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COMPUTER-AIDED INNOVATION FOR IMPROVING INDUSTRIAL INNOVATION INTELLIGENCE

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KORAY ALTUN
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Prof. Dr. Türkay DERELİ

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ABSTRACT

COMPUTER-AIDED INNOVATION FOR IMPROVING INDUSTRIAL INNOVATION INTELLIGENCE

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Computer-aided innovation is an emerging domain using information and communication technologies to improve efficiency and effectiveness of innovation process, any system of organized activities that transforms a technology from an idea to a commercial product. Low success rates of this risky/expensive endeavor and technological and managerial barriers in new product development (NPD) induced by increasing product complexities, dynamism on customer requirements and internationalization and/or decentralization of NPD make computer-aided innovation tools and methods crucial and unavoidable. This thesis presents two novel computer-aided innovation methods aiming to improve industrial innovation intelligence and hence to improve success rates in innovation process. The former is named as "*Quick Innovation Intelligence Process*" and it is a novel technology assessment process trying to assess innovation potential of candidate technologies by considering their commercial potential, imitation potential and their trendiness all together. This process uses corresponding patent data, publication data and some market research reports in order to infer about innovation potential of candidate technologies. Type-2 fuzzy sets and a data-fusion approach are used to combine results of these different aspects. The latter is named as "*NegoQFD*" and it is a multi-issue negotiation based quality function deployment (QFD) method. It uses a novel, clear, rational and an easy-to-use mechanism for multi-issue negotiation, named as "*Modified Even-Swaps*" that is also developed in the scope of this thesis. It aims to provide a mode for customer co-creation in NPD while concept generation and evaluation.

Key Words: Computer-aided innovation, innovation intelligence, customer co-creation, multi-issue negotiation

ÖZET

ENDÜSTRİYEL İNOVASYON ZEKASININ İYİLEŞTİRİLMESİ İÇİN BİLGİSAYAR DESTEKLİ İNOVASYON

ALTUN, Koray
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Bilgisayar destekli inovasyon (BDİ) bilgi ve iletişim teknolojilerini kullanan ve teknolojinin fikirden ticari ürüne dönüşümü ile ilgili organize aktiviteler sistemi olarak tanımlanan inovasyon sürecinin etkililiğini ve etkinliğini iyileştirmeyi amaçlayan yeni bir çalışma alanıdır. BDİ araç ve metotları teknolojik inovasyon sürecinin riskli/pahalı uğraşları kapsadığı düşünüldüğünde ve buna ek olarak yükselen ürün karmaşasına, müşteri ihtiyaçlarındaki hareketliliğe ve yeni ürün geliştirme (YÜG) yapılarındaki uluslararasılaşma ve dağıtıklaşmaya indirgenebilen teknolojik ve yönetsel engeller göz önünde bulundurulduğunda hayati ve kaçınılmaz olduğu söylenebilir. Bu tezde endüstriyel inovasyon zekasını artırmayı amaçlayan ve neticesinde inovasyon sürecinin başarı oranını artırmayı hedefleyen iki adet BDİ metodu sunulmaktadır. Bunlardan ilki "Hızlı İnovasyon Zekası Süreci" olarak isimlendirilmiştir ve aday teknolojilerin ticari potansiyellerini, taklit edilme potansiyellerini ve trend derecelerini göz önünde bulundurarak inovasyon potansiyellerini değerlendirmeye çalışan yeni bir teknoloji değerlendirme sürecidir. Bu süreç: ilgili patent verisi, yayın verisi ve bazı pazar araştırma raporlarını aday teknolojilerin inovasyon potansiyeli hakkında çıkarsama yapabilmek için kullanmaktadır. Bu farklı boyutların sonuçlarının birleştirilmesi aşamasında tip-2 bulanık kümeler ve bir veri füzyonu yaklaşımı kullanılmaktadır. Geliştirilen ikinci BDİ metodu ise "*NegoQFD*" olarak isimlendirilmiştir ve çok kriterli müzakere tabanlı bir kalite fonksiyon göçerimi (KFG) metodudur. "*Modified Even-Swaps*" olarak isimlendirilen, bu tez kapsamında geliştirilmiş, yeni, açık, rasyonel ve kullanımı kolay çok kriterli müzakere mekanizması kullanmaktadır. YÜG sürecinde, konsept üretme ve değerlendirme aşamasında müşteri ile geliştirmeye imkan sağlamayı amaçlamaktadır.

Anahtar kelimeler: Bilgisayar destekli inovasyon, inovasyon zekası, müşteri ile birlikte geliştirme, çok kriterli müzakere

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Popularity of the term "*innovation*" has grown exponentially over the last decades. Loads of researchers and practitioners have dedicated themselves to studying "*management of innovation*" since they believe in that "*innovation is crucial to survival*". Use of this sentence has served as a vital base for constructing efforts devoted to management of innovation, and therefore numerous studies related to innovation and management of innovation have started their discussions by using this cliché sentence.

We also agree with that innovation is an important instrument to remain competitive and to survive in today's business world. However, it should not be ignored that innovation creates temporary monopolies, allowing abnormal profits that would soon be competed away by rivals and imitators (Pol & Carroll, 2006). Furthermore, achieving innovation is burdened by two sources of uncertainty; first, the time span between investing is realized and its financial return is obtained, and second because it could be easily copied without incurring in the cost of "*research & development (R&D)*" (Escribano & Giarratana, 2011).

There are plenty of resources discussing essentials and life cycle of a typical innovation process. It is a common concept that we can hear/see nearly everywhere in our daily life. Therefore, instead discussing its origin where this word comes from and how it is defined and classified in well-respected manuals (e.g. "*Oslo Manual*"), in this thesis, we only focus on "*Computer-Aided Innovation (CAI)*" that is mostly related to "*technological innovation*", "*product innovation*", and "*incremental innovation*".

Although it is a well-known concept and it has wide-spread usage by any scale of society, we would like to give our understanding to help readers to be aware of what we mean with "*innovation*" throughout this thesis. "(*Technological) innovation process*" can be considered as the transformation process of a technology from an idea to a commercial product. This process has three main phases that have to be carried out sequentially as illustrated in Figure-1.1, namely as; "*fuzzy front end (FFE)*", "*new product development (NPD)*" and "*commercialization*". FFE is the idea generation phase initiating the process. Major outcomes of this phase are a well-defined concept, clear development requirements and a business plan aligned with the corporate strategy (Kim & Wilemon, 2002). The second phase aims to produce concrete products as outcomes. Commercialization is the last step of the innovation process. Without achieving commercialization phase, outcome of the process may be called as "*invention*". The market determines whether an invention becomes an innovation (Kusiak, 2009). Having commercialized, the process continues with adoption of introduced innovation. However, from companies' perspective, the process ends with (duplicative and/or creative) imitation by competitors.

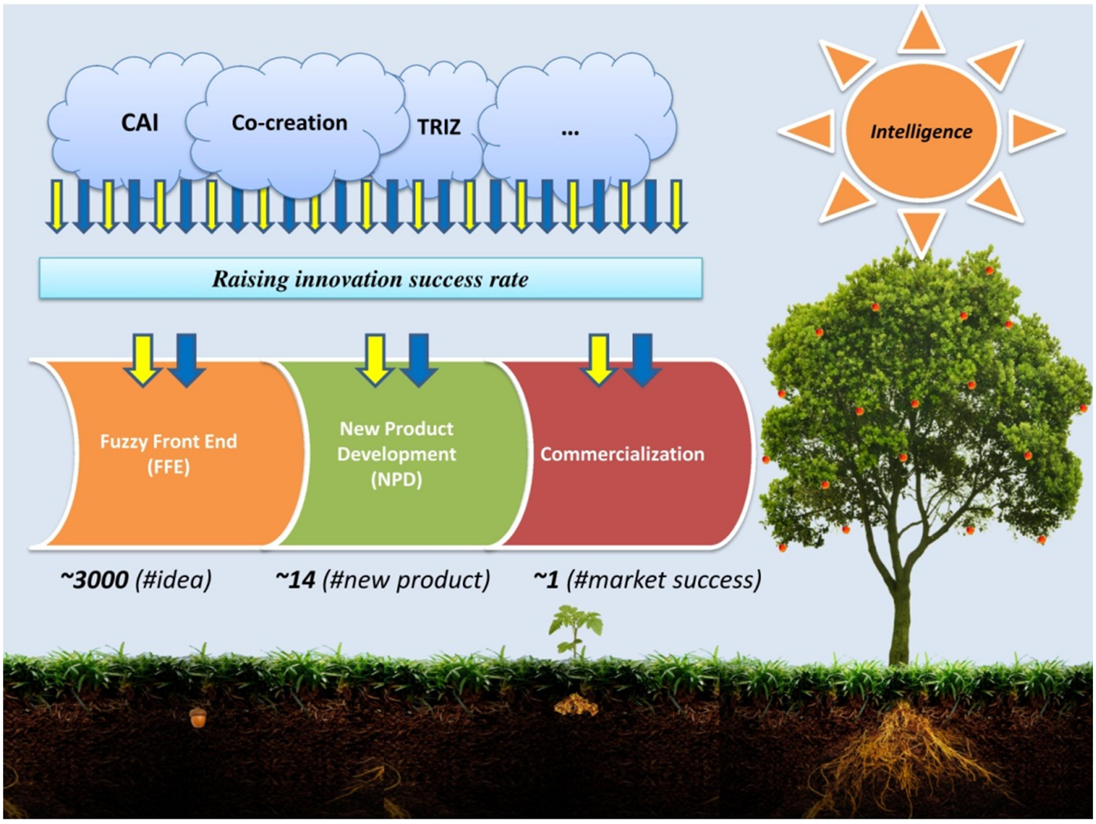


Figure 1.1 Three main phases of a typical innovation process

Innovation is a risky and expensive endeavour resulting in low success rates, reported roughly like that three thousand ideas transform into fourteen new products and one of these new products becomes successful in the market (Cormican & O'Sullivan, 2004). For this reason, focusing efficiency and effectiveness in innovation process is intrinsically inevitable to raise the success obtained through innovation.

"*Computer-Aided Innovation (CAI)*" is an emerging domain using "*information and communication technologies (ICTs)*" to improve efficiency and effectiveness of innovation process. Low success rates of this risky/expensive endeavor and technological and managerial barriers in NPD induced by increasing product complexities, dynamism on customer requirements and internationalization and/or decentralization of NPD make CAI tools and methods crucial and unavoidable. It is anticipated that changes in innovation paradigms will occur through the use of CAI, and new ICTs such as semantic web, automated negotiation, agent-based systems, text & data mining will play an important role in the future of CAI (see Leon, 2009).

This thesis presents two novel CAI methods aiming to improve "*industrial innovation intelligence*" for successfully completion of the innovation process. Former is named as "*Quick Innovation Intelligence Process*" and it is a novel approach for assessment of candidate technologies with respect to their innovation potentials. Through this novel assessment process, this thesis aims to contribute innovation process in "*doing right things*". Latter is named as "*NegoQFD*" and it is a novel "*Quality Function Deployment (QFD)*" structure that is improved by adaptation of a multi-issue negotiation mechanism, called as "*Modified Even-Swaps*" that is also a novel multi-issue negotiation mechanism developed in this thesis study. Through adaptation of multi-issue negotiation to QFD and also to NPD, we provide a mode for customer co-creation in NPD and hence we contribute innovation process in "*doing things right*" by this way. Ultimately, this thesis aims to support its users in doing right things right in the innovation process to obtain effective success as illustrated in Figure-1.2.

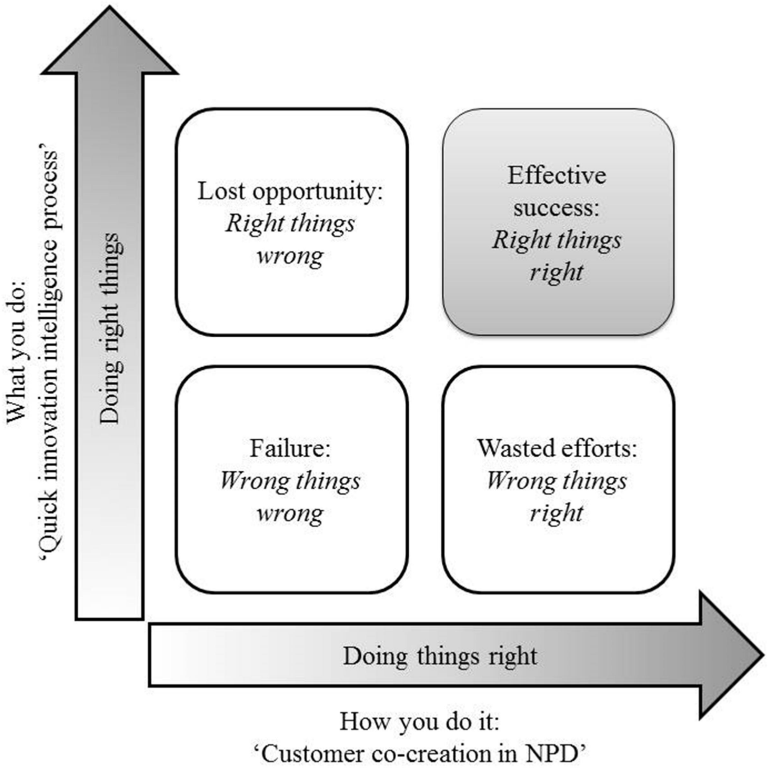


Figure 1.2 Effective success in innovation process

This thesis is organized as follows;

In Chapter-2, we present a research profiling study on CAI to better understand what CAI is and how it is perceived by researchers working on this domain. In this chapter, papers related to CAI literature are handled as a whole by bibliometric analysis to draw the big picture helping us to understand the scope of CAI better.

In Chapter-3, we introduce the "*Quick Innovation Intelligence Process*", a novel approach for assessment of candidate technologies with respect to their innovation potentials by considering commercialization, imitation and trendiness factors all together. According to our best knowledge, this process is the first attempt in the literature that is dedicated to winning innovation intelligence and takes above mentioned factors together into account. Main input resources of the process are patents, scientific publications and market research reports. While trendiness of technologies is evaluated with the help of a fuzzy inference system that combines patent data and publication data, commercial and imitation potentials are evaluated by means of some marketing indicators and determinants in the proposed assessment process.

In Chapter-4, we propose a novel technology evaluation approach based on an advanced/improved version of fuzzy logic, namely; "*interval type-2 fuzzy sets and systems (IT2FSSs)*". Proposed approach enables us to make a strategic evaluation directing considerations to use-inspired basic researches, hence achieving science-based technological improvements which are more beneficial for society. This approach is an extended version of a part of the "*Quick Innovation Intelligence Process*" using a "*type-1 fuzzy inference system*" in order to evaluate *trendiness* of candidate technologies. In this chapter, influence of the use of IT2FSSs is also investigated by comparison with the results of its type-1 counterpart. Comparison results show that proposed approach provides handling more uncertainty through modelling it by using IT2FSSs and therefore it improves technology evaluation outcomes.

In Chapter-5, we discuss the imovator's dilemma concerning how to decide when to be offensive and when to be defensive. Although being an "*innovator*" has some merits, being an "*imitator*" has its own merits as well. Staying competitive therefore requires consideration of "*imovation*" – both innovation and imitation, simultaneously. An "*imovator*" should play role of "*offensive imovator*" (near to being pure innovator) when innovation is worthwhile. In case of otherwise, being a "*defensive imovator*" (near to being early imitator) can be compatible strategy. How to decide when to be offensive/defensive greatly depends on "*innovation potentials*" assessed by consideration of both corresponding technological and market conditions. This chapter discusses how the Quick Innovation Intelligence Process can contribute to solution of the imovator's dilemma.

In Chapter-6, we propose a novel, clear, rational, and an easy-to-use mechanism for multi-issue negotiation named as "*Modified Even-Swaps*". This mechanism is an important part of the "*NegoQFD*" that is a multi-issue negotiation based QFD structure contributing to QFD in terms of various aspects as discussed in Chapter-9, comprehensively. "*Even-Swaps*" is a well-known and easy-to-use trade-off methodology providing several useful features to decision makers. It allows them to find the difference among alternatives in terms of any issue under consideration. In a typical negotiation environment, allocating these differences in terms of a bargainable issue can help the negotiators to clarify the agreement area for each alternative. This allocation can contribute to make bargaining decisions more rationally. However, this feature could not be used in the original version of the Even-Swaps method because of its rigid structure trying to reveal only the best alternative. The original Even-Swaps method also provides several hypothetical questions to decision makers while performing issue trade-offs. It is believed that the original Even-Swaps method can be improved upon (adapted) by forwarding the hypothetical questions to counter-side and by developing a modified/flexible structure considering all bargainable alternatives. With these modifications are successfully realized, an agent can generate counter-offers and interact with counter-side for bargaining by means of an appropriate automated negotiation mechanism. This chapter proposes a modified version of Even-Swaps as a novel multi-issue negotiation mechanism, finding differences among alternatives and making use of those differences to assess the value of multi-issue offers. It uses a fuzzy inference system for bargaining on several issues, simultaneously. In order to accomplish the steps of the proposed mechanism, a supplementary decision aid tool, so called: "*Modified Even-Swaps Agent (MESA)*" is also developed and introduced in this chapter.

