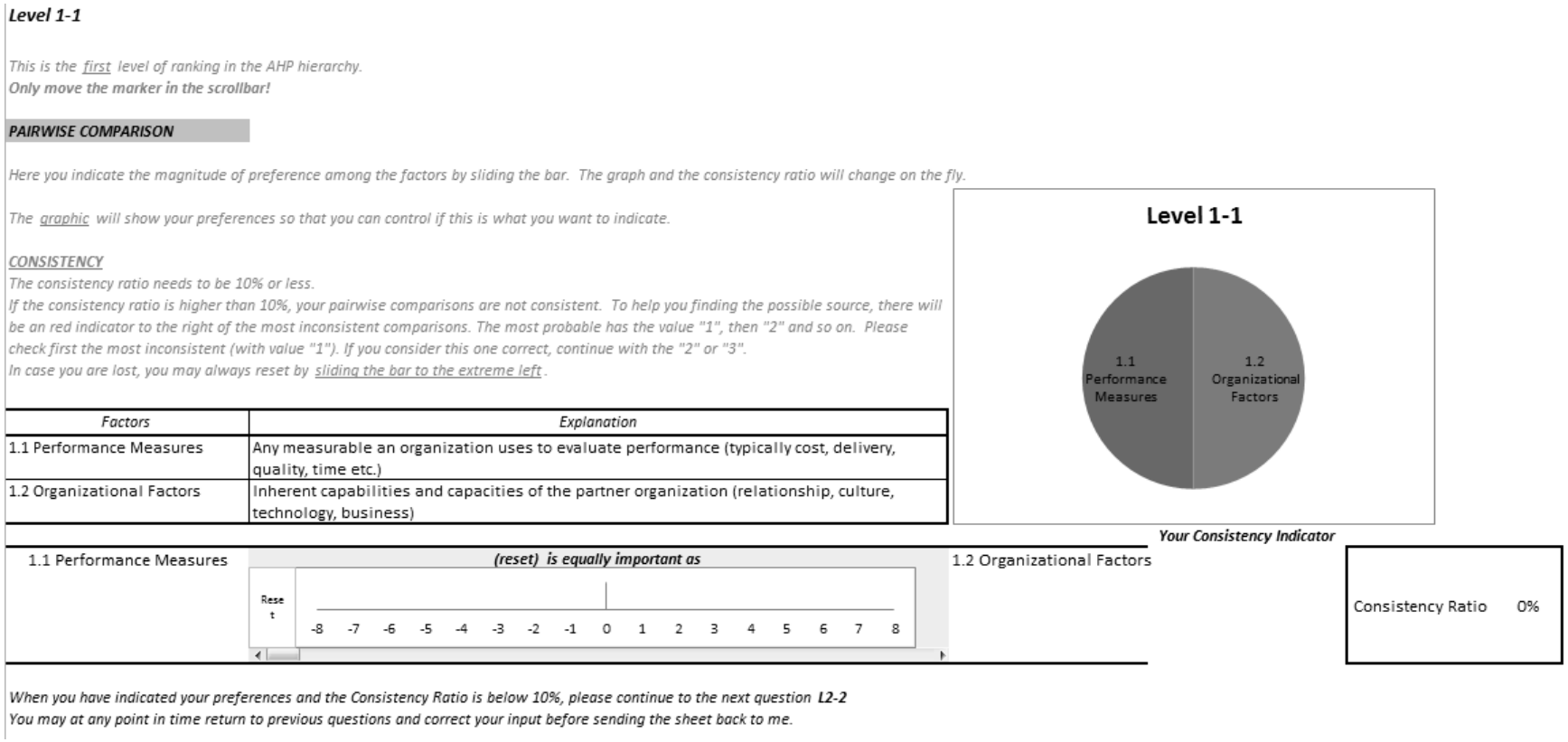


Figure D3. Pairwise comparison second level of factors.

Level 2-2 - Performance Measures

This is the second level of ranking in the AHP hierarchy.
Only move the marker in the scrollbar!

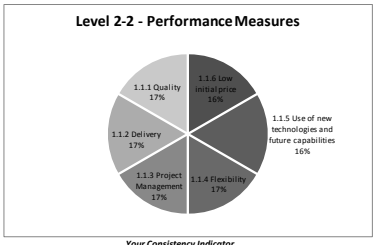
PAIRWISE COMPARISON

Here you indicate the magnitude of preference among the factors by sliding the bar. The graph and the consistency ratio will change on the fly.

The graphic will show your preferences so that you can control if this is what you want to indicate.

CONSISTENCY
The consistency ratio needs to be 10% or less.
If the consistency ratio is higher than 10%, your pairwise comparisons are not consistent. To help you finding the possible source, there will be an red indicator to the right of the most inconsistent comparisons. The most probable has the value "1", then "2" and so on. Please check first the most inconsistent (with value "1"). If you consider this one correct, continue with the "2" or "3".
In case you are lost, you may always reset by sliding the bar to the extreme left.

Factor	*Explanation*
1.1.1 Quality	The vendor has a focus on quality and can prove it. Procedural and measurable quality. Product quality, positive track-record, international quality certificates like ISO 9001
1.1.2 Delivery	The vendor has a focus on timeliness/Lead time and constency of quality over time.
1.1.3 Project Management	The vendor emphasizes on quality of the project management. Responsiveness and qualification of PMs.
1.1.4 Flexibility	The vendor has a high peakload capacity and shows flexibility in schedules.
1.1.5 Use of new technologies and future capabilities	The vendor focusses on development and use of modern technology/software.
1.1.6 Low initial price	The vendor offers a low initial price



Your Consistency Indicator

1.1.1 Quality	*(reset) is equally important as*	1.1.2 Delivery
1.1.1 Quality	*(reset) is equally important as*	1.1.3 Project Management
1.1.1 Quality	*(reset) is equally important as*	1.1.4 Flexibility
1.1.1 Quality	*(reset) is equally important as*	1.1.5 Use of new technologies and future capabilities
1.1.1 Quality	*(reset) is equally important as*	1.1.6 Low initial price
1.1.2 Delivery	*(reset) is equally important as*	1.1.3 Project Management
1.1.2 Delivery	*(reset) is equally important as*	1.1.4 Flexibility
1.1.2 Delivery	*(reset) is equally important as*	1.1.5 Use of new technologies and future capabilities
1.1.2 Delivery	*(reset) is equally important as*	1.1.6 Low initial price
1.1.3 Project Management	*(reset) is equally important as*	1.1.4 Flexibility
1.1.3 Project Management	*(reset) is equally important as*	1.1.5 Use of new technologies and future capabilities
1.1.3 Project Management	*(reset) is equally important as*	1.1.6 Low initial price
1.1.4 Flexibility	*(reset) is equally important as*	1.1.5 Use of new technologies and future capabilities
1.1.4 Flexibility	*(reset) is equally important as*	1.1.6 Low initial price
1.1.5 Use of new technologies and future capabilities	*(reset) is equally important as*	1.1.6 Low initial price

Reset

-8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8

Consistency Ratio 0%

When you have indicated your preferences and the Consistency Ratio is below 10%, please continue to the next question ***L3-3***
You may at any point in time return to previous questions and correct your input before sending the sheet back to me.

Figure D4. Ranking and pairwise comparison Level 3 - performance measures.

Level 3-3 - Performance Measures>Quality

This is the third level of ranking in the AHP hierarchy.
Only move the marker in the scrollbar!

PAIRWISE COMPARISON

Here you indicate the magnitude of preference among the factors by sliding the bar. The graph and the consistency ratio will change on the fly.

The graphic will show your preferences so that you can control if this is what you want to indicate.

CONSISTENCY
The consistency ratio needs to be 10% or less.
If the consistency ratio is higher than 10%, your pairwise comparisons are not consistent. To help you finding the possible source, there will be an red indicator to the right of the most inconsistent comparisons. The most probable has the value "1", then "2" and so on. Please check first the most inconsistent (with value "1"). If you consider this one correct, continue with the "2" or "3".
In case you are lost, you may always reset by sliding the bar to the extreme left.

Factor	*Explanation*
Product quality	The vendor offers a focus on product quality.
International quality certifications	The vendor provides internationally accepted certifications like ISO 9001, SA 8000, ISO 14001.
Reputation and positive track-record	The vendor has a proven set of positive references in similar jobs.

Your Consistency Indicator

Product quality	***(reset) is equally important as*** Reset -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8	International quality certifications
Product quality	***(reset) is equally important as*** Reset -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8	Reputation and positive track-record
International quality certifications	***(reset) is equally important as*** Reset -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8	Reputation and positive track-record

Consistency Ratio 0%

When you have indicated your preferences and the Consistency Ratio is below 10%, please continue to the next question ***L3-4***
You may at any point in time return to previous questions and correct your input before sending the sheet back to me.

Figure D5. Ranking and pairwise comparison Level 4 - quality.

Level 3-4 - Performance Measures>Delivery

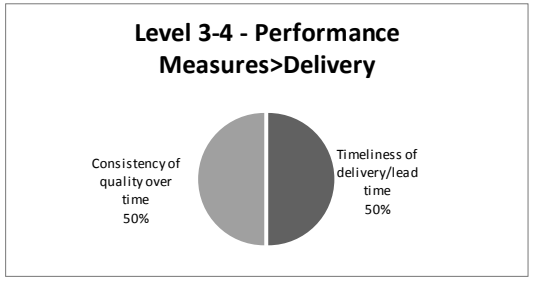
This is the third level of ranking in the AHP hierarchy.
Only move the marker in the scrollbar!

PAIRWISE COMPARISON

Here you indicate the magnitude of preference among the factors by sliding the bar. The graph and the consistency ratio will change on the fly.

The graphic will show your preferences so that you can control if this is what you want to indicate.

CONSISTENCY
The consistency ratio needs to be 10% or less.
If the consistency ratio is higher than 10%, your pairwise comparisons are not consistent. To help you finding the possible source, there will be an red indicator to the right of the most inconsistent comparisons. The most probable has the value "1", then "2" and so on. Please check first the most inconsistent (with value "1"). If you consider this one correct, continue with the "2" or "3".
In case you are lost, you may always reset by sliding the bar to the extreme left.



Factor	*Explanation*
Consistency of quality over time	The vendor is able to maintain the required level of quality over time.
Timeliness of delivery/lead time	The vendor has a reputation to deliver on the committed deadline.

Your Consistency Indicator

Consistency of quality over time	***(reset) is equally important as***	Timeliness of delivery/lead time

Reset -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8

Consistency Ratio 0%

When you have indicated your preferences and the Consistency Ratio is below 10%, please continue to the next question ***L3-5***
You may at any point in time return to previous questions and correct your input before sending the sheet back to me.

Figure D6. Pairwise comparison Level 4 - delivery.

Level 3-5 - Performance Measures>Project Management

This is the third level of ranking in the AHP hierarchy.
Only move the marker in the scrollbar!

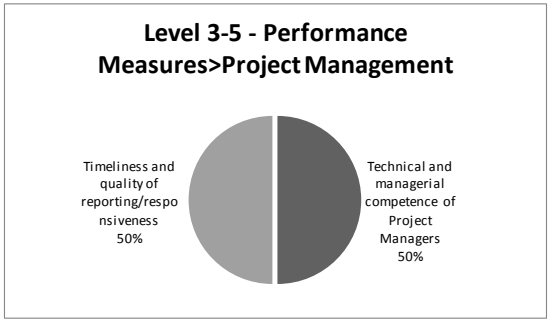
PAIRWISE COMPARISON

Here you indicate the magnitude of preference among the factors by sliding the bar. The graph and the consistency ratio will change on the fly.

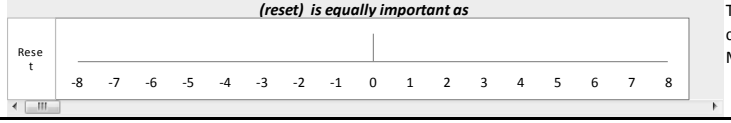
The graphic will show your preferences so that you can control if this is what you want to indicate.

CONSISTENCY
The consistency ratio needs to be 10% or less.
If the consistency ratio is higher than 10%, your pairwise comparisons are not consistent. To help you finding the possible source, there will be an red indicator to the right of the most inconsistent comparisons. The most probable has the value "1", then "2" and so on. Please check first the most inconsistent (with value "1"). If you consider this one correct, continue with the "2" or "3".
In case you are lost, you may always reset by sliding the bar to the extreme left.

Factor	*Explanation*
Timeliness and quality of reporting/responsiveness	The vendor-reports are as per agreement, complete, consistent, and in time.
Technical and managerial competence of Project Managers	The vendor's staff indicates professionalism in project management.



Timeliness and quality of reporting/responsiveness	*(reset) is equally important as*	Technical and managerial competence of Project Managers



Your Consistency Indicator

Consistency Ratio	***0%***

When you have indicated your preferences and the Consistency Ratio is below 10%, please continue to the next question ***L3-6***
You may at any point in time return to previous questions and correct your input before sending the sheet back to me.

Figure D7. Pairwise comparison Level 4 - project management.

Level 3-6 - Performance Measures>Flexibility

This is the third level of ranking in the AHP hierarchy.
Only move the marker in the scrollbar!

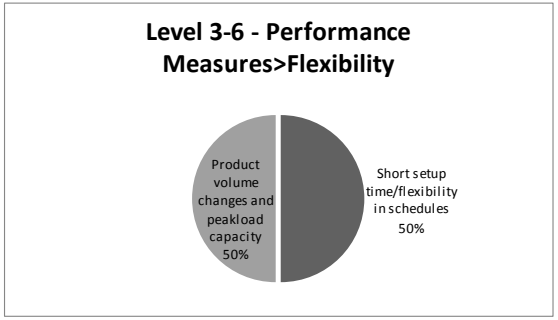
PAIRWISE COMPARISON

Here you indicate the magnitude of preference among the factors by sliding the bar. The graph and the consistency ratio will change on the fly.

The graphic will show your preferences so that you can control if this is what you want to indicate.

CONSISTENCY
The consistency ratio needs to be 10% or less.
If the consistency ratio is higher than 10%, your pairwise comparisons are not consistent. To help you finding the possible source, there will be an red indicator to the right of the most inconsistent comparisons. The most probable has the value "1", then "2" and so on. Please check first the most inconsistent (with value "1"). If you consider this one correct, continue with the "2" or "3".
In case you are lost, you may always reset by sliding the bar to the extreme left.

Factor	*Explanation*
Product volume changes and peakload capacity	The vendor has the capacity to change his productioncapacity according to your requirements up to a high maximum (peakload) capacity.
Short setup time/flexibility in schedules	The vendor is able to react fast to new project requirements and is able to change the delivery schedules.



Your Consistency Indicator

Product volume changes and peakload capacity	***(reset) is equally important as*** Reset -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8	Short setup time/flexibility in schedules

Consistency Ratio	***0%***

When you have indicated your preferences and the Consistency Ratio is below 10%, please continue to the next question ***L2-7***
You may at any point in time return to previous questions and correct your input before sending the sheet back to me.

Figure D8. Pairwise comparison Level 4 - flexibility.

Level 2-7 - Organizational Factors

This is the second level of ranking in the AHP hierarchy.
Only move the marker in the scrollbar!

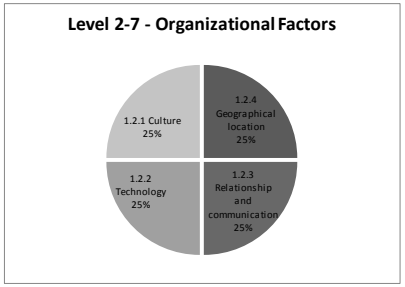
PAIRWISE COMPARISON

Here you indicate the magnitude of preference among the factors by sliding the bar. The graph and the consistency ratio will change on the fly.

The graphic will show your preferences so that you can control if this is what you want to indicate.

CONSISTENCY
The consistency ratio needs to be 10% or less.
If the consistency ratio is higher than 10%, your pairwise comparisons are not consistent. To help you finding the possible source, there will be an red indicator to the right of the most inconsistent comparisons. The most probable has the value "1", then "2" and so on. Please check first the most inconsistent (with value "1"). If you consider this one correct, continue with the "2" or "3".
In case you are lost, you may always reset by sliding the bar to the extreme left.

Factor	*Explanation*
1.2.1 Culture	The vendor business acts according to acceptable Management and cooperation standards and strategically fits my business
1.2.2 Technology	Vendor technology is compatible, on a high standard, and the vendor's staff has a good technical education
1.2.3 Relationship and communicati	Vendor's values and behavior in the relationship and communication are based on trust, honesty, and openness.
1.2.4 Geographical location	The vendor's geographical location, language, and time zone.



Your Consistency Indicator

Consistency Ratio ***0%***

1.2.1 Culture	***(reset) is equally important as*** Reset -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8	1.2.2 Technology
1.2.1 Culture	***(reset) is equally important as*** Reset -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8	1.2.3 Relationship and communication
1.2.1 Culture	***(reset) is equally important as*** Reset -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8	1.2.4 Geographical location
1.2.2 Technology	***(reset) is equally important as*** Reset -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8	1.2.3 Relationship and communication
1.2.2 Technology	***(reset) is equally important as*** Reset -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8	1.2.4 Geographical location
1.2.3 Relationship and communication	***(reset) is equally important as*** Reset -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8	1.2.4 Geographical location

When you have indicated your preferences and the Consistency Ratio is below 10%, please continue to the next question ***L3-8***
You may at any point in time return to previous questions and correct your input before sending the sheet back to me.