Number of trade-offs performed significantly influences routines of the Modified Even-Swaps mechanism. In Chapter-7, we introduce a novel approach providing "*practical dominance reinforcement*" to accelerate the mechanism through eliminating unnecessary trade-offs. This approach proposes to use of "*Simple Additive Weighting (SAW)*" method in order to combine issues which have high variation among consequences of alternatives under consideration. As a result, these issues utilize a combined consequence for each alternative. Phase of the mechanism aiming to identify dominated alternatives is executed by using revised decision-matrix including consequences of issues having high variation as combined. This revision allows the mechanism to identify dominated alternatives more practically. Possible improvements are demonstrated and discussed with some cases in this chapter.

Clarification of an agreement area is essential for rational automated & multi-issue negotiation. Modified Even-Swaps mechanism provides a well-defined agreement area for each negotiable issue in multi-issue negotiation environment in where each consequence of alternatives is defined as a crisp value. However, if something is negotiable, its definition is also fuzzy. Fuzziness resulting from competitive environment and fuzziness from the definition of negotiable issues create a "*footprint of uncertainty (FOU)*" in fuzzy sets corresponding to agreement areas, requiring a type-2 fuzzy approach to handle them. In Chapter-8, we therefore address how to handle type-2 fuzziness in multi-issue negotiation environment by means of the Modified Even-Swaps mechanism.

In complex product design environments, new product development (NPD) becomes all about trade-offs and therefore trade-off management gets an important responsibility for designers. Correspondingly, in these environments, customer co-creation in NPD requires multi-issue negotiation with issue trade-offs. However, there is no study researching customer co-creation in NPD through multi-issue negotiation with issue trade-offs according to our best knowledge. Chapter-9 presents a framework for customer co-creation in NPD through Modified Even-Swaps to fill this gap. In the proposed framework, customers are represented by "*lead-user*". Thus, negotiation is performed between lead-user and designer. In order to show how the framework works, an illustrative example is also presented.

QFD is one of the most common methodologies in NPD because it provides a systematic procedure for effective and efficient knowledge creation and sharing. However, it becomes unreasonable because of some technical obstacles mostly induced by increasing product complexities, dynamism on customer requirements and decentralization of NPD. Adaptation of multi-issue negotiation mechanisms to QFD methodology has a great potential to tackle these obstacles because; *i*) a negotiation based structure may enable QFD to define a large number of interdependent decision parameters while handling complicated design trade-offs, *ii*) a negotiation based structure may be faster as it includes changing customer requirements in real-time rather than a cycle-time determined by length of the product development process, *iii*) a negotiation based structure may allow decentralized NPD teams to negotiate each other and customers, concurrently. Correspondingly, in Chapter-10, we propose the "*NegoQFD*" - a multi-issue negotiation based QFD methodology adapting the *Modified Even-Swaps* mechanism.

An example addressing "*washing machine development*" is also provided to give some practical insights when using the methodology proposed in this chapter.

In Chapter-11, we conclude by summarizing key contributions of this thesis and by suggesting future research directions.

CHAPTER 2

COMPUTER-AIDED INNOVATION

"*Computer-Aided Innovation (CAI)*" is an emerging domain in the array of "*computer-aided technologies (CA*)*" (Leon, 2009). It is explicitly known that it aims to support enterprises throughout the entire innovation process (Leon, 2009). However, definition of the term CAI is still fuzzy (Hüsig & Kohn, 2009). Instead classical literature review, "*research profiling*" studies are more supportive to understand the structure, important variables, pertinent methods and key needs of any subject (Porter et al., 2002). Therefore, in this chapter, a research profiling study is performed to understand the scope of CAI and how it is perceived by researchers working on this domain.

Most development pertinent to research profiling falls under the term "*bibliometrics*" (Porter et al., 2002). Bibliometric analysis is a widely used research method for detecting state of the art for a particular field. This method is capable of utilizing quantitative analysis and statistics to describe patterns of publications within a given period or body of literature. Researchers employ bibliometric analysis for determining the evaluation of a field of study or to ascertain influences and the relationships of several distinct fields.

One favourable way of conducting bibliometric analysis has been searching for publications listed in the Social Science Citation Index, the Science Citation Index or the Arts and Humanities Citation Index. Similarly, we have collected the papers on CAI domain through a search from the "*Thomson Reuters' Web of Science/Knowledge (WoS/K)*" with Conference Proceedings, consisting Science Citation Index-Expanded (SCI-E), Social Science Citation Index (SSCI), Conference Proceedings Citation Index- Science (CPCI-S) and Conference Proceedings Citation Index- Social Science & Humanities (CPCI-SSH) databases.

"*Computer aided innovation*" has been searched as the main keyword in the topics of the studies to retrieve the relevant works. The articles including the keyword in their topics were considered as main candidates for inclusion in the review. It can be seen from the search results that there are less than fifty scientific papers. From the results, it can also be seen that these papers are from conference proceedings and journal issues, which are especially dedicated to CAI. Therefore, we have also added to the pool of candidate papers the rest of the papers which they do not include the term "*computer aided innovation*" in their topics but they are published in proceedings of the conferences and in the journals.

It has also been observed that amount of the papers published in conference proceedings is much more than amount of the papers published in journals. A higher occurrence in conferences might mean that this idea/topic is in its infancy where researches are still looking for a peer-to-peer debate (Porter et al., 1991). When considered the distribution of corresponding studies, we can conclude that CAI is in its infancy.

In research profiling studies, related studies are handled as a whole to understand the big picture of the research domain. Particularly, visual forms (e.g. maps, networks etc.) enable a human to recognize the attributes of things fast and to understand the big picture clearly (Yoon, 2010). Keywords in a scientific paper help us to be informed about the content of the study. Correspondingly, a "*keyword-correlation map*" which is drawn by using retrieved keywords from relevant papers can also enable us for information extraction about general perception of CAI domain.

Correspondingly, we have drawn correlation map of keywords retrieved from CAI publications in the literature. Figure-2.1 shows the keyword-correlation map of CAI literature. Each node represents a keyword used in CAI related papers. Connecting lines, i.e., arcs, as per the legend, indicate the correlation of any couple of keywords. Existing links indicate that corresponding keywords have been used together in the same article, and their thickness shows the relative degree of association.

When reviewed Figure-2.1, it is explicitly seen that the highest frequency of being used together is between "*computer aided innovation*" and the "*theory of inventive* *problem solving (TRIZ)*". Therefore, relation between CAI and TRIZ needs to be reviewed firstly to understand the scope of CAI.

Making technology forecasting for future innovation is an ill-structured problem (Runhua, 2011). TRIZ is developed for stimulating invention via forecasting the evolution of technologies. It is specific for solving "*inventive problems*", a sub-set of ill-structured problems (Runhua, 2011). For that reason, it can be said that TRIZ has been popular in CAI domain since TRIZ based CAI tools help users to solve the ill-structured problems. Additionally, it is considered that TRIZ is not only a specific technology for innovation but also the technology for software development of CAI (Runhua, 2005). This consideration brings into sharp relief existing relationship between CAI and TRIZ.

Innovative idea generation is the key step of technological innovation processes. In a review study, it is reported that nearly the half of all CAI tools (*46%*) falls into the idea management category, *33%* of the CAI products supports strategy management, *17%* of them aims to support patent management activities, and *4%* of them aims to support for holistic solutions (Hüsig & Kohn, 2009). Idea management related CAI tools support fuzzy-front-end (FFE) phase of the innovation process. On the other hand, CAI tools developed for the patent management activities are generally used to improve creativity and ultimately innovation. Therefore, these tools can also be considered as they aim to support FFE phase. As a result, it can be said that up to now most of the CAI tools have been focused on FFE phase of the innovation process.

Figure-2.2 shows the map of CAI – TRIZ – * correlations. When Figure-2.2 is reviewed, it is observed that CAI studies have been constructed on three pillars; "*design*" (computer aided design, concept design etc.), "*problem solving technique*" (TRIZ, standard solutions etc.), and "*optimization*" (evolutionary algorithms, genetic algorithm etc.). When these pillars of CAI are taken into account, perception of the term innovation within the scope of CAI can be abstracted as; Innovation is any improvement on the product performance with the implementation of value added changes which overcome the existing problems in design.

Leon (2009) claims that in recent a more comprehensive vision conceives CAI as beginning at the FFE of perceiving business opportunities and customer demands, then continuing during the creative stage in developing inventions and, further on, providing help up to the point of turning inventions into successful innovations. As being collinear with the recent vision of CAI, this thesis proposes two CAI approaches. While the Quick Innovation Intelligence Process aims to direct considerations to perception of business opportunities and customer demands in a strategic manner, the NegoQFD aims to create a mode for customer co-creation in NPD to improve the provided utility to customers and hence to improve commercial success in the market.

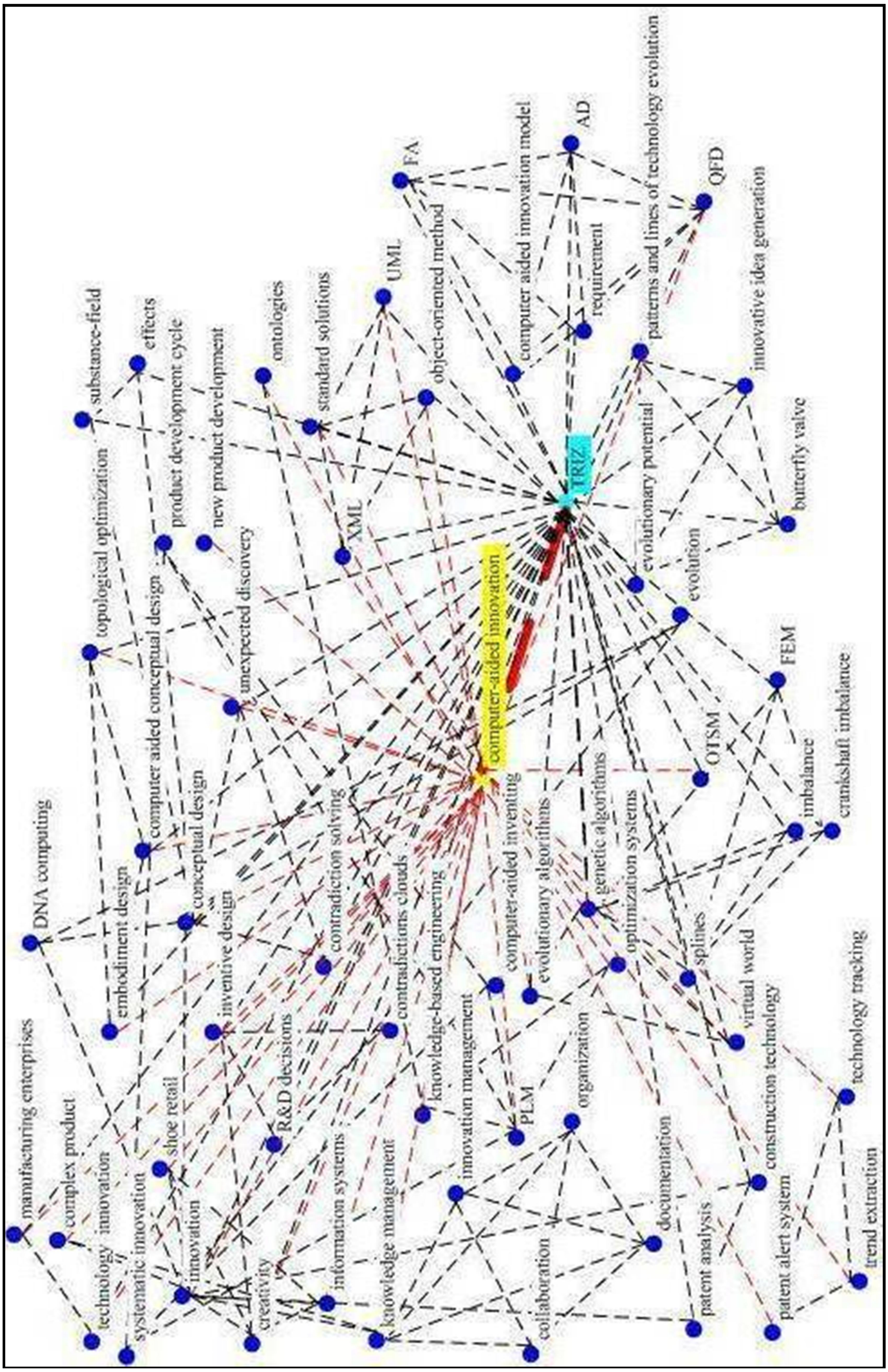


Figure 2.1 Keyword-correlation map of CAI: Map of all correlations

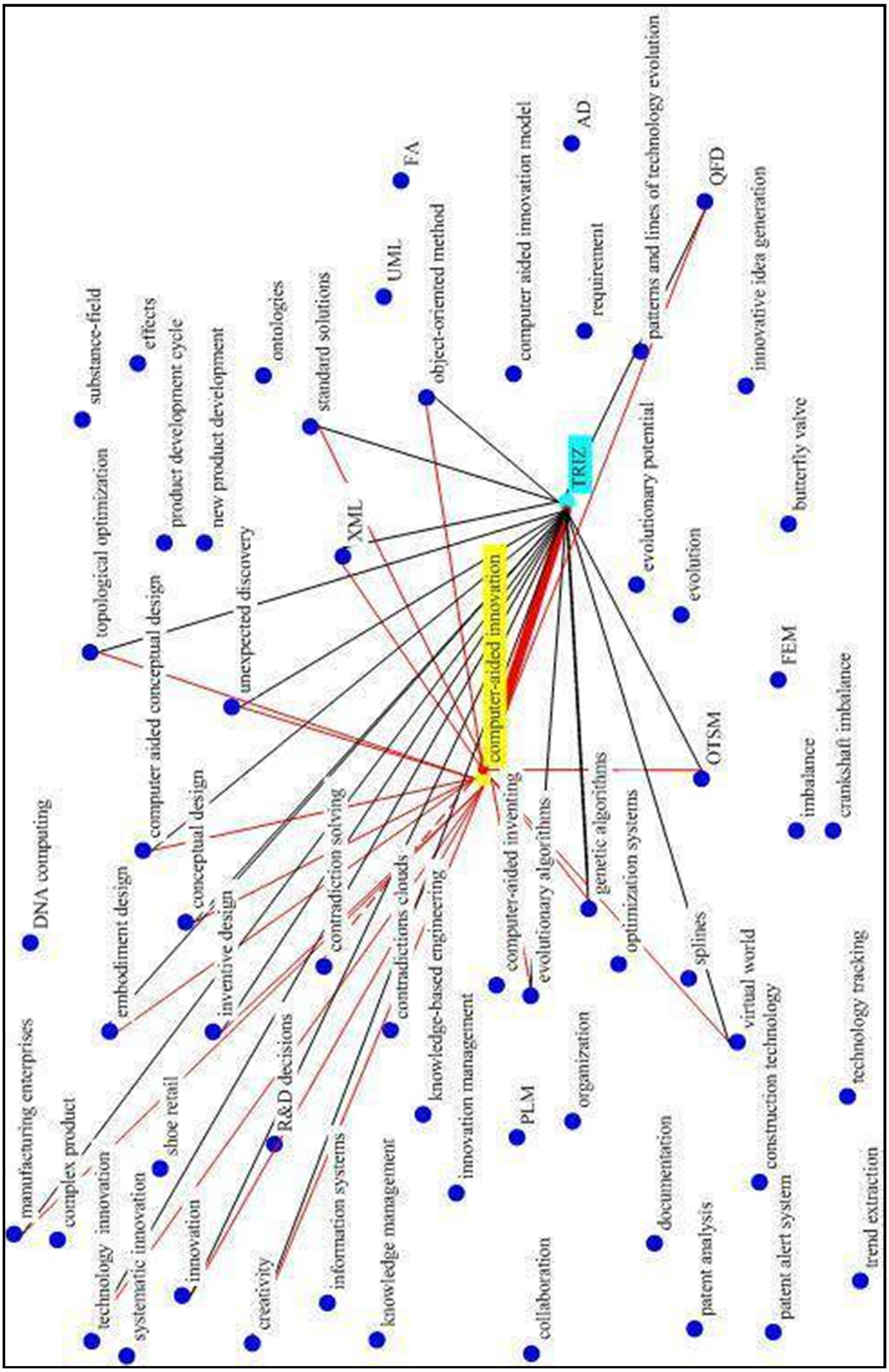


Figure 2.2 Keyword-correlation map of CAI: Map of CAI-TRIZ-*

CHAPTER 3

A NOVEL APPROACH FOR ASSESSMENT OF CANDIDATE TECHNOLOGIES WITH RESPECT TO THEIR INNOVATION POTENTIALS

3.1 Introduction

"*Intelligence*" is considered as the ability to use limited resources optimally to achieve goals (Kurzweil, 2000). Innovation process has its drawbacks and it is burdened by two sources of uncertainty. Former is related to the time span between investment is realized and its financial return is obtained. And latter is because it could be easily copied without incurring in the cost of R&D (Escribano & Giarratana, 2011). Innovation is considered as a risky and expensive endeavour, which results in low success rates (Cormican & O'Sullivan, 2004) and assessment of innovation potentials is therefore essential when making strategic decisions.