Figure D9. Ranking and pairwise comparison Level 3 - organizational factors.

Level 3-8 - Organizational Factors>Culture

This is the third level of ranking in the AHP hierarchy.
Only move the marker in the scrollbar!

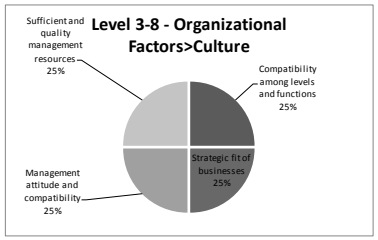
PAIRWISE COMPARISON

Here you indicate the magnitude of preference among the factors by sliding the bar. The graph and the consistency ratio will change on the fly.

The graphic will show your preferences so that you can control if this is what you want to indicate.

CONSISTENCY
The consistency ratio needs to be 10% or less.
If the consistency ratio is higher than 10%, your pairwise comparisons are not consistent. To help you finding the possible source, there will be an red indicator to the right of the most inconsistent comparisons. The most probable has the value "1", then "2" and so on. Please check first the most inconsistent (with value "1"). If you consider this one correct, continue with the "2" or "3".
In case you are lost, you may always reset by sliding the bar to the extreme left.

Factor	*Explanation*
Sufficient and quality management resources	Vendor's management behaves professionally and educated.
Management attitude and compatibility	The vendor's top- and middle management has the same values as your own management.
Strategic fit of businesses	The vendor business supports the overall strategy of your own business.
Compatibility among levels and functions	Technical levels of your and the vendor's company are able to collaborate conflict free and in mutual understanding.



Your Consistency Indicator

Sufficient and quality management resources	***(reset) is equally important as***	Management attitude and compatibility
Sufficient and quality management resources	***(reset) is equally important as***	Strategic fit of businesses
Sufficient and quality management resources	***(reset) is equally important as***	Compatibility among levels and functions
Management attitude and compatibility	***(reset) is equally important as***	Strategic fit of businesses
Management attitude and compatibility	***(reset) is equally important as***	Compatibility among levels and functions
Strategic fit of businesses	***(reset) is equally important as***	Compatibility among levels and functions

Reset / Reset to step 1 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8

Consistency Ratio	***0%***

When you have indicated your preferences and the Consistency Ratio is below 10%, please continue to the next question ***L3-9***
You may at any point in time return to previous questions and correct your input before sending the sheet back to me.

Figure D10. Ranking and pairwise comparison Level 4 - culture.

Level 3-9 - Organizational Factors>Technology

This is the third level of ranking in the AHP hierarchy.
Only move the marker in the scrollbar!

PAIRWISE COMPARISON

Here you indicate the magnitude of preference among the factors by sliding the bar. The graph and the consistency ratio will change on the fly.

The graphic will show your preferences so that you can control if this is what you want to indicate.

CONSISTENCY
The consistency ratio needs to be 10% or less.
If the consistency ratio is higher than 10%, your pairwise comparisons are not consistent. To help you finding the possible source, there will be an red indicator to the right of the most inconsistent comparisons. The most probable has the value "1", then "2" and so on. Please check first the most inconsistent (with value "1"). If you consider this one correct, continue with the "2" or "3".
In case you are lost, you may always reset by sliding the bar to the extreme left.

Factor	*Explanation*
Compatibility of technical platforms	The vendor's platform is technically easily compatible with your own.
Technical specialization and educational level of staff	The vendor's staff has proven general and specialist knowledge in your specific field of interest.
Existing communication and online systems	The vendor has advanced online delivery and communication systems.
Present technological capacity	The vendor has a large and specialised installed capacity.

Your Consistency Indicator

Consistency Ratio 0%

Compatibility of technical platforms	***(reset) is equally important as*** Reset -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8	Technical specialization and educational level of staff
Compatibility of technical platforms	***(reset) is equally important as*** Reset -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8	Existing communication and online systems
Compatibility of technical platforms	***(reset) is equally important as*** Reset -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8	Present technological capacity
Technical specialization and educational level of staff	***(reset) is equally important as*** Reset -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8	Existing communication and online systems
Technical specialization and educational level of staff	***(reset) is equally important as*** Reset -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8	Present technological capacity
Existing communication and online systems	***(reset) is equally important as*** Reset -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8	Present technological capacity

When you have indicated your preferences and the Consistency Ratio is below 10%, please continue to the next question ***L3-10***
You may at any point in time return to previous questions and correct your input before sending the sheet back to me.

Figure D11. Ranking and pairwise comparison Level 4 - technology.

Level 3-10 - Organizational Factors>Relationship and Communication

This is the third level of ranking in the AHP hierarchy.
Only move the marker in the scrollbar!

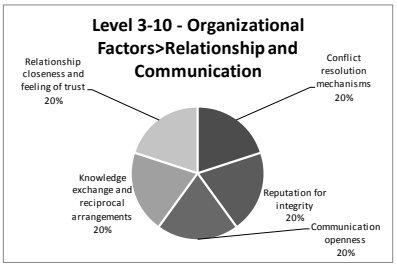
PAIRWISE COMPARISON

Here you indicate the magnitude of preference among the factors by sliding the bar. The graph and the consistency ratio will change on the fly.

The graphic will show your preferences so that you can control if this is what you want to indicate.

CONSISTENCY
The consistency ratio needs to be 10% or less.
If the consistency ratio is higher than 10%, your pairwise comparisons are not consistent. To help you finding the possible source, there will be an red indicator to the right of the most inconsistent comparisons. The most probable has the value "1", then "2" and so on. Please check first the most inconsistent (with value "1"). If you consider this one correct, continue with the "2" or "3".
In case you are lost, you may always reset by sliding the bar to the extreme left.

Factor	*Explanation*
Relationship closeness and feeling of trust	The personal relationship between the contact partners can be very close.
Knowledge exchange and reciprocal arrangements	Also sensitive information can be trustfully exchanged; the vendor offers unique and interesting information.
Communication openness	The vendor shows interest in a high level of transparency.
Reputation for integrity	The vendor has a high level of business and personal integrity.
Conflict resolution mechanisms	There are formal conflict reolution mechanisms in place.



Your Consistency Indicator

Relationship closeness and feeling of trust	***(reset) is equally important as***	Knowledge exchange and reciprocal arrangements
Relationship closeness and feeling of trust	***(reset) is equally important as***	Communication openness
Relationship closeness and feeling of trust	***(reset) is equally important as***	Reputation for integrity
Relationship closeness and feeling of trust	***(reset) is equally important as***	Conflict resolution mechanisms
Knowledge exchange and reciprocal arrangements	***(reset) is equally important as***	Communication openness
Knowledge exchange and reciprocal arrangements	***(reset) is equally important as***	Reputation for integrity
Knowledge exchange and reciprocal arrangements	***(reset) is equally important as***	Conflict resolution mechanisms
Communication openness	***(reset) is equally important as***	Reputation for integrity
Communication openness	***(reset) is equally important as***	Conflict resolution mechanisms
Reputation for integrity	***(reset) is equally important as***	Conflict resolution mechanisms

Reset
-8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8

Consistency Ratio	***0%***

When you have indicated your preferences and the Consistency Ratio is below 10%, please continue to the next question ***L3-11***
You may at any point in time return to previous questions and correct your input before sending the sheet back to me.

Figure D12. Ranking and pairwise comparison Level 4 - relationship and communication.

Level 3-11 - Organizational Factors>Geographical Location

This is the third level of ranking in the AHP hierarchy.
Only move the marker in the scrollbar!

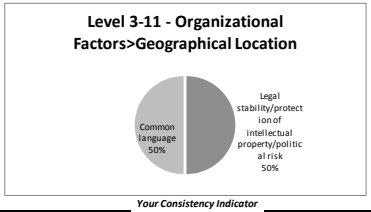
PAIRWISE COMPARISON

Here you indicate the magnitude of preference among the factors by sliding the bar. The graph and the consistency ratio will change on the fly.

The graphic will show your preferences so that you can control if this is what you want to indicate.

CONSISTENCY
The consistency ratio needs to be 10% or less.
If the consistency ratio is higher than 10%, your pairwise comparisons are not consistent. To help you finding the possible source, there will be an red indicator to the right of the most inconsistent comparisons. The most probable has the value "1", then "2" and so on. Please check first the most inconsistent (with value "1"). If you consider this one correct, continue with the "2" or "3".
In case you are lost, you may always reset by sliding the bar to the extreme left.

Factor	*Explanation*
Common language	The vendor communicates on all levels in your own language.
Legal stability/protection of intellectual property/political risk	Intellectual property rights, arbitration laws, legal system, general political stability for business and travel.



Your Consistency Indicator

Common language	*(reset) is equally important as*	Legal stability/protection of intellectual property/political risk

Reset -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8

Consistency Ratio	***0%***

When you have indicated your preferences and the Consistency Ratio is below 10%, ***YOU HAVE MADE IT****. Please continue to* ***"Your Results".***

You may at any point in time return to previous questions and correct your input before sending the sheet back to me.

When you feel that it is complete, please open ***http://dbinbox.com/simudb*** *and drop the file in my inbox.*

Thank you for your collaboration! I will come back to you once I have the consolidated results.

Best regards
Simon Musaeus

Figure D13. Ranking and pairwise comparison Level 4 – geographical location.

Appendix E: Follow-up Survey Results – Local Priorities by Evaluator

Data	*Evaluator 1*	*Evaluator 2*	*Evaluator 3*	*Evaluator 4*	*Evaluator 5*	*Evaluator 6*	*Evaluator 7*	*Evaluator 8*	*Evaluator 9*	*Evaluator 10*	*Evaluator 11*	*Evaluator 12*	*Evaluator 13*	*Evaluator 14*	*Evaluator 15*
vate here with "1" if only specific evaluators desired. Else leave "0" or blank.	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
1.1 Performance Measures	80,0%	87,5%	80,0%	80,0%	83,3%	87,5%	83,3%	50,0%	87,5%	85,7%	75,0%	87,5%	87,5%	75,0%	75,0%
1.2 Organizational Factors	20,0%	12,5%	20,0%	20,0%	16,7%	12,5%	16,7%	50,0%	12,5%	14,3%	25,0%	12,5%	12,5%	25,0%	25,0%
Pairwise comparison for Level 3															
1.1 Performance Measures															
1.1.1 Quality	38,8%	46,2%	38,8%	36,7%	32,1%	43,5%	32,9%	52,8%	44,2%	39,0%	39,9%	15,7%	35,5%	23,7%	23,7%
1.1.2 Delivery	27,3%	15,3%	27,3%	11,9%	33,1%	16,5%	24,6%	7,4%	23,8%	24,3%	14,7%	15,7%	26,7%	27,8%	27,8%
1.1.3 Project Management	10,9%	5,3%	10,9%	11,0%	13,3%	5,6%	17,9%	13,3%	19,2%	10,4%	14,1%	12,5%	4,6%	5,3%	5,3%
1.1.4 Flexibility	9,9%	10,0%	9,9%	16,9%	7,6%	5,7%	12,0%	5,4%	5,1%	10,0%	15,3%	14,8%	3,9%	15,7%	15,7%
1.1.5 Use of new technologies and future capabilities	8,4%	3,6%	8,4%	14,5%	5,2%	7,4%	6,9%	8,4%	5,1%	7,8%	9,5%	11,8%	11,5%	7,2%	7,2%
1.1.6 Low initial price	4,7%	19,6%	4,7%	9,1%	8,7%	21,3%	5,7%	12,8%	2,7%	8,5%	6,5%	29,4%	17,8%	20,3%	20,3%
Pairwise comparison for Level 4															
1.1 Performance Measures															
1.1.1 Quality															
Product quality	55,7%	47,4%	55,7%	36,8%	56,8%	68,5%	41,1%	45,2%	79,0%	78,0%	65,5%	64,6%	70,2%	33,3%	33,3%
International quality certifications	12,3%	5,3%	12,3%	13,9%	9,8%	9,3%	32,8%	7,2%	8,1%	8,3%	13,3%	6,4%	7,2%	33,3%	33,3%
Reputation and positive track-record	32,0%	47,4%	32,0%	49,3%	33,4%	22,1%	26,1%	47,6%	12,9%	13,7%	21,1%	29,0%	22,7%	33,3%	33,3%
1.1.2 Delivery															
Consistency of quality over time	75,0%	50,0%	75,0%	80,0%	80,0%	83,3%	50,0%	75,0%	66,7%	75,0%	75,0%	80,0%	80,0%	75,0%	75,0%
Timeliness of delivery/lead time	25,0%	50,0%	25,0%	20,0%	20,0%	16,7%	50,0%	25,0%	33,3%	25,0%	25,0%	20,0%	20,0%	25,0%	25,0%
1.1.3 Project Management															
Timeliness and quality of reporting/responsiveness	20,0%	50,0%	20,0%	80,0%	25,0%	83,3%	50,0%	80,0%	50,0%	75,0%	33,3%	80,0%	75,0%	66,7%	66,7%
Technical and managerial competence of Project Managers	80,0%	50,0%	80,0%	20,0%	75,0%	16,7%	50,0%	20,0%	50,0%	25,0%	66,7%	20,0%	25,0%	33,3%	33,3%
1.1.4 Flexibility															
Product volume changes and peakload capacity	33,3%	50,0%	33,3%	33,3%	50,0%	25,0%	50,0%	16,7%	20,0%	75,0%	33,3%	50,0%	20,0%	50,0%	50,0%
Short setup time/flexibility in schedules	66,7%	50,0%	66,7%	66,7%	50,0%	75,0%	50,0%	83,3%	80,0%	25,0%	66,7%	50,0%	80,0%	50,0%	50,0%
1.1.5 Use of new technologies and future capabilities															
Use of new technologies and future capabilities	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
1.1.6 Low initial price															
Low initial price	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%

(table continues)

Data	*Evaluator 1*	*Evaluator 2*	*Evaluator 3*	*Evaluator 4*	*Evaluator 5*	*Evaluator 6*	*Evaluator 7*	*Evaluator 8*	*Evaluator 9*	*Evaluator 10*	*Evaluator 11*	*Evaluator 12*	*Evaluator 13*	*Evaluator 14*	*Evaluator 15*
vate here with "1" if only specific evaluators desired. Else leave "0" or blank.	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
1.2 Organizational Factors															
1.2.1 Culture	19,4%	31,2%	19,4%	17,1%	16,0%	19,0%	34,4%	7,7%	8,2%	60,3%	22,5%	15,9%	11,2%	30,8%	30,8%
1.2.2 Technology	31,3%	41,0%	31,3%	26,3%	31,5%	21,8%	19,7%	37,4%	59,5%	14,2%	37,1%	41,3%	56,8%	30,8%	30,8%
1.2.3 Relationship and communication	41,7%	24,4%	41,7%	44,6%	44,5%	52,8%	24,7%	41,2%	27,6%	10,5%	31,4%	34,6%	27,9%	30,8%	30,8%
1.2.4 Geographical location	7,6%	3,5%	7,6%	11,9%	8,0%	6,4%	21,1%	13,7%	4,6%	15,0%	9,0%	8,2%	4,0%	7,7%	7,7%
1.2 Organizational Factors															
1.2.1 Culture															
Sufficient and quality management resources	16,5%	20,0%	16,5%	33,0%	22,1%	61,1%	37,4%	40,1%	56,2%	50,4%	50,8%	8,6%	34,3%	11,2%	11,2%
Management attitude and compatibility	16,5%	30,7%	16,5%	15,2%	20,0%	26,5%	17,7%	31,0%	31,1%	23,4%	21,2%	19,7%	11,1%	13,9%	13,9%
Strategic fit of businesses	39,2%	13,6%	39,2%	20,2%	8,1%	6,1%	24,1%	8,9%	5,7%	17,6%	10,6%	31,9%	10,1%	19,4%	19,4%
Compatibility among levels and functions	27,9%	35,7%	27,9%	31,5%	49,7%	6,2%	20,8%	20,0%	7,0%	8,5%	17,4%	39,9%	44,6%	55,5%	55,5%
1.2.2 Technology															
Compatibility of technical platforms	26,0%	45,5%	26,0%	35,8%	24,0%	12,0%	28,0%	13,8%	9,1%	57,5%	9,9%	20,0%	55,6%	34,6%	34,6%
Technical specialization and educational level of staff	45,0%	17,0%	45,0%	42,1%	52,5%	65,0%	24,5%	37,9%	56,1%	23,5%	46,3%	32,9%	22,7%	24,6%	24,6%
Existing communication and online systems	12,0%	6,9%	12,0%	15,5%	16,7%	11,1%	31,6%	30,2%	13,0%	10,5%	18,6%	14,2%	9,1%	20,4%	20,4%
Present technological capacity	17,1%	30,6%	17,1%	6,6%	6,8%	12,0%	15,9%	18,2%	21,8%	8,5%	25,1%	32,9%	12,6%	20,4%	20,4%
1.2.3 Relationship and communication															
Relationship closeness and feeling of trust	7,6%	29,9%	7,6%	32,6%	6,0%	28,2%	32,6%	15,5%	46,6%	38,8%	10,3%	15,3%	41,0%	16,6%	21,9%
Knowledge exchange and reciprocal arrangements	21,2%	10,5%	21,2%	8,9%	30,2%	5,8%	19,2%	10,7%	5,7%	21,3%	34,9%	14,4%	11,5%	16,6%	16,4%
Communication openness	14,3%	28,5%	14,3%	36,4%	19,4%	26,6%	19,2%	20,6%	15,8%	12,7%	30,9%	23,4%	18,0%	22,1%	21,2%
Reputation for integrity	45,9%	28,5%	45,9%	16,9%	35,2%	11,1%	14,5%	31,3%	26,4%	8,3%	11,0%	12,9%	22,9%	31,3%	30,2%
Conflict resolution mechanisms	11,0%	2,7%	11,0%	5,1%	9,1%	28,2%	14,5%	21,9%	5,4%	18,8%	13,0%	34,0%	6,6%	13,4%	10,3%
1.2.4 Geographical location															
Common language	16,7%	80,0%	16,7%	80,0%	66,7%	87,5%	50,0%	50,0%	90,0%	85,7%	66,7%	75,0%	20,0%	50,0%	50,0%
Legal stability/protection of intellectual property/political risk	83,3%	20,0%	83,3%	20,0%	33,3%	12,5%	50,0%	50,0%	10,0%	14,3%	33,3%	25,0%	80,0%	50,0%	50,0%