"*Innovation intelligence*" is related to use of intelligent approaches for assessment of technologies according to their innovation potentials to make maximum profits. It is about the provision of relevant information on innovations and the evaluation of their impact on the corporation (Golovatchev & Budde, 2010). Innovation intelligence can also be considered as a process aiming to identify, qualify and evaluate technologies in order to develop a viable innovation strategy (Golovatchev & Budde, 2010). It is necessary for doing the right things, i.e., for effective innovation processes. It is expected that performance on making money (i.e., profitability) is better during the time from commercialization of invention to imitation of innovation because of monopoly power. Share of innovator on the benefits obtained from innovation decreases with the imitation process performed by competitors. For this reason, in order to generate "*winning innovation intelligence*", innovation potentials should be evaluated by considering the ability for commercialization and the resistance for imitation. In other words, when considered the cycle of a typical innovation, winning innovation intelligence can be possible with evaluation of commercial and imitation potentials, and then, to infer about innovation potentials, combination of their results with a suitable data-fusion methodology (see Figure-3.1).

Although corresponding literature is scarce, there are some preliminary attempts to assess innovation potential. Justel et al. (2007) proposes a method for assessing innovation potential of product concepts for selecting the concept having greater probability of success. This method takes into account the degree of novelty of product concepts. In another study, Jayanthi et al. (2009) uses "*data envelopment analysis (DEA)*" to evaluate innovation potential of US photovoltaic industry. In this study, innovation potential is measured in terms of the relative efficiency by considering a best practices frontier. Gupta et al. (2011) proposes a method to decide innovation potential and type of innovation for a design concept.

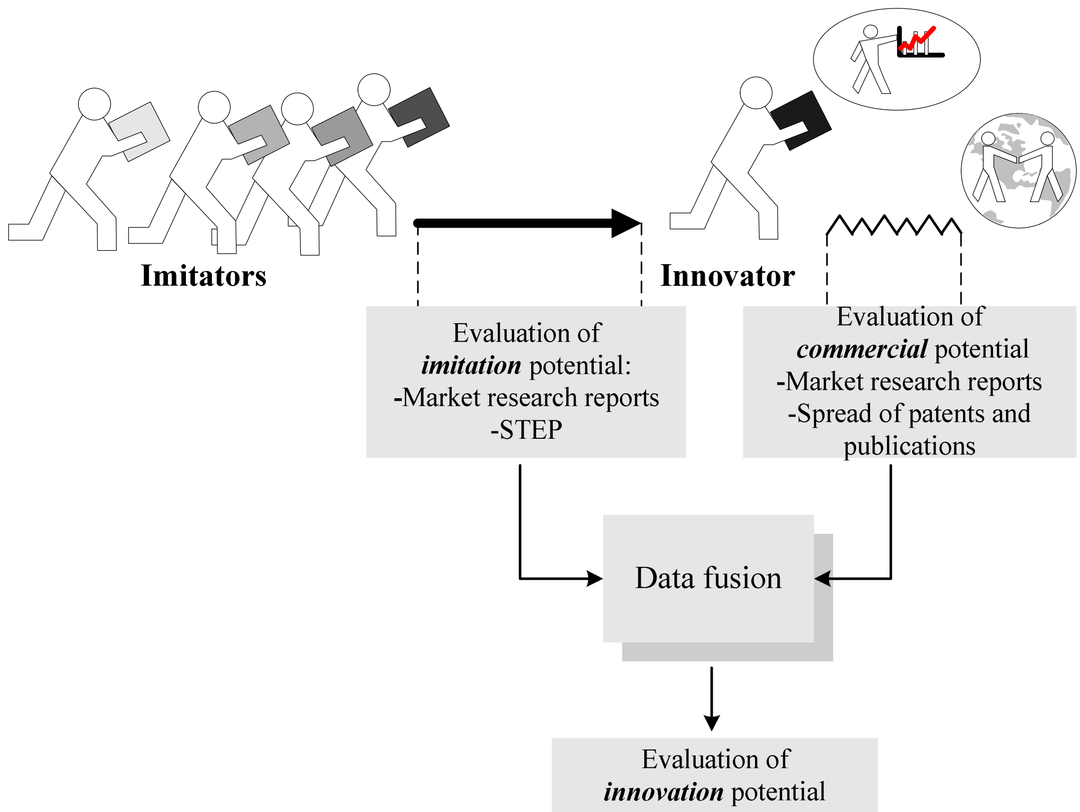


Figure 3.1 Generation of the winning innovation intelligence

In this chapter, a novel approach for assessment of candidate technologies with respect to their innovation potentials, named as; "quick innovation intelligence process" is proposed. According to our best knowledge, the proposed approach is the first attempt in the literature that is dedicated to generate the winning innovation intelligence and that takes commercialization, imitation and trendiness factors all together into account. In the proposed approach, while trendiness of candidate technologies is evaluated with the help of a fuzzy inference system combining patent data and publication data, commercial and imitation potentials are evaluated by means of some marketing indicators and determinants. Furthermore, the proposed approach has been designed to be supported by ICTs. Therefore, it can be considered as a contribution to the CAI literature.

3.2 Proposed approach

As it is discussed in the first section of this chapter, it can be said that evaluation of innovation potential by firstly evaluating commercial and imitation potentials and then by combining their results with a suitable data-fusion methodology is essential to generate the winning innovation intelligence. However, it should also be taken into account that everyday numerous different ideas come to mind but so many of them are not worth evaluating as a candidate. For this reason, a pre-elimination process is needed to be quick during the evaluation process. This also enables us to respond quickly to sides corresponding to the candidate technologies those are not worthwhile to evaluate seriously.

Proposed approach includes four main phases as follows; Trendiness evaluation as a pre-elimination process, commercial potential evaluation, imitation potential evaluation, and finally a phase grouping and prioritizing candidate technologies according their innovation potentials.

3.2.1 Pre-elimination through evaluation of trendiness

Scientific and technological findings are generally transformed into publications, patents and/or industrial applications in due course in order to introduce, protect and/or commercialize those findings. For this reason, patents and publications are able to reflect the advances in science and technology, and also publications and patents – as by-products of the exploitation and exploration of science and technology – provide a lot of insight into actual practices leading to technological innovation (Porter & Cunningham, 2005).

Once a specific technological thrust has been identified, bibliometric methods can be used to determine its status in its life cycle (Martino, 2003). Use of publication and patent data to determine whether a technology is emerging / growing is therefore considered as one of the most reasonable approaches (Arman et al., 2009). Correspondingly, in this phase, we use patent and publication data to evaluate candidate technologies according to their trendiness. Patent data is retrieved from the online database of the European Patent Office (EPO). The European Classification System (ECLA) is used by EPO for carrying out the searches. ECLA, in which the entire range of technologies is divided into sections, classes, sub-classes, and groups according to their scope, is used to collect patent data for corresponding technologies. WoS/K database is used to reach publication data.

The evaluation process is illustrated in Figure-3.2, and it is as follows. Firstly, ECLA class for each candidate technology is determined since ECLA class of a technology can reflect its status. Subsequently, some keywords are generated to make a link between patents and publications corresponding to candidate technology. And then, for patents and publications, their yearly total amounts for last ten years are collected from publication and patent database above-mentioned. "*Hotness*" is measured in order to evaluate candidate technologies. It is simply calculating a ratio of amounts of patents/publications appeared in last three years to those appeared in last ten years (Arman et al., 2009). Consideration of only amounts could yield bias since amounts of patents/publications may be important for a specific technology but for another technology they may not be important. Use of "*hotness*" enables us to tackle this obstacle. Mamdani-type fuzzy inference system is used to fuse patent and publication data. Fuzzy input sets are generated by considering hotness values. Patent data and publication data are classified into three groups as low, medium and high by using k-means algorithm. The values limiting these clusters are used to define fuzzy membership functions. And then, output variables and their ranges are defined as trendy, classical and dated. A rule-base is also generated by considering which data source is more reliable.

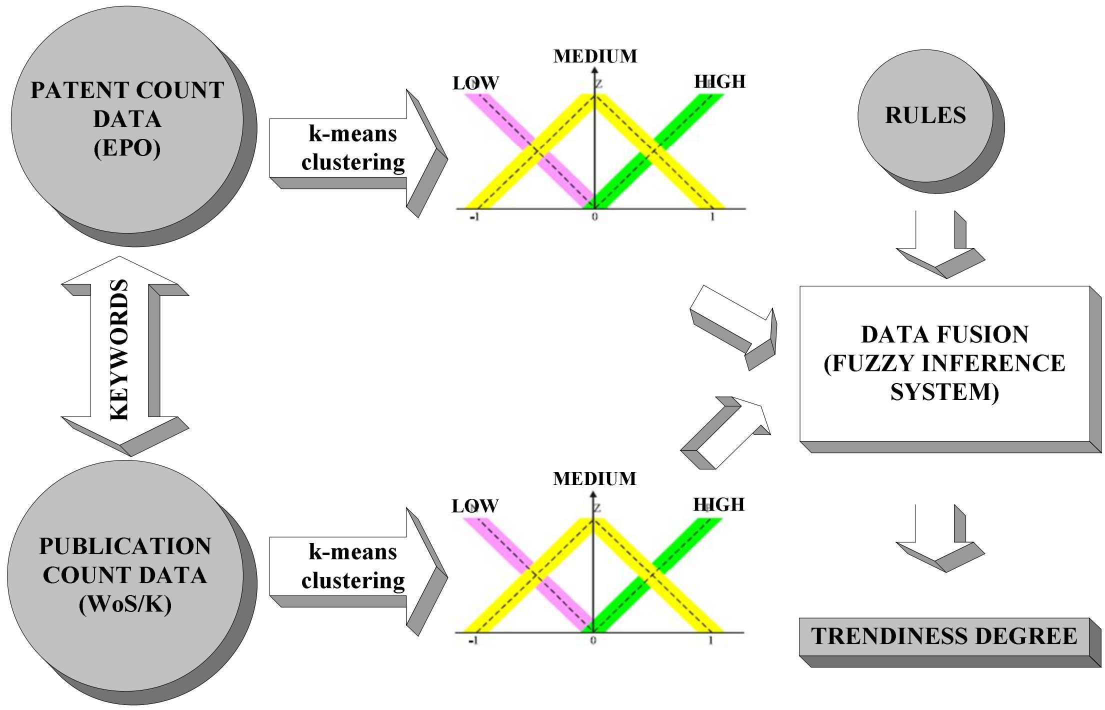


Figure 3.2 Pre-elimination through evaluation of trendiness

For each candidate technology, this system generates a crisp value representing the trendiness degree in the end of the process. A ranking list is obtained by taking these trendiness degrees into account. This ranking enables us to eliminate candidate technologies those are not worth for further evaluation when compared to the rest. Candidates remaining after this pre-elimination proceed to further evaluation phases of the quick innovation intelligence process.

3.2.2 Evaluation of commercial potential

As technology develops in a speedy manner, its life cycle tends to be reduced faster and the importance of successful commercialization of developed technology is getting higher (Sohn et al., 2005). Evaluation of commercial potentials of candidate technologies is decisive in private sectors and in public sides. In the literature, various evaluation methods have been developed. A literature review on these evaluation methods can be found in Bandarian (2007) and Sohn et al. (2005).

According to Jain et al. (2003), the "*Strategic Technology Evaluation Program (STEP)*" is the most appropriate tool to evaluate new technologies at the early stages of technology development. STEP was formulated as a synthesis of six evaluations including; technology evaluation, process evaluation, economic evaluation, market evaluation, perception evaluation, and regulatory/policy evaluation (Bandarian, 2007). Figure-3.3 shows the STEP using fuzzy inference system. Evaluations are made by experts. In real world applications, precise data concerning commercial potential factors are not available or are very hard to extract (Bandarian, 2007). Furthermore, use of words while evaluating is preferred by experts. Therefore, Bandarian (2007) proposed a fuzzy inference based STEP to overcome these obstacles.

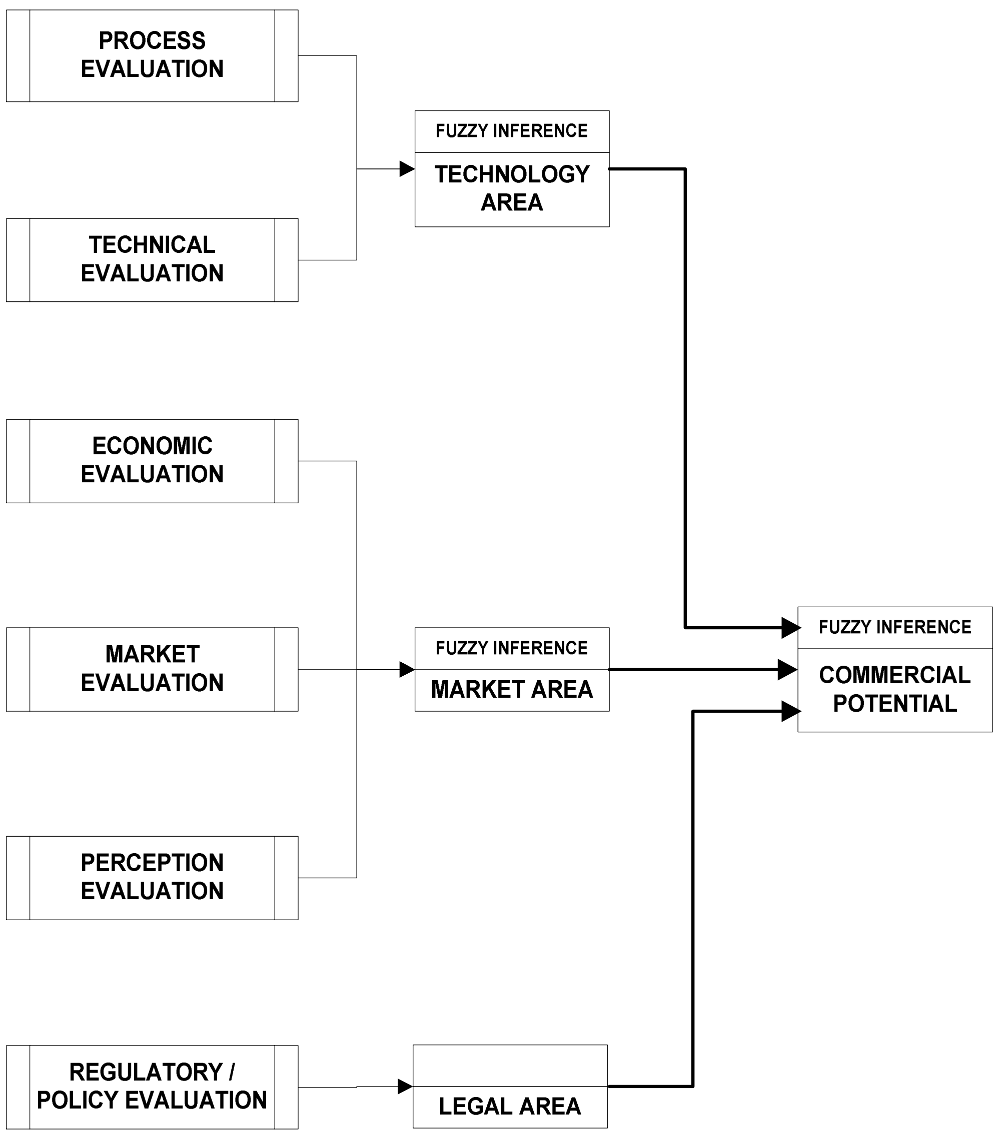


Figure 3.3 Fuzzy inference based STEP

It is a fact that many evaluation methods have been developed but they generally need opinion of experts. Use of determinants is another approach enabling us to perform evaluation without experts. Rahal & Rabelo (2006) provide some commercialization-related determinants those are crucial to the successful commercialization of university technologies. An evaluation system depending on experts' opinions prevents computerizing the process. A CAI tool should therefore use determinants and/or indicators instead opinions of experts.