Note: If the details are not readable, then please ask the author for a digital copy.

Appendix F: Consistency Ratios by Cluster and Evaluator

	Evaluator 1	*Evaluator 2*	*Evaluator 3*	*Evaluator 4*	*Evaluator 5*	*Evaluator 6*	*Evaluator 7*	*Evaluator 8*	*Evaluator 9*	*Evaluator 10*	*Evaluator 11*	*Evaluator 12*	*Evaluator 13*	*Evaluator 14*	*Evaluator 15*
	1	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
1.1 Performance Measures	8,7%	9,6%	8,7%	9,2%	8,3%	9,0%	9,1%	9,6%	9,4%	9,0%	5,1%	5,5%	8,4%	7,5%	7,5%
1.2 Organizational Factors	4,5%	7,0%	4,5%	9,5%	6,9%	8,4%	6,9%	0,9%	5,8%	9,5%	7,4%	6,3%	8,8%	0,0%	0,0%
1.1.1 Quality	2,0%	0,0%	2,0%	9,9%	2,8%	7,3%	4,8%	0,3%	9,1%	5,8%	6,9%	9,6%	7,6%	0,0%	0,0%
1.1.2 Delivery	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.1.3 Project Management	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.1.4 Flexibility	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.1.5 Use of new technologies and future capabilities	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.1.6 Low initial price	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.2.1 Culture	2,6%	4,5%	2,6%	4,4%	5,8%	9,3%	9,1%	4,5%	8,8%	9,5%	7,0%	7,0%	4,8%	6,8%	6,8%
1.2.2 Technology	3,1%	8,0%	3,1%	7,7%	8,7%	1,0%	4,7%	9,2%	8,9%	8,1%	5,2%	2,5%	6,6%	2,3%	2,3%
1.2.3 Relationship and communication	4,2%	8,4%	4,2%	7,3%	5,8%	6,2%	2,7%	7,7%	8,5%	9,3%	2,5%	6,3%	9,3%	2,3%	5,1%
1.2.4 Geographical location	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Note: Calculation of the CR was only possible when the cluster contained more than two factors.

Appendix G: Results from Aggregation of Local and Global Priorities

	Local priorities			Global Priorities		
	Arithmetic mean activated	*Variance activated*	*Standard Deviation activated*	***Global priorities activated***	***Variance activated***	***Standard Deviation activated***
1.1 Performance Measures	80,3%	0,9%	9,7%	**80,33%**	**0,94%**	**9,67%**
1.2 Organizational Factors	19,7%	0,9%	9,7%	**19,67%**	**0,94%**	**9,67%**
Pairwise comparison for Level 3						
1.1 Performance Measures						
1.1.1 Quality	36,2%	0,9%	9,6%	**28,86%**	**0,60%**	**7,74%**
1.1.2 Delivery	21,6%	0,5%	7,4%	**17,62%**	**0,40%**	**6,34%**
1.1.3 Project Management	10,7%	0,2%	4,6%	**8,52%**	**0,16%**	**3,95%**
1.1.4 Flexibility	10,5%	0,2%	4,4%	**8,43%**	**0,12%**	**3,51%**
1.1.5 Use of new technologies and future capabilities	8,2%	0,1%	2,8%	**6,55%**	**0,06%**	**2,42%**
1.1.6 Low initial price	12,8%	0,6%	8,0%	**10,34%**	**0,49%**	**6,99%**
1.2 Organizational Factors						
1.2.1 Culture	22,9%	1,8%	13,3%	**4,51%**	**0,06%**	**2,36%**
1.2.2 Technology	34,1%	1,5%	12,4%	**6,70%**	**0,15%**	**3,89%**
1.2.3 Relationship and communication	33,9%	1,1%	10,6%	**6,68%**	**0,20%**	**4,48%**
1.2.4 Geographical location	9,1%	0,2%	4,7%	**1,78%**	**0,03%**	**1,61%**
1.1 Performance Measures						
1.1.1 Quality						
Product quality	55,4%	2,4%	15,4%	**16,52%**	**0,56%**	**7,52%**
International quality certifications	14,2%	1,0%	10,1%	**3,72%**	**0,04%**	**2,01%**
Reputation and positive track-record	30,40%	1,3%	11,3%	**8,62%**	**0,17%**	**4,13%**
1.1.2 Delivery						
Consistency of quality over time	73,0%	1,0%	10,1%	**12,86%**	**0,26%**	**5,12%**
Timeliness of delivery/lead time	27,0%	1,0%	10,1%	**4,76%**	**0,06%**	**2,35%**
1.1.3 Project Management						
Timeliness and quality of reporting/responsiveness	57,0%	5,4%	23,3%	**4,55%**	**0,06%**	**2,49%**
Technical and managerial competence of Project Managers	43,0%	5,4%	23,3%	**3,97%**	**0,09%**	**3,06%**
1.1.4 Flexibility						
Product volume changes and peakload capacity	39,3%	2,5%	16,0%	**3,61%**	**0,05%**	**2,13%**
Short setup time/flexibility in schedules	60,7%	2,5%	16,0%	**4,82%**	**0,04%**	**1,98%**
1.1.5 Use of new technologies and future capabilities						
Use of new technologies and future capabilities	100,0%	0,0%	0,0%	**6,55%**	**0,06%**	**2,42%**
1.1.6 Low initial price						
Low initial price	100,0%	0,0%	0,0%	**10,34%**	**0,49%**	**6,99%**
1.2 Organizational Factors						
1.2.1 Culture						
Sufficient and quality management resources	31,3%	3,1%	17,6%	**1,27%**	**0,01%**	**1,10%**
Management attitude and compatibility	20,6%	0,4%	6,6%	**0,84%**	**0,00%**	**0,47%**
Strategic fit of businesses	18,3%	1,2%	11,2%	**0,82%**	**0,00%**	**0,60%**
Compatibility among levels and functions	29,9%	2,8%	16,8%	**1,32%**	**0,02%**	**1,25%**
1.2.2 Technology						
Compatibility of technical platforms	28,8%	2,4%	15,4%	**1,71%**	**0,01%**	**0,97%**
Technical specialization and educational level of staff	37,3%	2,1%	14,4%	**2,48%**	**0,03%**	**1,68%**
Existing communication and online systems	16,2%	0,5%	7,2%	**1,20%**	**0,02%**	**1,31%**
Present technological capacity	17,7%	0,6%	7,9%	**1,23%**	**0,01%**	**0,88%**
1.2.3 Relationship and communication						
Relationship closeness and feeling of trust	23,4%	1,8%	13,3%	**1,33%**	**0,01%**	**0,83%**
Knowledge exchange and reciprocal arrangements	16,6%	0,7%	8,4%	**1,14%**	**0,01%**	**0,83%**
Communication openness	21,6%	0,4%	6,7%	**1,52%**	**0,01%**	**1,08%**
Reputation for integrity	24,8%	1,5%	12,2%	**1,89%**	**0,03%**	**1,72%**
Conflict resolution mechanisms	13,7%	0,8%	8,8%	**1,00%**	**0,01%**	**1,09%**
1.2.4 Geographical location						
Common language	59,0%	6,6%	25,6%	**1,08%**	**0,01%**	**0,88%**
Legal stability/protection of intellectual property/political risk	41,0%	6,6%	25,6%	**0,84%**	**0,01%**	**0,88%**

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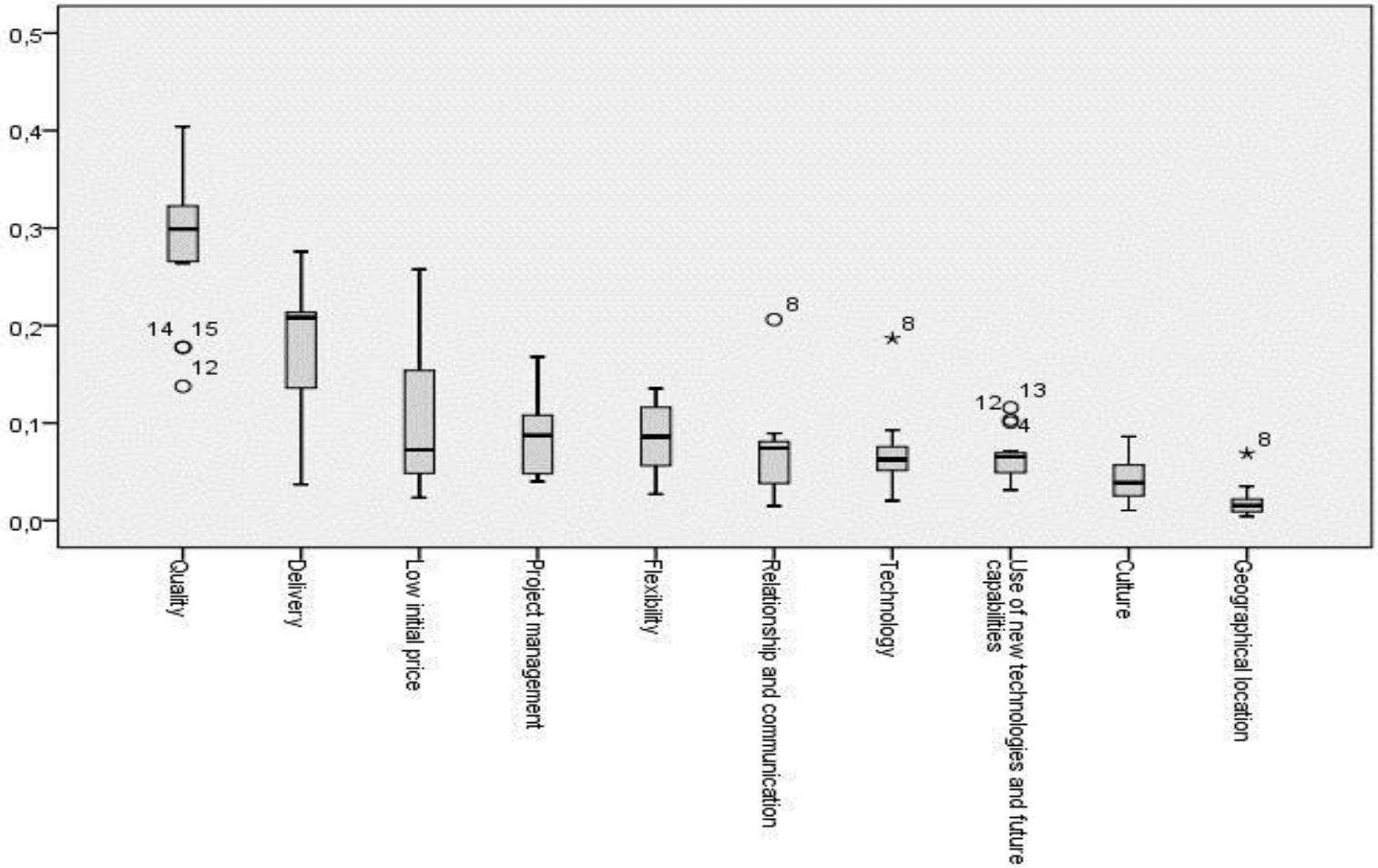
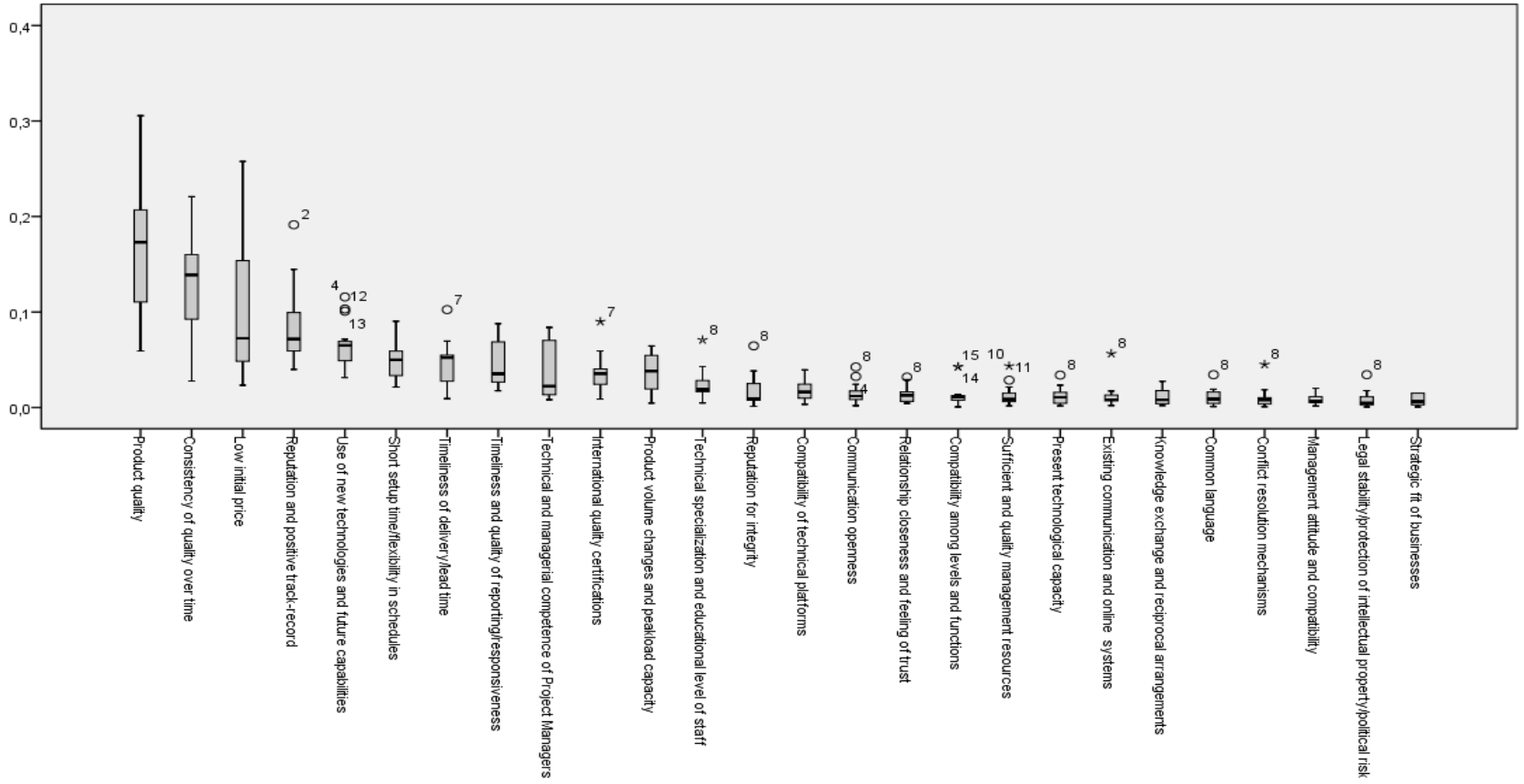
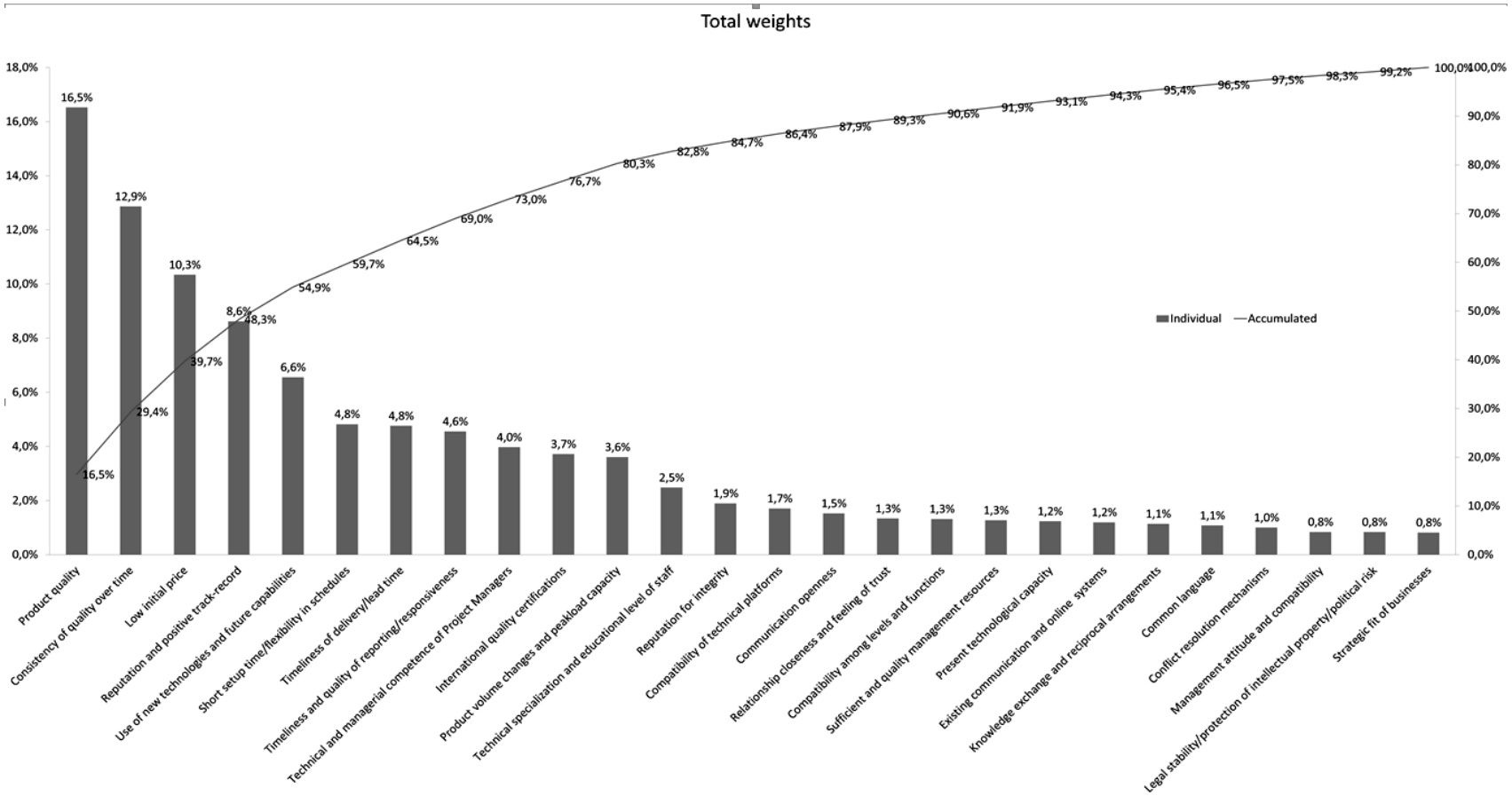
Appendix H: Boxplot of Global Priorities Level 3