Correspondingly, the Quick Innovation Intelligence Process uses the results of market researches as determinants of commercial potential rather than opinions of experts. "*Market Research Monitor (www.researchmonitor.euromonitor.com)*" is a brand new online collection of huge amounts of market reports. It is designed specifically for libraries and users gain a complete view of the consumer marketplace in 80 countries. It enables its users to access professional and high quality market data to identify leading subcategories in each market, to know five-year forecasts to assess how each category will develop. For that reason, database of Market Research Monitor is used to evaluate commercial potential of candidate technologies.

3.2.3 Evaluation of imitation potential

The innovator firms lose their monopoly power and also their market shares gets smaller after imitation by competitors. For this reason, imitation has great influence on benefits of innovation. Protection of innovation has therefore been intensively studied (see Lemer, 2009; Park, 2008; Qian, 2007) but according to our best knowledge evaluation of imitation potentials of candidate technologies at their early stages has hardly ever studied.

Robert (2009) asserts that tacit knowledge and complexity are especially important to prevent imitation. It is generally accepted that tacit knowledge is non-codified, disembodied know-how that is acquired via the informal take-up of learned behaviour and procedures (Howels, 1996). It prevents imitating since it is accepted that tacit knowledge cannot be directly or easily transmitted by codifying and learning. Tacit knowledge is therefore a key barrier in imitation process, and it can help innovators to resist imitation by competitors.

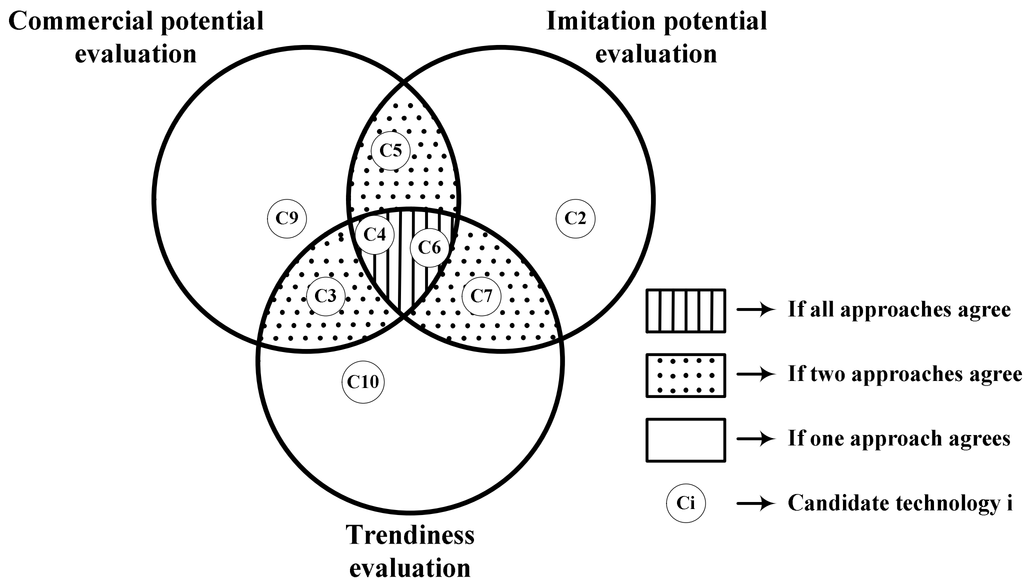
How can we realize at early stages whether a technology includes tacit knowledge or not? In order to do this, we can utilize patent and publication data. We may infer about tacit knowledge in technology by observing spread of patent and publication. For example, if huge amounts of patents have been granted by same country, it may mean that this technology class includes tacit knowledge. Alternatively, we may measure similarity by performing text mining. In that case, tacit knowledge may be measured with the help of similarity degrees. Market Research Monitor may also be helpful to evaluate imitation potentials. Observing top players and their brands, and assessment of company shares in the market may give an idea about imitation potentials.

3.2.4 Grouping and prioritizing candidate technologies

Having performed above-mentioned evaluation steps, each evaluation gives a ranking list for candidate technologies. However, we have to obtain a unique ranking in the end of process. For this reason, we need to fuse (combine) the data obtained from these evaluations. The problem faced in this stage is that there is no explicit correlation among results between results of evaluations. Therefore, a data fusion process in order to obtain a unique ranking list may be questionable.

For a similar problem, Arman et al. (2009) used a simple prioritizing method for the same situation which there is no explicit correlation between data sources. Through this method, rather than ranking precisely, a grouping is achieved in order to emphasize the importance of candidate technologies. The Quick Innovation Intelligence Process uses this method to make grouping and prioritizing candidate technologies according to their innovation potentials.

Figure-3.4 shows graphically how the grouping method works. Assume that there 10 candidate technologies and they are evaluated according to their commercial potentials, imitation potentials and trendiness. Three different ranking lists are obtained after these evaluations. At this stage, a limit is needed to be specified by considering budget that is available. Assume that top five candidate technologies will be considered. If a candidate technology is in the top five in every list, this technology will be a member of Class-A. If the technology is in the top five of any two of these lists, this technology will be member of Class-B. And the rest of them will be member of Class-C. The candidate technologies which they are not in top five in any list will be member of Class-D. As a result, the Quick Innovation Intelligence Process enables us to classify candidate technologies according their innovation potentials.



A	C4, C6
B	C3, C5, C7
C	C2, C9, C10
D	C1, C8

Figure 3.4 Grouping and prioritizing according to innovation potentials

3.3 An illustrative example

In this section of this chapter, an application of the proposed approach is presented. There are nine candidate technologies waiting for investment decision in this application. Table-3.1 gives the details corresponding to these technologies.

Initially, corresponding patent data are retrieved from EPO database. Hotness values are calculated by using the data (see Table-3.2). Three types of hotness values are used to generate input fuzzy sets. *Hotness1* is determined by calculating the ratio of appearance in the last two years to appearance in the last ten years. The ratio of appearance in the last three years to appearance in the last ten years is used to determine *Hotness2*. And similarly the ratio of appearance in the last four years to appearance in the last ten years is used to determine *Hotness3*.

The next step is to generate some keywords to make a link between patents and publications. The keywords are obtained from our earlier study (Dereli et al., 2010). They are determined by using the definitions of the each sub-class. Afterward, the numbers of publications are obtained by using the database of WoS/K. *Hotness* values for publications are calculated by using the data (see Table-3.2).

Both patent and publication data are classified into three groups as *low*, *medium* and *high* based on estimated numbers of data in each class by using *k-means clustering* algorithm. The values limiting these clusters are used to define fuzzy membership functions for a certain patent and publication data (see Figure-3.5).

Table 3.1 The candidate technologies

Candidates	Market	ECLA
C1	Camcorders	H01L
C2	Cameras	H01P
C3	Computers and Peripherals	H01S
C4	Home Audio and Cinema	H01G
C5	In-car-Entertainment	H01B
C6	Mobile Phones	H01T
C7	Portable Media Players	H01Q
C8	Televisions and Projectors	H01R
C9	Video Players	H01C

Table 3.2 Calculated hotness values for corresponding patents and publications

	Patent			Publication		
	Hotness1	Hotness2	Hotness3	Hotness1	Hotness2	Hotness3
H01B	0,25241128	0,35031847	0,45859872	0,27841205	0,38002160	0,46729204
H01C	0,20125786	0,30188679	0,38679245	0,31037362	0,40222190	0,48144636
H01F	0,18294177	0,26879942	0,35229847	0,30072004	0,39975112	0,48421295
H01G	0,19095349	0,28511916	0,38374674	0,22750239	0,33111672	0,42182419
H01H	0,19621663	0,29261466	0,38480608	0,38273707	0,47931690	0,55305254
H01J	0,14966946	0,24279512	0,34739213	0,29233578	0,39251002	0,47649936
H01K	0,16053811	0,24702114	0,36169122	0,31525037	0,41957511	0,50569044
H01L	0,19338792	0,29100337	0,38861881	0,24807718	0,35232506	0,43877492
H01M	0,23228754	0,34438461	0,45088130	0,31208353	0,44226874	0,55840285
H01P	0,14895647	0,22617078	0,30895266	0,23797623	0,34567709	0,44185813
H01Q	0,18846092	0,29038448	0,39403285	0,31735356	0,43989074	0,53755386
H01R	0,19437470	0,29358411	0,38803575	0,30524811	0,40579946	0,48691035
H01S	0,14653865	0,22800880	0,31235322	0,23519941	0,34182805	0,43456460
H01T	0,18889250	0,28549357	0,37900471	0,24693790	0,35314775	0,43768736

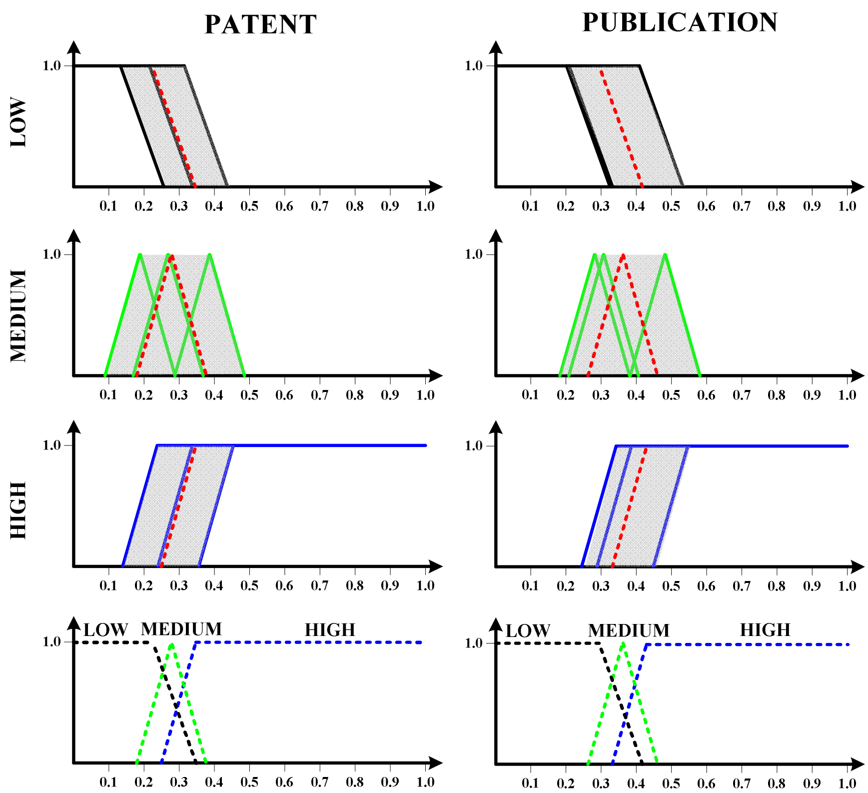


Figure 3.5 Fuzzy sets for input variables

Table 3.3 Rule base

R1	If (Hotness of Patent is *Low*) and (Hotness of Publication is *Low*) then (Trendiness of Technology is *Dated*)
R2	If (Hotness of Patent is *Low*) and (Hotness of Publication is *Medium*) then (Trendiness of Technology is *Dated*)
R3	If (Hotness of Patent is *Low*) and (Hotness of Publication is *High*) then (Trendiness of Technology is *Classical*)
R4	If (Hotness of Patent is *Medium*) and (Hotness of Publication is *Low*) then (Trendiness of Technology is *Dated*)
R5	If (Hotness of Patent is *Medium*) and (Hotness of Publication is *Medium*) then (Trendiness of Technology is *Classical*)
R6	If (Hotness of Patent is *Medium*) and (Hotness of Publication is *High*) then (Trendiness of Technology is *Trendy*)
R7	If (Hotness of Patent is *High*) and (Hotness of Publication is *Low*) then (Trendiness of Technology is *Classical*)
R8	If (Hotness of Patent is *High*) and (Hotness of Publication is *Medium*) then (Trendiness of Technology is *Trendy*)
R9	If (Hotness of Patent is *High*) and (Hotness of Publication is *High*) then (Trendiness of Technology is *Trendy*)

According to importance of patents and publications, a rule-base is designed. Table-3.3 shows the rule base used in this application. When reviewed the rules, it can be seen that patents and publications have same importance. Having designed the fuzzy system, the hotness values are entered to the system for each candidate alternative. For each alternative, the system gives a crisp output representing the trendiness degree of the technologies via center of gravity defuzzification method. These degrees are used to make a ranking list for candidate technologies. Table-3.4 shows the results of trendiness evaluation of candidate technologies.

In order to evaluate the commercial potential of candidate technologies, the database of Market Research Monitor is used. It enables us to know five-year forecasts about corresponding markets which candidate technologies will be a participant. Commercial potentials are ranked in accordance with the percentage of expected average growth (PEAG) of each market in Turkey. Table-3.5 shows the ranking list obtained from commercial potential.

While evaluating imitation potential of technology classes, we don't have information about the complexity of candidate technologies in our example. In that case, competitive landscape of the candidate technologies can help us to infer about imitation potential. As we discussed before, information about top players and assessment of company shares in corresponding market can give an idea about imitation potential. Therefore, in this stage, we have used the competitive landscape data of Turkey by using database of Market Research Monitor. A ranking list is obtained in accordance with the average market shares of top players of the corresponding technologies. The ranking list is given in Table-3.6.

After evaluating the technologies in accordance with the three different aspects, the last step of the Quick Innovation Intelligence Process, grouping, is performed to combine the ranking lists. Figure-3.6 shows groups obtained by combining the ranking lists. Grouping shows that "*C1*" and "*C8*" are the technologies which are agreed by all approaches. "*C4*" and "*C5*" are agreed by two approaches. The rest of them are agreed by only one approach. As a result of the proposed process, the candidate technologies are classified according to their innovation potential. The output of the process can be helpful making more reliable decisions to the decision makers.

Table 3.4 Ranking list obtained from trendiness evaluation

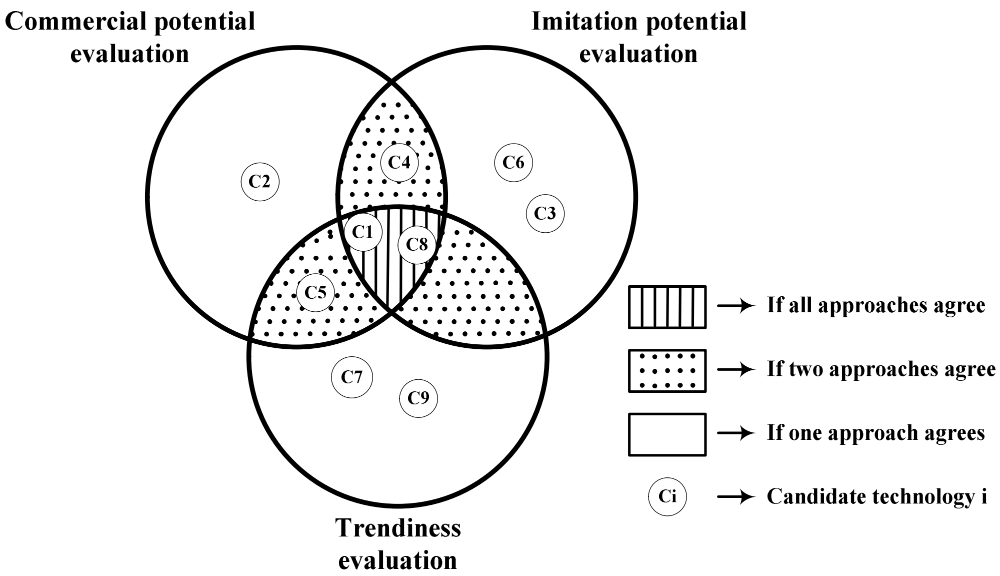
Technology	C1	C2	C3	C4	C5	C6	C7	C8	C9
Trendiness deg.	0,46	0,369	0,366	0,43	0,588	0,448	0,61	0,539	0,546
Rank	5	8	9	7	2	6	1	4	3

Table 3.5 Ranking list obtained from evaluation of commercial potential

Technology	C1	C2	C3	C4	C5	C6	C7	C8	C9
PEAG	37,7	39	16,6	23,8	17,5	8,6	10	27	1
Rank	2	1	6	4	5	8	7	3	9

Table 3.6 Ranking list obtained from evaluation of imitation potential

Technology	C1	C2	C3	C4	C5	C6	C7	C8	C9
Rank	4	6	3	5	7	1	9	2	8



A	C1, C8
B	C4, C5
C	C2, C3, C6, C7, C9
D	

Figure 3.6 Grouping candidate technologies according to their innovation potentials

3.4 Conclusion

Above and beyond its crucial importance to remain competitive and to survive in today's business world, innovation is also risky and expensive endeavor which results in low success rates. For this reason, being efficient and effective in innovation process gets very important issue to raise the obtained success through innovation. Correspondingly, a novel technology assessment process that is dedicated to winning innovation intelligence was proposed in this chapter to improve the effectiveness of innovation process. The process aims to evaluate technologies in accordance with their innovation potential through consideration of commercialization, imitation and trendiness factors all together. Patent data, publication data and market research reports are the main input resources of the proposed process. Several major advantages of the proposed technology assessment process can be given as follows.