Appendix I: Boxplot of Global Priorities Level 4



Appendix J: Presentation of Global Priorities from Follow-up Survey



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Education	Dipl.-Ing. (univ.) Vermessungswesen, University of the Federal Armed Forces, Munich, Germany, 1993, (equivalent to Master of Science in Engineering Survey and Geodesy) Presently D.B.A. (Doctor of Business Administration) Studies with Walden University, Minnesota, USA, expected to be finished in 2014
Member of Professional Organizations:	
	Swedish Society for Photogrammetry and Remote Sensing. Nordic Society of Applied Geophysics. Swedish National Committee for Geodesy and Geophysics. German Association of Geodesists (Deutscher Verein füer Vermessungswesen)

KEY QUALIFICATIONS

Mr. Musäus is today the director of mapping services in the COWI group and responsible for all COWI-operations this domain. Specific focus is on the development of international markets and expand COWI's leading position in the geospatial industry.
Mr. Musäus possesses 25 years of experience in projects dealing with topography, geodesy, photogrammetry and GIS in Europe, Africa, Asia and Latin America. He possesses profound knowledge in planning, management and quality control in medium and large scale projects. His technical expertise is mainly in the global positioning system, cadaster, GIS and photogrammetry.
Due to his experience as project manager of major projects for Worldbank and European Union and in his position as managing director in COWI El Salvador and technical and managing director in COWI India he has acquired a sound knowledge of economic and administrative processes and is able to master them in all assignments.
Mr. Musäus is today the global market director mapping of COWI A/S and responsible for all COWI mapping operations internationally.

Project Management/Leadership

In the moment global market director in COWI A/S, Kongens-Lyngby, Denmark, Mr Musäus has the responsibility for the area of mapping in the COWI Group. Previously managing director in COWI India (P) Ltd., he was in charge of all administrative and operative requirements and strategic planning/implementation in the company.
As technical director mapping of COWI India, his responsibilities overarched all mapping and GIS-activities in the international market which included the contract-management, leading of project managers and project-group managers, Administrative and technical responsibility for production and planning and supervision of R&D-staff.
Before he worked on assignment as project manager in an EU-financed project for the Romanian National Agency for Cadaster and Land registration (NACLR). Until 31/01/08 he bore a double responsibility being at the same time managing director in El Salvador. As project manager of a Land Cadaster-Project in Panamá he lead successfully a team of 120 specialists in technical and legal areas, dealing in a remote location responsibly with a Worldbank-financed major project. Previously he could collect experience as technical director of a large scale Land Cadaster-Project in El Salvador, where planning, coordination and motivation of various production units carrying out the project, management of personnel, monitoring and supervision of production and technical communication with the client (National Register and Land Cadaster) formed his

area of responsibility. His special focus laid on optimization of production procedures and quality assurance.
Additionally Mr Musäus possesses experience of 10 years in HR-management and leadership as officer of the Federal Armed Forces in commanding positions.

Training and personal development

Mr Musaeus has throughout his career been responsible for development and implementation of training for different types of projects. In the military he was educated formally on methodology and didactics, which continued later training topographers in the civil market. His academic period saw him as trainer in engineering projects and assistant professor in the GIS working group of the University of Federal Armed Forces in Germany. As a head of section Mapping & GIS in a large scale cadaster project and later on technical director he could collect ample experience in job-descriptions, procedures and recruiting. In the more recent higher positions as Managing director and technical director he led trainings and designed training strategies.
Since November 2009 he is in the D.B.A. (Doctor of Business Administration) program of Walden University, Minnesota with specialization in international business and finance. His specific interest is in global supply networks and optimization of the geospatial industry and services. The expected year of graduation is 2014.

Technical expertise

Excellent knowledge of technical aspects regarding topography, geodesy, geoinformation Systems, photogrammetry and cadaster.
During the last years his focus has changed to the area of management with special focus on international supply-chains, and sourcing strategies.

	Speak	Read	Write
Language			
German	Mother tongue		
Spanish	Fluent	Fluent	Fluent
English	Fluent	Fluent	Fluent
Portuguese	Fair	Very Good	Fair
French	Poor	Fair	Poor
Arabic	3 Semesters in 1996/97, no active knowledge, but refreshable		

PROFESSIONAL EXPERIENCE

Denmark, 01/2014- today

Global Market director and director of the International Business Line Mapping; COWI A/S, Denmark; General responsibility for the business with offices in Denmark, India, Norway, Poland, Switzerland, and UK;

- Leading COWI's Mapping area
- Supervision of international operations including an aerial sensor fleet with four airplanes
- Strategy and budgeting
- Business development
- Business analysis and profitability analyses
- Consulting and institutional development

India, 01/2011- 12/2013

Managing director; COWI India (P) Ltd., COWI Group Company established in New Delhi for Mapping, Photogrammetry, and Engineering Design services; 470 Employees, General responsibility for the company with offices in various locations in India

- Planning, budgeting, reporting, coordination with COWI and subcontractors
- Design of supply chain mechanisms for distributed work in traditional engineering disciplines and mapping
- Business analysis and profitability analyses
- Business development
- Consulting and institutional development
- Quality systems
- Client relationship management
- Collaboration in COWI's strategy

India, 06/2008 - 12/2010

Technical director Mapping and deputy managing director; COWI India (P) Ltd., COWI Group Company established in New Delhi for mapping, photogrammetry and engineering design services;

- General responsibility for the mapping divisions, 2D aerial mapping, cadastre and GIS, 3D Vector Mapping, Orthophotos, DTM. LIDAR, AT and research & development
- Planning, budgeting, reporting, coordination with COWI and subcontractors for the Mapping Sector
- Business development
- Consulting and institutional development
- Quality systems for mapping
- Client relationship management
- Collaboration in the strategy of COWI worldwide mapping strategies
- Responsible for 300+ operators and supporting staff
- Development and training of new operational and management staff
- Leading R&D-projects in the mapping and GIS-sector