- In the literature, although "*commercialization*" and "*trendiness*" factors have been taken mostly separately but rarely together into account, "*imitation*" has not been taken into account by the researchers for technology assessment in the early stage. Proposed technology assessment process considers these three factors all together. Therefore, outcomes of the assessment results can be more beneficial for sustainable success of firms and national economies when the process is executed.

- The proposed process uses determinants and indicators of innovation potential rather than opinions of experts. The framework reduces the overall duration of evaluations. Moreover, being independent from the opinion of experts gives an opportunity to develop computer aided tools. Therefore, quick innovation intelligence process developed in this study can also be considered within the scope of CAI methods.

- In the trendiness evaluation step, patents data and publications data are matched through a fuzzy inference system. This matching provides to direct considerations to "*use-inspired basic researches*", i.e. "*Pasteur's quadrant*" (Stokes, 1997). Focusing use-inspired basic researches can enhance the science-based technological improvements those are more value added and crucial for sustainable success

Although fuzzy logic is an effective tool for fusing two different kinds of data sources, it has not found any application in the literature for fusing publication and patent data within a technology evaluation framework. This study is also the first attempt in the literature that proposes a trendiness evaluation that is based on fuzzy logic. However, this study uses type-1 fuzzy sets and systems. The use of type-2 fuzzy sets and systems is considered to handle more uncertainties in the next chapter.

Besides, it is a fact that the reliability of the produced output is naturally influenced by the reliability of the input. For this reason, researching for more reliable input should be another topic for future studies. Moreover, in the last step of the Quick Innovation Intelligence Process, three different ranking lists are combined (fused) to classify candidate technologies. Fuzzy classification or developing different ranking fusion method can be addressed in the future studies. Making comparative analysis of the existing industrial regions through proposed assessment process and generating strategic roadmaps should also be addressed in the future studies.

CHAPTER 4

TECHNOLOGY EVALUATION THROUGH THE USE OF INTERVAL TYPE-2 FUZZY SETS AND SYSTEMS

4.1 Introduction

Scientific and technological findings are generally transformed into publications, patents or industrial applications in due course. This transformation process is quite essential in order to introduce, protect and commercialize those findings. For this reason, publications and patents are the most reliable indicators which are able to reflect the status of science and technology, respectively. Although technology is not the binding goal for developing science as in pure applied researches, and science is not the necessary prerequisite for developing technology as in pure basic researches, they can produce high benefit for the society when they are matched (Dvorkin, 2010). Therefore, investments and incentives for R&D activities should be inspired not only with the goal of fundamental understanding but also on occasion with the goal of use while policy-making (Stine, 2009).

"*Scientometrics*" and "*Technometrics*" are well-established methods in the evaluation of science and technology. Publications and patents – as by-products of the exploitation and exploration of science and technology – provide a lot of insight into actual practices leading to technological innovation (Porter & Cunningham, 2005). Any attempt to match existing metrics to the evaluation scheme would almost encounter gaps, challenges, and unanswered questions (Geisler, 2002).

Therefore, while performing strategic technology evaluation, data derived from patents and publications should be used together as matching each other in order to direct the considerations to use-inspired basic researches (also called as Pasteur's quadrant) and hence to achieve science-based technological improvements those are more beneficial for the society.

Matching different kinds of data sources and inferring about something that is depended to these data sources require a proper data-fusion methodology. Fuzzy logic is an effective and the most common data-fusion methodology where logical inferences can be derived on the basis of matching different kind of data sources. Fuzzy logic has found so many applications in variety of fields since it was introduced by Zadeh (1965) through his first paper in the field. Over these about fifty years, interest in fuzzy logic has grown exponentially bringing some new theoretical advances such as type-2 fuzzy sets and systems (Zadeh, 1975) and fuzzy functions (Celikyılmaz & Türksen, 2009). Nevertheless, fuzzy logic has not found any application for matching patent and publication data sources within a technology evaluation framework. In order to fill this gap and to demonstrate the usefulness of fuzzy logic in technology evaluation, this study proposes a novel technology evaluation framework based on an advanced/improved version of fuzzy logic, namely; "*interval type-2 fuzzy sets and systems (IT2FSSs)*".

The reminder of this chapter is organized as follows: Section-4.2 presents a literature review on technology evaluation. Section-4.3 presents basic concepts, operators of type-2 fuzzy sets and structure of type-2 FISs. In Section-4.4, the proposed technology evaluation framework that is based on IT2FSSs is presented. In Section-4.5, an application is given to show how the framework works and a comparison is performed by handling the same problem with type-1 counterpart. Finally, concluding remarks and future work are presented.

4.2 Literature review

Scientometrics (sometimes called as Bibliometrics) is a research method focused frequency based quantitative exploration of publications. This research method aims to describe patterns within a part of scientific literature and hence to obtain a better understating of what is actually taking place in the literature. This deeper understanding can better inform those charged with making difficult choices about allocating resources, generally in the context of peer review (Pendlebury, 2008).

Technometrics takes place instead of Scientometrics when patent data are explored. Once a specific technological thrust has been identified, Scientometrics and

Technometrics can be used to determine its position in its life cycle (Martino, 2003). For this reason, many researchers have used data derived from publications and patents in order to evaluate science and technology (Arman et al., 2009).

Some previous studies on technology evaluation have ignored the scientific publications while evaluating. For instance, Lee et al. (2012) used data derived from patents for modelling trends and patterns of innovation in energy sector. In another study, Yu & Lo (2009) developed a type-1 fuzzy inference system (FIS) for technological strategy planning by the help of using only patent data as input of the system. Huang & Li (2010) proposed a framework based on time series analysis, patent analysis and patent international-patent-classification (IPC) analysis in order to evaluate technology trend.

There is nevertheless a need to consider the linkages between the conceptual background of scientific generation and progress – and the measurement of its process and outcomes (Geisler, 2005). However, limited study addresses matching data of patents and publications in the literature. Daim et al. (2006) forecasted some emerging technology areas through integrating the use of bibliometrics and patent analysis into scenario planning, growth curves and analogies. Bengisu & Nekhili (2006) used the data derived from patents and publications to quantify and test expert views on selected technologies comparing the number of patents and publications related to the same technologies for a given year. In another study, Arman et al. (2009) developed a methodology that tries to combine three different rankings obtained from publications, patents and experts opinions in order to obtain a unique ranking. In a recent study, Quintella et al. (2011) presented a contextualized overview of CO2 capture technology, with critical evaluation of state-of-art and technological development through patents applications and scientific publications. In another recent study, Zhang et al. (2011) proposed a process integrating expert knowledge and bibliometric methods includes terms frequency analysis and association analysis in order to engage the challenge of technology road mapping. Their terms frequency analysis uses technology core terms and IPCs retrieved from publication and patent documents.

In the previous chapter of this thesis, we have also matched patent data and publication data. Patent data and publication data have been matched by using a type-1 FIS in order to evaluate trendiness of candidate technologies. While producing "*membership functions (MFs)*", we have used a linguistic term indicating uncertainty, calling this "*hotness*" in the previous chapter. The perception of hotness can change from expert to expert, although it is commonly thought of as the number of appearances in the last three years compared to the percentage of those which appeared in the last ten years. This uncertainty has been camouflaged through averaging in the previous chapter by determining the membership functions as type-1 fuzzy sets. Celikyilmaz & Türksen (2009) state that membership functions of type-1 fuzzy sets are crisp sets and they do not provide sufficient support for many kinds of uncertainty that appears in subjectively expressed knowledge of experts. The uncertainty that we have faced in the previous chapter of this thesis actually requires the use of "*type-2 fuzzy sets and systems (T2FSSs)*" since handling more uncertainty can be possible by using fuzzy-MFs, i.e., "membership of membership". In this chapter, we extend our previous approach in order to handle more uncertainty through modelling the uncertainty in the problem by using T2FSSs. However, we employ interval valued type-2 fuzzy sets since full type of type-2 fuzzy sets are computationally complex.

4.3 Type-2 fuzzy sets

4.3.1 Why type-2 fuzzy sets should be used

Levels of uncertainty increase from "*number*", to "*word*" and to "*perception*", respectively (John & Coupland, 2009). Traditional mathematical modelling techniques are expected to tackle the problems that contain crisp data, i.e., numbers. However, we are living in a world full of uncertainty and we make decisions in uncertain environments. For this reason, traditional mathematical modelling techniques are insufficient to handle this uncertainty. Therefore, fuzzy sets and systems have been used in a wide range of fields since Zadeh (1965, 1975) introduced type-1 fuzzy sets to model words and type-2 fuzzy sets to model perceptions.

Türksen (2002) argued that type-1 representation does not provide a good approximation to meaning in representation of words and doesn't allow "*computing-with-words (CWW)*" within a richer platform, since it discards the spread of membership values by using averaging or curve fitting techniques and hence, camouflages the uncertainty in the definition of the MFs. Industrial applications of T2FSSs also show that handling more uncertainty and hence producing more accurate and robust results can be achievable with the use of T2FSSs (Dereli et al., 2011). Handling more uncertainty means making less assumption and making less assumption provides more realistic solutions to the real life problems. Because of these advantages, type-2 fuzzy sets have potential to go beyond type-1 fuzzy sets, and therefore an evolution from CWW to "*computing-with-perceptions (CWP)*" has started but it still appears to be in its infancy according to a recent review study (Dereli et al., 2011).

4.3.2 Basic concept

$\tilde{A}$ denotes a type-2 fuzzy set on a universe of discourse X. It is characterized by a set of pairs $\{x, \mu_{\tilde{A}}(x)\}$, where $x \in X$ and $\mu_{\tilde{A}}(x)$ is the membership degree defined in [0, 1] interval.

$$\tilde{A} = \int_{x \in X} \mu_{\tilde{A}}(x)/x = \int_{x \in X} \left[\int_{u \in J_x} f_x(u)/u \right] / x,\ J_x \subseteq [0,1] \tag{1}$$

Secondary MF is denoted as $f_x(u)$ and u is the argument of this function. J_x is the primary membership of x. $\int$ represents that the function is defined for continuous universe of discourse. $\sum$ takes place instead of $\int$ for discrete universe of discourse.

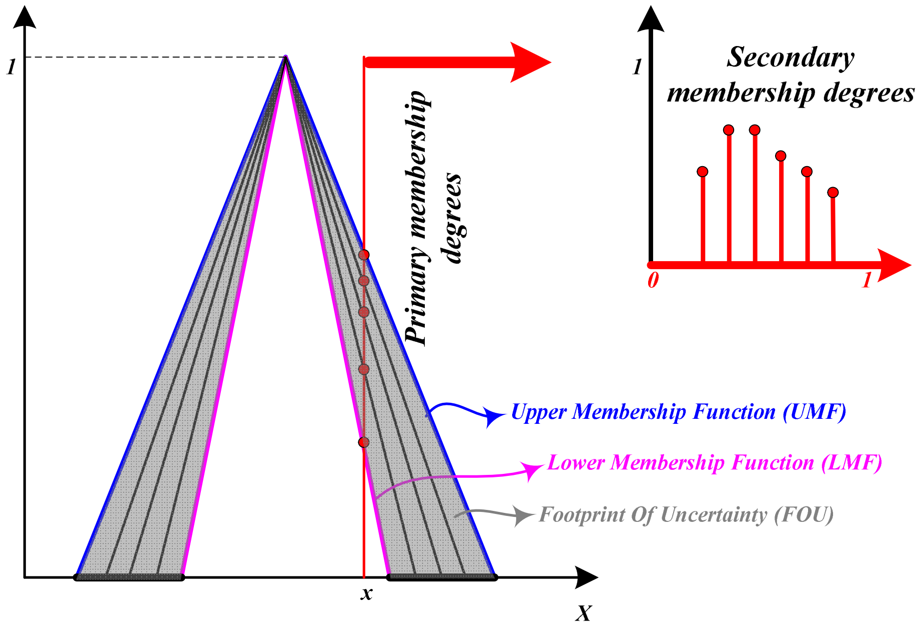


Figure 4.1 A triangular type-2 fuzzy set

Figure-4.1 shows a type-2 MF. Type-2 MFs are three-dimensional because of secondary membership degrees. Secondary MFs provide new design degrees of freedom for handling more uncertainties. However, full type-2 fuzzy sets are computationally complex when the number of variables is large. Therefore, interval type-2 fuzzy sets (IT2FSs) are generally preferred by researchers (Celikyilmaz & Türksen, 2009; Karnik et al., 1999; Kazemzadeh et al., 2008; Mendel et al., 2006). IT2FSs have bounded from above and below inferior MF, i.e., "*lower MF (LMF)*", and superior MF, i.e., "*upper MF (UMF)*", respectively. The area between LMF and UMF is called as "*footprint of uncertainty (FOU)*". An IT2FS is denoted by equation (2).

$$\tilde{A} = \int_{x \in X} \left[\int_{u \in [\underline{J}_x, \bar{J}_x]} 1/u \right] / x\,,\ [\underline{J}_x, \bar{J}_x] \subseteq [0,1] \tag{2}$$

4.3.3 Operators of type-2 fuzzy sets

T-conorm and t-norm operations between type-1 fuzzy sets are utilized in order to perform operations as union and intersection on type-2 fuzzy sets since membership degrees of type-2 fuzzy sets are type-1 fuzzy sets (Zarandi et al., 2009). Therefore following definitions are given (adapted from Karnik & Mendel, 1999):

I. The *union* of two type-2 fuzzy sets, $\tilde{A}$ and $\tilde{B}$, is given equation (3).

$$\tilde{A}\cup\tilde{B}=\int_{x\in X}\mu_{\tilde{A}}(x)\cup\mu_{\tilde{B}}(x)=\int_{x\in X}\left[\int_{u\in\left[\underline{J}_{x(\tilde{A})}\vee\underline{J}_{x(\tilde{B})},\bar{J}_{x(\tilde{A})}\vee\bar{J}_{x(\tilde{B})}\right]}1/u\right]/x \tag{3}$$

II. The *intersection* of two type-2 fuzzy sets, $\tilde{A}$ and $\tilde{B}$, is given equation (4).

$$\tilde{A}\cap\tilde{B}=\int_{x\in X}\mu_{\tilde{A}}(x)\cap\mu_{\tilde{B}}(x)=\int_{x\in X}\left[\int_{u\in\left[\underline{J}_{x(\tilde{A})}\wedge\underline{J}_{x(\tilde{B})},\bar{J}_{x(\tilde{A})}\wedge\bar{J}_{x(\tilde{B})}\right]}1/u\right]/x \tag{4}$$

III. The *complement* of type-2 fuzzy set, $\tilde{A}$, $\bar{\tilde{A}}$ is given equation (5).

$$\bar{\tilde{A}}\Leftrightarrow\mu_{\bar{\tilde{A}}}(x)=\neg\mu_{\tilde{A}}(x)=\int_{x\in X}\left[\int_{u\in\left[1-\bar{J}_x,1-\underline{J}_x\right]}1/u\right]/x \tag{5}$$

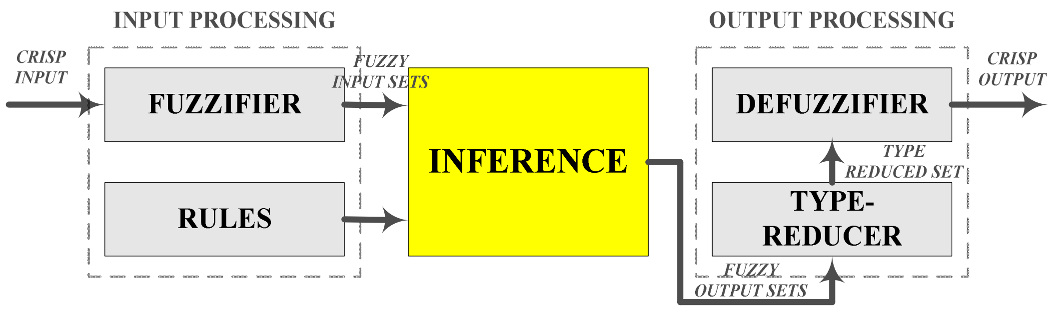


Figure 4.2 Structure of type-2 fuzzy inference system

4.3.4 Type-2 fuzzy inference system

Figure-4.2 shows the schematic diagram of type-2 FIS. It is similar to type-1 FIS. The only difference is having an additional process, namely; "*type-reduction*". Type-2 FISs have type-2 antecedent and/or consequent sets. When an input applied to a type-2 FIS, inference engine computes type-2 output set corresponding to each rule. "*Defuzzifier*" requires a type-1 fuzzy set to produce crisp output but the output sets of the inference engine are type-2 fuzzy sets. Therefore, "*type-reduction*" process which aims to transform type-2 fuzzy sets into type-1 fuzzy sets takes place between "*defuzzifier*" process and "*inference*" process.

4.4 Designing a type-2 FIS for technology evaluation

This section introduces a novel framework for technology evaluation that is based on IT2FSSs. Figure-4.3 shows general structure of the technology evaluation framework. Following subsections of this section present in details about which data sources are used, how they are derived and processed, and how this structure works, step by step.

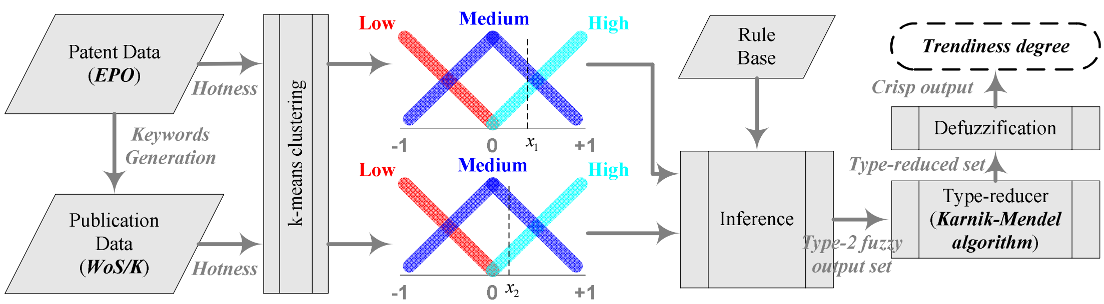


Figure 4.3 Technology evaluation framework based on type-2 FIS

4.4.1 Input processing

"Patent counts" and "*publication counts*" are the uncontaminated input sources of this technology evaluation framework. The patent count data is retrieved from the online database of European Patent Office (EPO). European Classification System (ECLA) is used by EPO for carrying out searches of patent applications. ECLA, in which the entire range of technologies is divided into sections, classes, sub-classes, and groups according to their scope, is used to collect patent data in the corresponding technology groups. For retrieving publication count data, the framework uses online database of Web of Science / Knowledge (WoS/K).

It should be stated here that the transition from resource-based products to knowledge-based products is forcing the new product development (NPD) process to be more innovative, and making technological innovation process ever more challenging (Leon, 2009). Preference of customers of today is dissimilar than they had in a few decades ago. *Innovativeness* is getting an important issue beside price and quality when making buying decisions.

This change leads to shorten product life cycles. Shortened product life cycles compel companies to be innovative. It can be said that sustainable success on innovation is possible with having innovation cultures. Technology is the core of technological innovation. Therefore, while evaluating technologies by considering the sustainability, assessment of the corresponding technology classes/subclasses can be more appropriate approach rather than assessment of a specific technology as unit of analysis. The recent literature therefore seems to have taken assessment this direction, whereby classes/subclasses are taken as units of analysis (see Fleming, 2001; Lee, Cho, et al., 2012; Lee, Lee, et al., 2012).

For this reason, ECLA classes are the core of this technology evaluation framework. For each candidate technology, an ECLA class is specified. Afterwards, some keywords are needed to be generated to make a connection between patents and their related publications. The selection of keywords is a critical issue because it can greatly influence the results (Bengisu & Nekhili, 2006). Robust selection of the keywords can be accomplished with the help of experts of relevant technology class. For another way, given definitions for the corresponding classes by ECLA can also be very helpful to generate keywords. The generated keywords can be validated through controlling with probability plot of patents and publications trends.

4.4.2 Generation of fuzzy sets

Taking the amounts of patents and publications into account while generating input fuzzy sets could yield bias since the grade of importance of amount can change from one technology class to another technology class. Use of *"hotness"* values instead of amounts is more appropriate to evaluate trendiness of technologies since it is related with growth rate of technologies that is more suitable for trendiness evaluation. Arman et al. (2009) determine *hotness* values by calculating the number of patents appearing in the last three years as a percentage of those that appeared in the last ten years. In this framework, we measure the *hotness* values in order to evaluate candidate technologies with respect to their trendiness. However, perception of the term, *hotness,* can vary from person to person. Therefore, the term *hotness* is also fuzzy. In order to handle this uncertainty, type-2 fuzzy sets are used in this framework.

4.4.3 Design of membership functions

Both patent data and publication data are classified into three clusters as *low*, *medium* and *high.* In this step*,* in order to find centroids of the clusters, we use a well-known technique, namely; *k-means clustering* developed by MacQueen (1967). In the first step of this technique, initial guesses are made for the means of *low*, *medium* and *high*. These points represent initial group centroids. In the next step, every datum of patents and publications are assigned to the cluster that has the closest centroids. These two steps alternate until there are no changes in any mean. The proposed version for clustering patents and publications data into three clusters can be viewed as a greedy algorithm for partitioning the samples into three clusters in order to minimize the sum of the squared distances to the cluster centers. The values limiting these clusters are used to define fuzzy membership functions for a certain patent and publication data. In the design of input fuzzy sets, we use triangular membership functions; they have been frequently used because of their striking simplicity (Pedrycz, 1994). Having found centroids of the clusters, in order to find left and right end points, standard deviations of the patent data and publication data can be used.

4.4.4 Generating rule-base

After developing the fuzzy sets for each input and output variables, a rule-base is needed to be generated. We use *type-2 FIS* for matching patents and publications. Therefore, we do not need past experience to generate a rule-base. However, we should know which data source is more reliable. The rule-base should be generated in accordance with the importance weight of patent and publication data.

4.4.5 Inference process

Having performed input processing step, inference process is performed as follows;

Consider a rule-base that includes *N* rules as;

Rule (n) : If x_1 is $\tilde{X}_1^n$ and x_2 is $\tilde{X}_2^n$ then y is Y^n $\quad n=1,2,\ldots,N$

where $\tilde{X}_1^n$ are interval type-2 fuzzy sets which are generated from patent data and $\tilde{X}_2^n$ are interval type-2 fuzzy sets which are generated from publication data. x_1 and x_2 are the calculated patent and publication hotness values of candidate technologies respectively. Y^n values are intervals ($=\left[\underline{y}^n,\overline{y}^n\right]$) which represents the trendiness in a gradual manner.

Compute the membership of x_1 on each $\tilde{X}_1^n$, $\left[\mu_{\underline{X}_1^n}(x_1),\mu_{\overline{X}_1^n}(x_1)\right]$, $n=1,2,\ldots,N$.

Compute the membership of x_2 on each $\tilde{X}_2^n$, $\left[\mu_{\underline{X}_2^n}(x_2),\mu_{\overline{X}_2^n}(x_2)\right]$, $n=1,2,\ldots,N$.

Compute the firing interval of the nth rule, $F^n(x_1,x_2)$, through equation (6).

$$F^n(x_1,x_2)=\left[\mu_{\underline{X}_1^n}(x_1)\times\mu_{\underline{X}_2^n}(x_2),\mu_{\overline{X}_1^n}(x_1)\times\mu_{\overline{X}_2^n}(x_2)\right]\equiv\left[\underline{f}^n,\overline{f}^n\right],n=1,2,\ldots,N \quad (6)$$

4.4.6 Type-reduction process

Type-reduction process aims to convert type-2 fuzzy sets into type-1 fuzzy sets for preparation to defuzzification process. Centre of sets ($Y_{\cos}$) type reducer, that is one of the most commonly preferred type-reducers, is used to perform the type-reduction process. $Y_{\cos}$ is expressed as equation (7).

$$Y_{\cos}\left(x\right)=\bigcup_{\substack{f^n\in F^n(x)\\ y^n\in Y^n}}\frac{\sum_{n=1}^{N}f^n y^n}{\sum_{n=1}^{N}f^n}=\left[y_l,y_r\right] \tag{7}$$

y_l and y_r are the end points of the interval set. They are expressed as equations (8) and (9) respectively.

$$y_l=\frac{\sum_{n=1}^{L}\overline{f}^n\underline{y}^n+\sum_{n=L+1}^{N}\underline{f}^n\underline{y}^n}{\sum_{n=1}^{L}\overline{f}^n+\sum_{n=L+1}^{N}\underline{f}^n} \tag{8}$$

$$y_r=\frac{\sum_{n=1}^{R}\underline{f}^n\overline{y}^n+\sum_{n=R+1}^{N}\overline{f}^n\overline{y}^n}{\sum_{n=1}^{R}\underline{f}^n+\sum_{n=R+1}^{N}\overline{f}^n} \tag{9}$$

where switch points L and R are specified by $\underline{y}^L\le y_l\le\underline{y}^{L+1}$ and $\overline{y}^R\le y_r\le\overline{y}^{R+1}$.

Karnik-Mendel (KM) algorithm, which is one of the most common approaches in the literature, is employed in order to find switch points for each end points of the interval set. The steps of the algorithm are as follows (Mendel & Wu, 2010);

4.4.6.1 KM algorithm for computing y_l:

Step1- $\underline{y}_n$ values are sorted in increasing order.

Step2- The weights $F^n\left(x\right)$ are matched with their respective $\underline{y}_n$ values.

Step3- f^n are initialized through $f^n=\dfrac{\underline{f}^n+\overline{f}^n}{2}$ and then y is computed as;

$$y=\frac{\sum_{n=1}^{N}\underline{y}^{n}f^{n}}{\sum_{n=1}^{N}f^{n}}$$

Step4- Switch point $k\left(1\le k\le N-1\right)$ is found as $\underline{y}^{k}\le y\le \underline{y}^{k+1}$.

Step5- $f^{n}=\begin{cases}\overline{f}^{n}, & n\le k\\ \underline{f}^{n}, & n>k\end{cases}$ are set and then y' is computed as;

$$y'=\frac{\sum_{n=1}^{N}\underline{y}^{n}f^{n}}{\sum_{n=1}^{N}f^{n}}$$

Step6- Check if $y'=y$. If yes, stop and set $y_l=y$ and $L=k$. If no, go to *Step7*.

Step7- Set $y=y'$ and go to *Step4*.

4.4.6.2 KM algorithm for computing y_r:

Step1- $\overline{y}_n$ values are sorted in increasing order.

Step2- The weights $F^{n}\left(x\right)$ are matched with their respective $\overline{y}_n$ values.

Step3- f^{n} are initialized through $f^{n}=\frac{\underline{f}^{n}+\overline{f}^{n}}{2}$ and then y is computed as;

$$y=\frac{\sum_{n=1}^{N}\overline{y}^{n}f^{n}}{\sum_{n=1}^{N}f^{n}}$$

Step4- Switch point $k\left(1\le k\le N-1\right)$ is found as $\overline{y}^{k}\le y\le \overline{y}^{k+1}$.

Step5- $f^n = \begin{cases} \underline{f}^n, & n \le k \\ \overline{f}^n, & n > k \end{cases}$ are set and then y' is computed as;

$$y' = \frac{\sum_{n=1}^{N} \overline{y}^n f^n}{\sum_{n=1}^{N} f^n}$$

Step6- Check if $y' = y$. If yes, stop and set $y_r = y$ and $R = k$. If no, go to *Step7*.

Step7- Set $y = y'$ and go to *Step4*.

4.4.7 Defuzzification process

Having performed KM algorithm, we reach to value of switch points of the interval set. Afterwards, defuzzified output is computed using equation (10).

$$y = \frac{y_l + y_r}{2} \tag{10}$$

After defuzzification process, we obtain a crisp value for each candidate technology which shows the "*trendiness*" of corresponding technology through fusing patent data and publication data. These values are then used to rank the candidate technologies with respect to their trendiness.

4.5 Evaluation of H01-Basic Electric Elements class

An application of the proposed framework is given in this section. There are fourteen candidate technologies waiting for investment decision. Their technology classes are shown in Table-4.1. These technologies are evaluated with respect to their trendiness through the proposed technology evaluation framework.

Initially, patents count data are retrieved from the database of EPO. Table-4.2 shows the corresponding data. As it was discussed in the previous section of this study, the proposed technology evaluation framework uses *hotness* values rather than the amounts of the patents of the related technology classes. Therefore, after reaching the patent count data, they are processed to calculate *hotness* values. Three types of *hotness* values are used to generate type-2 fuzzy input sets for both patents and publications: *hotness*1 (*h*#1), *hotness*2 (*h*#2) and *hotness*3 (*h*#3). While calculating the first types of *hotness* values, i.e., *h*#1, total quantities of last two years are divided by total quantities of last ten years. The second types of *hotness* values, i.e., *h*#2, are calculated by dividing the last three years to last ten years. The total quantities of last four years are divided by total quantities of last ten years for calculating the third types of hotness values, i.e., *h*#3. The *hotness* values derived from corresponding patent classes are shown in Table-4.3.

Table 4.1 Patent classes of corresponding candidate technologies

Candidate	ECLA class	Related technologies
C1	H01B	Cables; Conductors; Insulators; Selection of materials for their conductive, insulating or dielectric properties
C2	H01C	Resistors
C3	H01F	Magnets; Inductances; Transformers; Selection of materials for their magnetic properties
C4	H01G	Capacitors; Capacitors, rectifiers, detectors, switching devices or light-sensitive devices, of the electrolytic type
C5	H01H	Electric switches; Relays; Selectors; Emergency protective devices
C6	H01J	Electric discharge tubes or discharge lamps
C7	H01K	Electric incandescent lamps
C8	H01L	Semiconductor devices; Electric solid state devices not otherwise provided for
C9	H01M	Processes or means, e.g. batteries, for the direct conversion of chemical into electrical energy
C10	H01P	Waveguides; Resonators, lines, or other devices of the waveguide type
C11	H01Q	Aerials
C12	H01R	Line connectors; Current collectors
C13	H01S	Devices using stimulated emission
C14	H01T	Spark gaps; Overvoltage arresters using spark gaps; Sparking plugs; Corona devices; Generating ions to be introduced into non-enclosed gases

Table 4.2 Annual quantities of corresponding patents

	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999
H01B	701	686	538	595	558	499	499	458	348	313	300
H01C	94	98	96	81	87	100	87	91	81	61	78
H01F	8167	7656	7426	7222	8145	7789	8147	9082	8062	7440	7356
H01G	4467	4563	4453	4664	4968	4570	4452	4653	3952	3626	2921
H01H	11232	11484	11160	10673	10653	10431	10024	10704	10245	9777	9387
H01J	12479	14033	16496	18528	19311	17614	17222	17531	15388	15097	13438
H01K	604	649	675	895	832	785	800	730	725	626	484
H01L	98112	100000	100000	100000	100000	100000	99209	99696	87813	76647	62951
H01M	25997	25808	25000	23751	22977	21423	20031	18981	15500	12979	10574
H01P	2382	2300	2427	2602	2963	3275	3452	3717	3131	2823	2360
H01Q	8188	8311	8923	9074	9004	8331	7949	8266	7768	6336	5396
H01R	18878	19525	19601	18661	19427	17904	17831	17352	17783	16451	14159
H01S	5909	6072	6661	6896	8193	8546	9412	9747	7972	6544	5808
H01T	1225	1098	1188	1150	1235	1171	1118	1120	1045	966	982

Table 4.3 Calculated *"hotness"* values of related patents and publications

	Patents			Publications		
	*hotness*1	*hotness*2	*hotness*3	*hotness*1	*hotness*2	*hotness*3
H01B	0,25241128	0,35031847	0,45859872	0,27841205	0,38002160	0,46729204
H01C	0,20125786	0,30188679	0,38679245	0,31037362	0,40222190	0,48144636
H01F	0,18294177	0,26879942	0,35229847	0,30072004	0,39975112	0,48421295
H01G	0,19095349	0,28511916	0,38374674	0,22750239	0,33111672	0,42182419
H01H	0,19621663	0,29261466	0,38480608	0,38273707	0,47931690	0,55305254
H01J	0,14966946	0,24279512	0,34739213	0,29233578	0,39251002	0,47649936
H01K	0,16053811	0,24702114	0,36169122	0,31525037	0,41957511	0,50569044
H01L	0,19338792	0,29100337	0,38861881	0,24807718	0,35232506	0,43877492
H01M	0,23228754	0,34438461	0,45088130	0,31208353	0,44226874	0,55840285
H01P	0,14895647	0,22617078	0,30895266	0,23797623	0,34567709	0,44185813
H01Q	0,18846092	0,29038448	0,39403285	0,31735356	0,43989074	0,53755386
H01R	0,19437470	0,29358411	0,38803575	0,30524811	0,40579946	0,48691035
H01S	0,14653865	0,22800880	0,31235322	0,23519941	0,34182805	0,43456460
H01T	0,18889250	0,28549357	0,37900471	0,24693790	0,35314775	0,43768736

Table-4.4 shows the keywords generated from each ECLA patent class in order to make a link between patents and publications. The keywords are obtained from one of our earlier studies (Dereli et al., 2010). They were determined by using the definitions of the each sub-class. Subsequently, the publications count data are obtained by using the database of WoS/K. *Hotness* values for publications are calculated by using the data of annual quantities of corresponding publications (Table-4.5).