Romania, 01/2007-05/2008

Team leader/project manager in the project "Services for data conversion to support implementation of the Cadaster and Real Property Rights Registration System in Romania"". EU-PHARE; client National Agency for Cadaster and Land Registration (NACLR/NACPI),

8500km2, Pilot Project Cadastral Index Map and Property Title Management System for two counties, 450.000 properties

- General responsibility for the Project (10 international experts with wide range of expertise like engineers, architects, topographers, and IT, National subcontractor with 50 employees)
- Planning, budgeting, reporting, coordination with COWI A/S and subcontractors
- Consulting and institutional development
- Coordination with the client (National Cadaster Agency-NACLR, Coordinating Financial Unit -CFCU, National Geodetic Fund NGF, Local Cadaster agencies-OCLR)

El Salvador. 04/2006-01/2008

Managing director COWI de El Salvador in El Salvador (Resident Manager)

- Complete responsibility for the company (180 employees)
- Business development
- Strategic planning for market development
- Supervision of surveying and GIS projects
- Development of new products (Low-cost GIS for Municipalities, webserver for Geomarketing, Integrated Cadastral Services)
- Quality systems
- Implementation of monitoring system in legal services
- Strategic planning for 2007/2008

India, February/March and May 2006

Quality and P\production assessment in the Photogrammetry Division of Kampsax India Private Limited. (Photogrammetry/GIS-Services)

- Elaboration of action plans for quality assurance, software implementation, work process improvement and Training
- Collaboration in the strategic planning of the company for 2006/2007

Panamá. 05/2005-12/2005

Project manager "Regularización de Tierras en 5 distritos de Chiriquí Oriente". (Regularization of legal property in 5 districts of Eastern Chiriquí) Financing BIRDF; client PRONAT (Proyecto Nacional de Administración de Tierras- National Project for Land-Administration), 2000km2, Regularization of 16000 urban and rural Parcels

- General responsibility for the project (113 employees with wide range of expertise like engineers, architects, lawyers, topographers, and IT)
- Coordination with the client and representation of COWI A/S in Panamá

El Salvador. 01/2003-04/2005

Technical director and QC-team leader in Kampsax A/S (COWI-Group) in El Salvador. Technical director of the project "Verification of legal rights and cadaster-limits in the new cadaster-system" in the departments of San Salvador-La Libertad. Financing BIRDF; client CNR (National Register) Cadastral survey of 124380 rural parcels 2125km2 and 164142 urban parcels in 88.6 km2

- Planning, coordination, organization and supervision of the departments "Field survey", "Mapping/GIS", "Legal", "Promotion and PR" and "Preparation" (total 231 employees)
- Process Optimization with focus on QA
- Technical coordination with the client
- Coordination and quality checks of base cartography (photogrammetry) with COWI-headquarters in Denmark and Kampsax India (P) Ltd-India
- Responsibility for quality of the two cadaster-projects San Salvador/La Libertad and La Paz
- Development and implementation of GIS-courses(ESRI) for GIS-department

El Salvador. 10/2001-12/2002

Head of mapping and GIS-department in Kampsax A/S (COWI-Group) in El Salvador. "Verification of legal rights and cadaster-limits in the new cadaster-system" in the departments of San Salvador-La Libertad. Financing; client CNR (National Register) Cadastral Survey of 124380 rural parcels 2125km2 and 164142 urban parcels in 88.6 km2

- Coordination and organization of activities in the mapping and GIS-department (total 36 employees)
- Deputy technical director
- Design of training plans for the complete project

- Elaboration of training plans for mapping/GIS-staff and topographers
- Elaboration and implementation of procedures for survey/cadaster and GIS-application in the project
- Implementation of geometrical QC-standards and procedures
- Planning, measurement, calculus and adjustment of a geodetic network for determination of a local geoide
- Implementation of GIS-courses
- Development of software applications

Germany. 01/2001-09/2001

Chief of Agency, Tiefenbach GmbH in Munich.
Development of positioning systems for guided traffic and monitoring systems for security measures in level-crossings. Sales and distribution.

- Coordination of different work-groups in soft- and hardware development, embedded GIS
- Application, development, sales and marketing for positioning, monitoring, and navigation systems
- Consultancy services in system-implementation of positioning-systems in the dispatching of guided traffic
- Resource management

Germany. **01/1998 – 12/2000**

Scientific Fellow in the GIS-Working Group at the University FAF, Munich

- Development of a precise remote positioning system for the guided traffic in industrial plants. Mobile embedded GIS techniques. Telecommunication network. Software and hardware development with documentation of the scientific background. Scientific and administrative management. Organization of a work-group of 5 scientific fellows and various students of IT and geodesy. Supervision of various bachelor and master theses in geodesy and GIS/IT
- Training of civil engineering students in topographic techniques
- Training of geodesy students in digital terrain models, statistics and network adjustment
- Scientific work on a project for assessment of various COTS-Software for GIS-feature extraction from remote-sensing data. Elaboration of an evaluation report for the geodetic service of the German FAF

- Scientific work on a project on automated map generalization for the geodetic service of the German FAF; Models for QA and QC in GIS
- Development of a monitoring system for level-crossings railroad/street based on the combination of terrestrial photogrammetric techniques and laser-scanning

Tanzania. **08/1998 and 11/1999**

Trainer in the Project RESOURCE PROTECTION AND BUFFERZONE DEVELOPMENT PROGRAMME – KfW, for application of differential GPS in land-administration, courses for employees of the German Technical Development Agency (GTZ) and German Development Aid (DED). Edition of manuals, theoretical, and practical training courses; Interface GPS/GIS with ArcView; with GAF (Munich)

Germany. **06/1996 - 12/1997**

Geodesy specialist and head of topographical surveying groups with Kirchner & Wolf Consult GmbH, Hildesheim, Germany.
Planning, execution, calculus, and QC of various topographic and geodetic projects.

- Site supervision for construction companies
- Deformation analysis
- Photogrammetric ground control
- High Precision Leveling
- Survey and adjustment of heterogeneous geodetic networks
- Training of topographers
- GIS-Data acquisition and handling

Bolivia. 11/1996 - 03/1997

Trainer in the project "Ayuda con equipamiento para la Cartografía Nacional"-KfW.
Work in the Military Geographic Institute in La Paz, Bolivia.
Training of the departments photogrammetry, geodesy, and cartography in application of various software-tools and procedures for topographic measurements. Introduction to work with Digital Terrain Models (Microstation, InRoads) and optimization of photogrammetric plotting for this reason (Pat-B), measurements with totalstations and introduction of an automated data-flow(Leica), handling of digitizing programs (Intergraph I-RAS-B and I-RAS-C).

Germany. **06/1995 – 05/1996**

In charge of the military topographic support groups for the re-establishment of a cadastral system and legal property register in Eastern Germany (former German Democratic Republic) in the state (Bundesland) Saxony-Anhalt. (8 officers, 12 sergeants, 24 military topographers)

- Resource management
- Civil-military cooperation
- Technical assessment of the cadastral works of the military teams

Germany. **07/1986 – 05/1996**

Artillery Officer in the Armed Forces of the Federal Republic of Germany.
Various positions in the officer's career of the Artillery-corps. During that time graduation at the University FAF, Munich in Geodesy.

- Battery-Commander of a School-battery at the Artillery-School in Idar-Oberstein, Germany. Training and leadership, 2 officers, 20 enlisted and 120 soldiers with responsibility for material of an Artillery-Battery
- Training in technical, political and social aspects
- Training of officers and sergeants in methodology and didactics
- Planning, preparation and implementation of military exercises
- Assignment to the command staff of an Artillery-battalion as intelligence-pfficer
- Training of topographic teams of the Artillery

PUBLICATIONS

Musäus, S. (2007). Chancen für Vermessungsingenieure in Internationalen Consultingprojekten; (Opportunities for Surveying Engineers in International Consulting Projects). *Proceedings Intergeo*, Leipzig 25.September 2007. Leipzig, Germany

Musäus, S. (2006). Combination of large-scale mapping and operations - its importance in wide-area cadaster-projects. *Proceedings International Conference on Enhancing Land Registration and Cadastre for Economic Growth in India*, Map India 2006, New Delhi, India.

Musäus, S. (2005). Experience of COWI A/S in the actualization of the Land Registry and Cadaster in El Salvador. *Landsurveyor, 5.* Copenhagen, Denmark.

Musäus, S. (2003). Experience of COWI A/S in Worldbank-financed cadaster projects in Central America. *Procedures Regional conference RECCAT*. San José, Costa Rica

Musäus, S., Reinhardt, W., Koppers, L. (2000). Determination of the position on units of the guided traffic (Ortsbestimmung von bewegten Trägern im Gleisnetz). *Conference Procedures "Verkehr und Technik" CCTS*. Braunschweig, Germany.