Table 4.4 Keywords generated from each ECLA patent class (Dereli et al., 2010)

	Keywords
H01B	electric* and (cable* or conductor*) or power cable* or insulator* or conductive bod*
H01C	resistor*
H01F	"magnet" or "magnets" or inductance* or transformer* or magnetic film* or conduct* and coil* or armature
H01G	detector* or capacitor* or rectifier* or switching and device*
H01H	electric* and switch* or electric* and relay* or electric* and selector* or electric* and fuse* or current fuse*
H01J	discharge* tube* or discharge* lamp* or x-ray tube* or cathode tube* or photoelectric tube* or vacuum tube* or cathode ray lamp* or transit time tube* or gas filled tube* or ion beam tube*
H01K	incandescent* lamp*
H01L	semiconductor* device* or solid* state* device* or "thermo* device*" or electrostrictive device* or magnetostrictive device*
H01M	"electrode and electrolytic*" or "primary cell*" or "secondary cell*" or "fuel cell*" or "hybrid cell*" or electrochemical battery*
H01P	waveguide* or resonator* or coupling device* or auxiliary device*
H01Q	antenna* and (wave* or radiat* or electric* or reflect* or device* or circuit* or transmission* or refract* or difract* or optic*)
H01R	line* connector* or current* and collector* or current* distributer* or rotary* and current collector*
H01S	stimulated* and emission* or laser* and red or maser* or wave energy
H01T	spark* and gap* or overvoltage* and arrester* or spark* and plug* or corona charge* or corona discharge* or spark gap and (oscilliat or rectif) or rotary spark* gap*

Table 4.5 Annual quantities of corresponding publications

	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999
H01B	17910	17913	13074	11229	11210	11317	10944	9539	8658	8677	8198
H01C	11266	10665	6490	5598	5921	6109	6034	5399	4186	4622	4370
H01F	34302	33606	22363	19073	19009	18151	19089	16429	14744	15436	13616
H01G	60132	62654	55922	48956	50293	49831	50160	44158	38497	39656	39454
H01H	15359	17228	8223	6278	6663	6311	6259	4852	4344	4950	4675
H01J	6990	6936	4772	4001	3974	4124	4217	3442	3069	3155	2957
H01K	422	409	275	227	240	195	210	184	151	188	135
H01L	37171	36466	30944	25661	26547	27296	27556	26837	19125	19802	19426
H01M	14548	15192	12406	11067	10807	9384	7511	5259	3702	3042	2377
H01P	12774	13317	11808	10545	11214	10356	10352	8454	7108	7167	6542
H01Q	12768	13374	10094	8045	8035	7076	6429	5224	4229	3806	3295
H01R	3826	3648	2462	1986	1880	2098	2020	1742	1608	1672	1543
H01S	2558	2555	2318	2016	2032	1921	1788	1782	1590	1607	1572
H01T	1471	1412	1240	987	1020	1023	1034	873	861	894	860

Table 4.6 Center values of the MFs

	MFs	Patents	Publications
*Hotness*1	*High*	0,2423	0,3827
	Medium	0,1921	0,3040
	Low	0,1514	0,2391
*Hotness*2	*High*	0,3474	0,4538
	Medium	0,2867	0,4000
	Low	0,2360	0,3448
*Hotness*3	*High*	0,4547	0,5497
	Medium	0,3833	0,4837
	Low	0,3302	0,4349

Calculated hotness values are classified into three groups as *low*, *medium* and *high* for both patents and publications through using *k-means clustering* technique. Table-4.6 shows the center values of the MFs. Three input type-1 fuzzy sets are obtained for each *hotness* values. Through observing LMFs and UMFs for each linguistic variable, type-2 fuzzy input sets are obtained as shown in Figure-4.4.

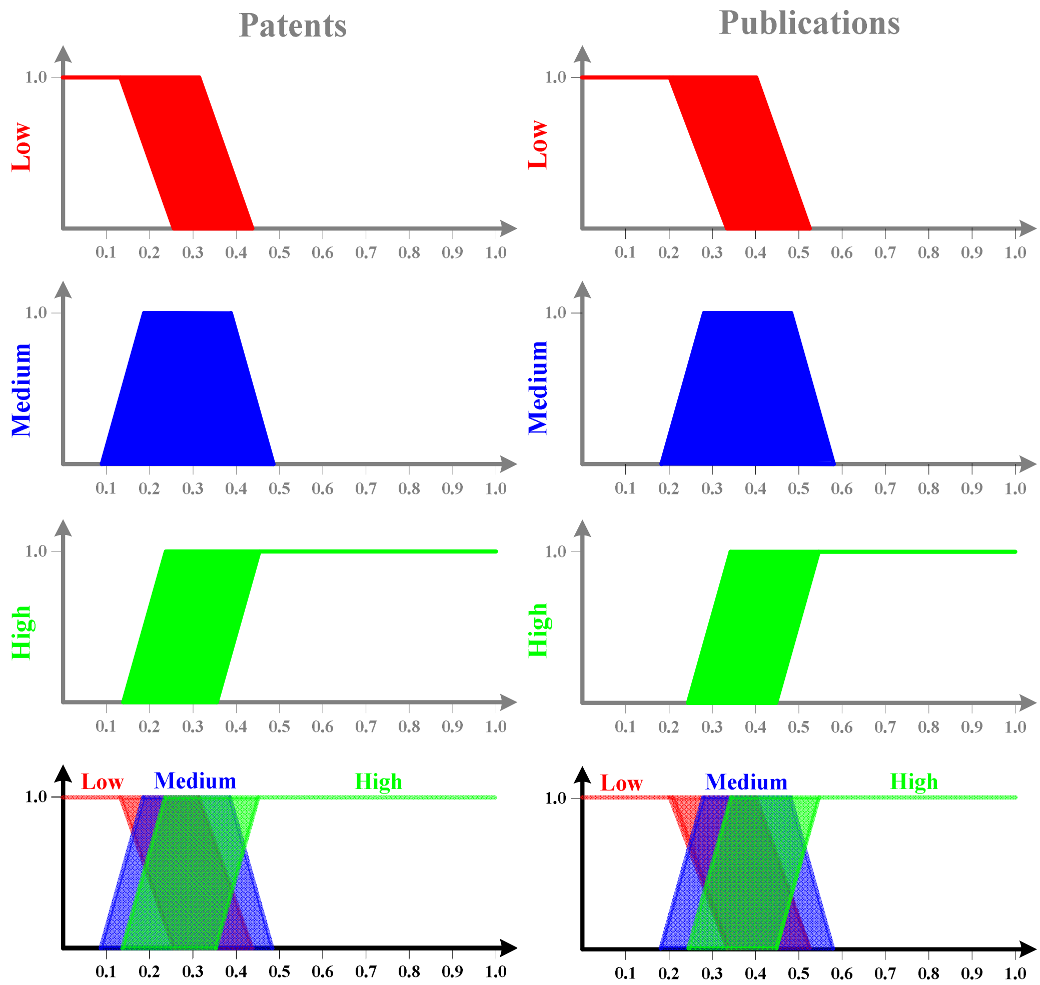


Figure 4.4 Type-2 fuzzy input sets for patents and publications

Beside the generation of input fuzzy sets, *input processing* phase also requires a rule-base for ending the process and starting to subsequent process, *inference*. The proposed technology evaluation framework uses FIS in order to match two different data sources, i.e., patents and publications. Therefore, generation of a rule-base with respect to earlier experiences and/or opinions of corresponding experts cannot be a feasible and appropriate approach. One way, can be observing similarity of patents and publications trends through probability plot. If the trends are the same, a rule-base that has homogenous consequence distribution can be generated. In other conditions, a rule-base that influences the consequences to more reliable data source should be generated.

Verbeek et al. (2002) paid attention to that some technology fields are highly science oriented while others are not. There are not equal likelihoods for different patent classes to link to science that is published in peer reviewed journals (Boyack &

Klavans, 2008). Therefore, science orientation of corresponding patent classes also need to be taken into account while generating a rule-base since reliability of publications and patents can change with respect to different patent classes. See Boyack & Klavans (2008) in order to review a map of IPC patent subclasses that includes the distribution of patent classes with high science orientation and low science orientation. *H01*-Basic Electric Elements class is one of the highest science oriented patent classes. Therefore, by taking into account this property provided by *H01*-Basic Electric Elements class, we generate a rule-base that has homogenous consequence distribution as shown in Table-4.7.

Inference process is ready to produce type-2 fuzzy output sets after finishing the *input processing*. Average *hotness* values of each technology class are the inputs of the inference system. The firing intervals of the nine rules are calculated for each candidate technology. In the type-reduction process, KM algorithm is executed to find the switch points for each end points of the interval set of each candidate technology. After finding the end points, *defuzzification* process is executed. For each candidate technology, type-2 FIS provides a crisp output which represents the trendiness degree that is obtained by matching the data of corresponding patents and publications.

Table 4.7 Rule-base

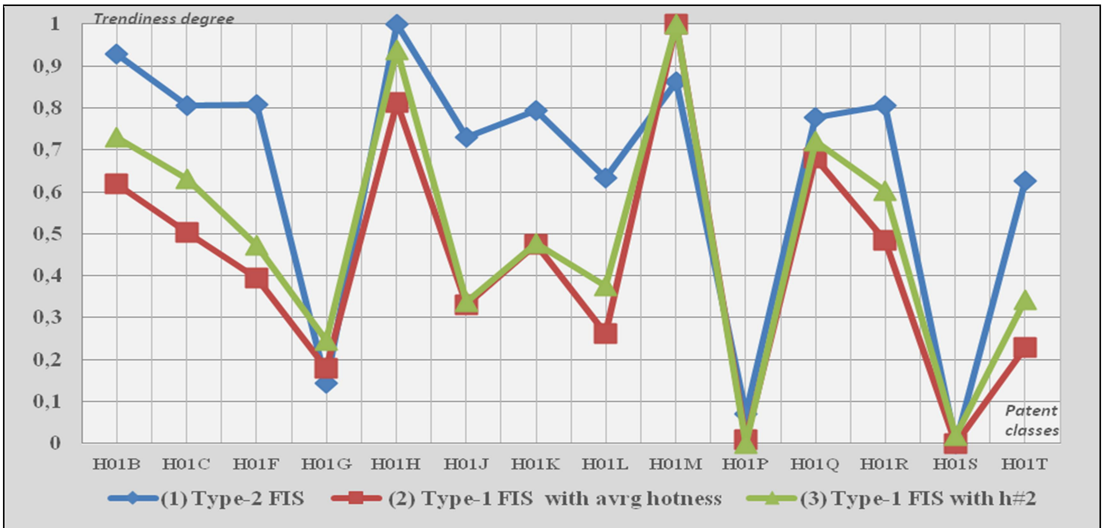
R1	If (Avrg *Hotness* of Patent is *Low*) and (Avrg *Hotness* of Publication is *Low*) then (Trendiness of Technology is [0.1,0.4])
R2	If (Avrg *Hotness* of Patent is *Low*) and (Avrg *Hotness* of Publication is *Medium*) then (Trendiness of Technology is [0.1,0.4])
R3	If (Avrg *Hotness* of Patent is *Low*) and (Avrg *Hotness* of Publication is *High*) then (Trendiness of Technology is [0.4,0.6])
R4	If (Avrg *Hotness* of Patent is *Medium*) and (Avrg *Hotness* of Publication is *Low*) then (Trendiness of Technology is [0.1,0.4])
R5	If (Avrg *Hotness* of Patent is *Medium*) and (Avrg *Hotness* of Publication is *Medium*) then (Trendiness of Technology is [0.4,0.6])
R6	If (Avrg *Hotness* of Patent is *Medium*) and (Avrg *Hotness* of Publication is *High*) then (Trendiness of Technology is [0.6,0.9])
R7	If (Avrg *Hotness* of Patent is *High*) and (Avrg *Hotness* of Publication is *Low*) then (Trendiness of Technology is [0.4,0.6])
R8	If (Avrg *Hotness* of Patent is *High*) and Avrg *Hotness* of Publication is *Medium*) then (Trendiness of Technology is [0.6,0.9])
R9	If (Avrg *Hotness* of Patent is *High*) and (Avrg *Hotness* of Publication is *High*) then (Trendiness of Technology is [0.6,0.9])

In order to analyze the effect of employing type-2 FIS on the evaluation, the candidate technologies are also evaluated with two different type-1 FISs. While former uses average of the calculated *hotness* values, latter uses only *h*#2 values. Type-1 FIS with average *hotness* camouflages the uncertainty in the definition of the type-2 fuzzy input sets through discarding the spread of membership values by averaging. Type-1 FIS with *h*#2 does not take into account the uncertainty in the definition of the membership functions. Therefore, type-1 FIS with average *hotness* can be considered as a inter phase between the type-1 FIS and the type-2 FIS with respect to handled uncertainties. Table-4.8 shows the evaluation results for each FIS. The evaluation results are standardized to make range from start (0) to end (1) in order to observe clearly how handling more uncertainty effects the evaluation results.

Table 4.8 Evaluation results of type-2 FIS, type-1 FIS with average *hotness* and type-1 FIS with *h*#2, and their standardized values

Patent classes	Type-2 FIS	Standardized to [0,1]	Type-1 FIS with avrg *hotness*	Standardized to [0,1]	Type-1 FIS with *h*#2	Standardized to [0,1]
H01B	0,6233	0,9281	0,5880	0,6201	0,5520	0,7307
H01C	0,6163	0,8056	0,5460	0,5027	0,5180	0,6301
H01F	0,6165	0,8091	0,5070	0,3938	0,4650	0,4733
H01G	0,5785	0,1436	0,4300	0,1787	0,3880	0,2455
H01H	0,6274	1	0,6570	0,8128	0,6220	0,9378
H01J	0,6120	0,7302	0,4840	0,3296	0,4190	0,3372
H01K	0,6156	0,7933	0,5360	0,4748	0,4660	0,4763
H01L	0,6064	0,6322	0,4600	0,2625	0,4320	0,3757
H01M	0,6196	0,8633	0,7240	1	0,6430	1
H01P	0,5743	0,0700	0,3690	0,0083	0,3050	0
H01Q	0,6147	0,7775	0,6100	0,6815	0,5490	0,7218
H01R	0,6163	0,8056	0,5390	0,4832	0,5090	0,6035
H01S	0,5703	0	0,3660	0	0,3110	0,0177
H01T	0,6061	0,6269	0,4480	0,2290	0,4210	0,3431

Figure-4.5 shows distribution of standardized values of evaluation results and rankings of the technology classes with respect to their trendiness degrees. When the results are reviewed in terms of trendiness degrees, it is observed that the results of type-2 FIS are generally the highest and the results of type-1 FIS with average *hotness* are generally the lowest for technology classes except H01G and H01M. When the results are reviewed in terms of rankings, it is seen that the evaluation results do not affect ranks of H01K and H01G technology classes. Handling more uncertainties affects rankings of H01H, H01R, H01F, H01J and H01P technology classes positively. In contrast to this, handling more uncertainties creates a negative effect for H01C, H01L, H01T and H01S technology classes. However, there is not a monotonic relation between uncertainties and technology classes for rankings of H01B and H01Q technology classes.



FIS \ *Rank*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
(1)	H01H	H01B	H01M	H01F	H01R	H01C	H01K	H01Q	H01J	H01L	H01T	H01G	H01P	H01S
(2)	H01M	H01H	H01Q	H01B	H01C	H01R	H01K	H01F	H01J	H01L	H01T	H01G	H01P	H01S
(3)	H01M	H01H	H01B	H01Q	H01C	H01R	H01K	H01F	H01L	H01T	H01J	H01G	H01S	H01P

Figure 4.5 Evaluation results of the FISs and rankings of the technology classes

It has been observed that handling more uncertainties can affect the evaluation results of candidate technologies and prioritizing of them by the help of this comparison. The use of IT2FSSs enables us to handle more uncertainties. Handling more uncertainties provides more realistic solutions to problems because of decreasing assumptions made while modeling. Therefore, it is believed that the evaluation results of IT2FSSs are more accurate and robust when compared with type-1 counterpart.

4.6 Conclusion

Evaluation and consideration of *"trendiness"* of candidate technologies is one of the most important prerequisites in order (i) to make rational investment decisions, (ii) to draw strategic roadmaps and (iii) to direct investments and incentives to the most rewarding technologies. This chapter presents a novel framework in order to evaluate candidate technologies according to their *"trendiness"*. This framework makes use of an interval type-2 fuzzy inference system that matches relevant publication and patent data to infer about *trendiness* of candidate technologies. We employed interval valued type-2 fuzzy sets since full type of type-2 fuzzy sets are computationally complex.

In order to demonstrate how it works, an ECLA class – H01-Basic Electric Elements – is evaluated by way of the proposed framework. How the results change upon the uncertainties handled in the problem in consideration is investigated by comparison with the results of type-1 counterpart of the proposed framework. Because of the utilization of interval valued type-2 fuzzy sets really handles the uncertainties (e.g. the description of the hotness values corresponding to patents and publication, etc.) and provides making less assumptions on the technology evaluation, the results are believed to be more realistic than those of the type-1 counterparts.

The main contribution of this chapter is the demonstration of usefulness of fuzzy logic in technology evaluation by presenting a unique framework. In addition to the theoretical contribution described above, this study has also provided new insights for making business policy. As is discussed in the second section of this chapter, this study is an extension of a part of the previous chapter. Technology evaluation framework proposed in this chapter therefore improves the Quick Innovation

Intelligence Process and hence, improves the business policy making by matching patents and publications data in a more concrete way. Thus, the focus and attention of business policy makers as well as investors can be directed into science-oriented and trendy technologies. The effective consideration of science orientation degree of candidate technologies into the technology evaluation process can enhance corresponding decisions by directing considerations into the technological innovations, which are more value-added and not easy to imitate because of the inclusion of more tacit knowledge, etc.

This study has used hotness indices for evaluation of trendiness. Utilization of the hotness indices has some limitations in case of the range, between quantities of patents and publications corresponding to candidate technologies, is considerably higher. In order to overcome this obstacle, future research can potentially address the use of more precise and reliable indices for trendiness detection. When the advancements on fuzzy logic become applicable easily, future work can address the use of full type-2 fuzzy logic and fuzzy functions within a technology evaluation framework in order to handle existing uncertainties more comprehensively.

CHAPTER 5

SELECTION OF IMOVATION STRATEGY BY MEANS OF THE QUICK INNOVATION INTELLIGENCE PROCESS

Making and leading the innovation wind rather than being possessed by it actually provides benefits of monopoly power. However, investing heavily in R&D with the intention of being innovator does not warrant success and its sustainability. Although being an "*innovator*" has some merits, being an "*imitator*" has its own merits as well.

There is a great attention devoted to these merits in the literature in order to find out which one is the best strategy being an "*innovator*" or an "*imitator*" (e.g., Lieberman & Montgomery, 1988; Bowman & Gatignon, 1996; Robinson & Min, 2002; Zhou, 2006; Chang & Harrington, 2007). Sometimes being an "*innovator*" is the best strategy while introducing a product, sometimes being an "*imitator*". Imitation is as important as innovation in reality even if innovation is associated with good perceptions.

Product development can take a mixed form between two extremes on a continuum, from brand new innovation to pure imitation. According to Shenkar (2010), consideration of "*imovation*" - both innovation and imitation simultaneously - is required in order to combine merits of them and hence to stay competitive. Figure-5.1 shows fuzzy sets analogy for product introduction strategy. Playing offense and defense is regarded as one of the ten rules of imovation stated by Shenkar (2010). An imovator should play role of "*offensive imovator*" (near to being pure innovator) when innovation is worthwhile. In the case of otherwise, being a "*defensive imovator*" (near to being early imitator) can be compatible strategy.

How to decide when to be *offensive*/*defensive* greatly depends on innovation potentials of industries assessed by consideration of both their *technological* and *market conditions*. High innovation potential can mean that making innovation is worthwhile, and vice versa. Evaluation of innovation potential can guide *imovators* to conclude when to be offensive and when to be defensive.

The Quick Innovation Intelligence Process has a great potential to solve above-mentioned imovator's dilemma. This process enables us to evaluate candidate technologies according to their innovation potentials, relatively. This process makes use of databases of patent & publication and some marketing indicators/determinants in order to take technological and market conditions into account. An imovator can be aware of which strategy is well-suited and can go through calculations about when innovation is worthwhile by taking likelihood of being imitated into account as well by means of the Quick Innovation Intelligence Process.

How to decide when to be *offensive/defensive* greatly depends on innovation potentials of industries assessed by consideration of both their *technological* and *market conditions*. High innovation potential can mean that making innovation is worthwhile, and vice versa. Evaluation of innovation potential can guide *imovators* to conclude when to be offensive and when to be defensive.

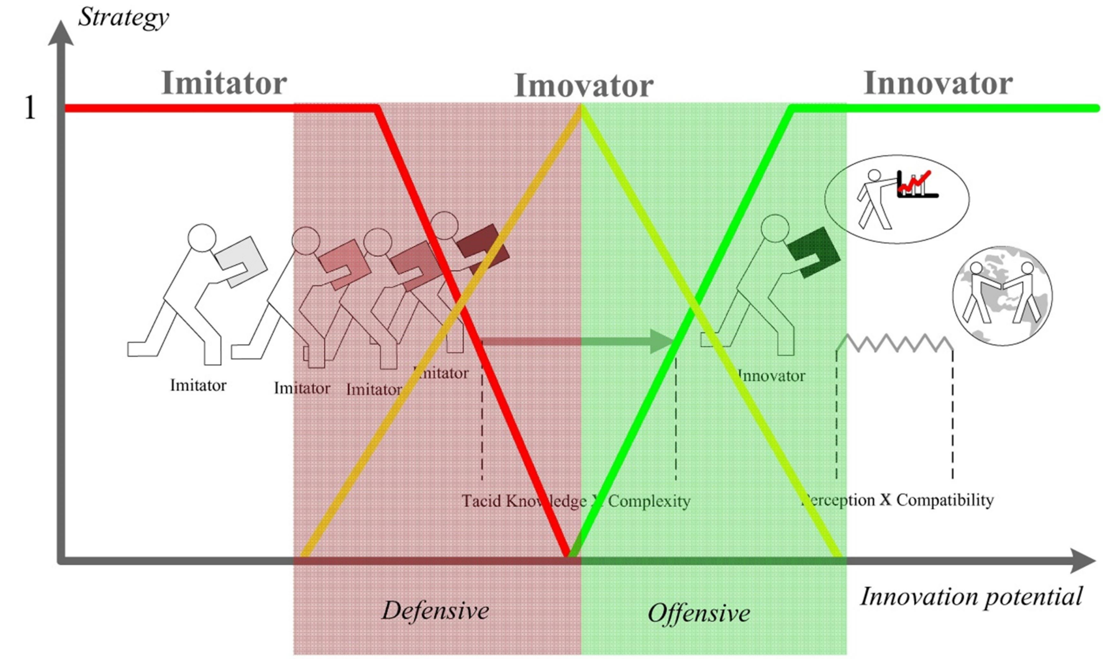


Figure 5.1 A suitable analogy for product introduction strategy

The Quick Innovation Intelligence Process has a great potential to solve above-mentioned imovator's dilemma. This process enables us to evaluate candidate technologies according to their innovation potentials, relatively. This process makes use of databases of patent & publication and some marketing indicators/determinants in order to take technological and market conditions into account. An imovator can be aware of which strategy is well-suited and can go through calculations about when innovation is worthwhile by taking likelihood of being imitated into account as well by means of the Quick Innovation Intelligence Process.

As it is discussed in the previous chapters, output of this process is the grouped and prioritized candidate technologies. If a candidate technology drops into class-A and class-B, it can be considered as a signal to pursue a strategy of "*higher offensive*" and "*offensive*" imovation, respectively. Class-C and class-D can also be considered as a signal to pursue a strategy of "*defensive*" and "*higher defensive*" imovation, respectively.

CHAPTER 6

DEVELOPMENT OF A NOVEL MULTI-ISSUE NEGOTIATION MECHANISM BY MODIFYING THE EVEN-SWAPS

6.1 Introduction

In order to be able to exploit short-terms contracts in combinatorial settings and to realize extensive comparisons between wide varieties of goods, effective ways of automated and multi-issue negotiation have been intensively researched (Sandholm, 1999; Lomuscio et al., 2003). Moreover, it is believed that agent technology will play an important role to play the roles of business entities in a reasonable way (e.g., buyer, seller, mediator, facilitator, and information provider) (see Lomuscio et al., 2003; Wooldridge & Jennings, 1995; Guttman et al., 1998). Correspondingly, researchers have paid more and more attention to this phenomenon and they have made intensive efforts and attempts to develop intelligent entities, i.e., negotiation agents, for automated negotiation and for enhancing abilities of the agents in order to understand the counterparts, their needs and limitations and to predict their behaviors.

"*Automated negotiation*" can be considered as a search process in which each agent in a multi-agent system (MAS) searches for an agreement collaboratively or competitively in a multidimensional space where each dimension corresponds to a negotiable issue (Cheng et al., 2006). Other than single issue (mostly it is price) generally there are many bargainable issues in business environments (as delivery time, service quality, etc.). Through appropriate issue trade-offs, obtaining reciprocal solutions is therefore possible in multi-issue negotiation (Lopez-Carmona et al., 2010). For example, paying higher price for a service can be possible if it is delivered sooner. Such an offer may also be embraced by providers. However, lots of current automated negotiation models have paid relatively little attention to the problem of making trade-offs among decision variables.

It is considered that making rational trade-offs is one of the most important steps of decision making processes and rational trade-offs is the heart of developing reasonable management strategies and plans (Gregory & Wellman, 2001). "*Even-Swaps*" is a rational and simple method for making trade-offs helping decision makers in considering value of one objective in terms of another (Hammond et al., 1998; Hammond et al., 1999; Kajanus et al., 2001; Mustajoki & Hamalainen, 2005). This method provides several useful features to decision makers. The most important one of these features is that it allows decision makers to find existing difference among alternatives in terms of any issue that is under consideration. Finding these differences in terms of a bargainable issue can help the negotiator in a negotiation environment to clarify agreement area for each alternative. This clarification can contribute to make bargaining decisions (e.g. generation of counter-offers and making accept/reject decision for an offer) more rationally. Nevertheless, this feature couldn't be used in the existing (original) version of the Even-Swaps method because of its structure that tries to reveal only the best alternative. Another important feature is that it generated a few hypothetical questions to decision makers while performing issue trade-offs. We believe in that it can generate some hypothetical questions to counter-side for bargaining through some modifications. When these modifications are successfully realized, an agent employing a modified Even-Swaps mechanism can interact with counter-side. Therefore, developing such a mechanism can contribute to management of interactions in automated negotiation.

In order to achieve above mentioned contributions, in this chapter, the Even-Swaps method is modified for automated and multi-issue negotiation. Making practical trade-offs during negotiation process can be possible with the Modified Even-Swaps proposed in this chapter. The proposed approach provides identification of both acceptable and unacceptable areas of the issue values to realize a rational negotiation process. In case there is one bargainable issue (i.e. price-only negotiation), selection of the best alternative is possible by means of Modified Even-Swaps, once negotiators have reached an agreement for each alternative. A fuzzy inference system is employed for bargaining on several issues all at once as well. In order to accomplish steps of the proposed mechanism, a supplementary semi-automated decision-aid tool entitled: "Modified Even-Swaps Agent (MESA)" is also developed. It is a generic mechanism for multi-issue negotiation. Its adaptation to New Product Development (NPD) is presented in further chapters of this thesis.

The rest of this chapter is organized as follows: Section-6.2 presents a literature review on automated negotiation with issue trade-offs. Section-6.3 introduces the Modified Even-Swaps mechanism. Semi-automated decision-aid tool that performs steps of the proposed mechanism is given in Section-6.4. Use of Modified Even-Swaps mechanism in case of multi-bargainable-issue is presented in section 6.5. Experimental evaluation of the proposed mechanism is given in Section-6.6. Finally, conclusions and future work are given.

6.2 Literature review

6.2.1 Automated negotiation with issue trade-offs

This section focuses on automated negotiation with issue trade-offs. Comprehensive reviews on automated negotiation, negotiation support systems and negotiation agents can be found in Resinas et al. (2012), An (2011), Carbonneau et al. (2008), Lopes et al. (2008), Zhang et al. (2007), and Kersten & Lo (2003).

In order to perform issue trade-offs in multi-issue negotiation, Faratin et al. (2002) and Chen & Wang (2007) employed "*fuzzy similarity*" method. Zhang & Qui (2005) and Cheng et al. (2006) used a "*fuzzy inference system*". Teuteberg (2001) and Luo et al. (2003) employed "*fuzzy utility scoring method*" and "*prioritized fuzzy constraints*", respectively. Although "*fuzzy-based approaches*" have been used intensively, there are also some other approaches in the literature. Lopez-Carmona et al. (2011) proposed a "*region-based automated negotiation*" protocol which can efficiently operate in complex utility spaces. Ragone et al. (2008) and Ragone et al. (2009) employed "*propositional logic*" and "*weighted description logic*", respectively, in order to perform multi-issue negotiation. Chen & Huang (2009) developed an automated bilateral multi-issue negotiation mechanism that generates "*trade-offs rules*" according to the some strategies which are determined by negotiator's attitude toward risk.

Although multi-issue negotiation literature has been growing, in a collinear manner multi-issue auction (also known as multidimensional auction) literature has been receiving a growing attention as well. In this regard, some researchers have discussed whether all e-commerce negotiations are auctions, or not (see Kersten & Teich, 2000). When the content of the papers related with multi-issue auction are reviewed, it is seen that the proposed methods for performing auctions are not so different from the methods proposed for multi-issue negotiation. Therefore, a brief overview on multi-issue auction is also given below.

Beil & Wein (2003) proposed a forward- and inverse-optimization based approach. This approach allows learning the negotiators' cost functions and then determining a "*scoring rule*" that maximizes the utility within the open-ascending auction format. There are many papers focusing on "*scoring auctions*". Bichler & Kalagnanam (2003), Parkes & Kalagnanam (2005) and Asker & Cantillon (2008) can be given as the examples of "*scoring-based*" multi-issue auction papers. Table-6.1 gives a summary of the corresponding literature through clusters.

Table 6.1 Summary table of literature review

	Author(s) (pub. year)	How to handle trade-offs
Fuzzy-based appr.	Faratin et al. (2002)	Fuzzy similarity
	Chen & Wang (2007)	Fuzzy similarity
	Zhang & Qui (2005)	Fuzzy inference system
	Cheng et al. (2006)	Fuzzy inference system
	Teuteberg (2001)	Fuzzy utility scoring
	Luo et al. (2003)	Prioritized fuzzy constraints
Scoring appr.	Beil & Weil (2003)	Scoring-based approach
	Bichler & Kalagnanam (2003)	Scoring-based approach
	Parkes & Kalagnanam (2005)	Scoring-based approach
	Asker & Cantillon (2008)	Scoring-based approach
Other appr.	Lopez-Carmona et al. (2011)	Region-based approach
	Ragone et al. (2008)	Propositional logic
	Ragone et al. (2009)	Weighted description logic
	Chen & Huang (2009)	Trade-off rules

6.2.2 Evaluation of the literature & relevance of the study

It can be seen from literature that buyer preferences in multi-issue negotiation have been expressed in a variety of ways. "*Determination via scoring*" and "*similarity criteria based determination*" are the most popular ones to reflect the trade-offs which decision makers are willing to make. Multi-issue negotiation requires the management of expressive agreement preferences regarding multiple issues so that they capture the relationships between issues and hence enable making trade-offs during negotiation (Resinas et al., 2012). Therefore, the main difficulty underlying multi-issue negotiation is elicitation of the negotiators' preferences over relevant issues (Wallenius et al., 2008). In many applications it may not be practical for a negotiator to reveal their entire utility function, either for strategic reasons, or because they are unable to express it (Chen-Ritzo et al., 2005). For that difficulty, "*price-only negotiation*" has been considered as a reasonable approach to adopt for some researchers (e.g. Yuan & Tsao, 2010) although the overall utility achieved in multi-issue negotiation formats is significantly higher than in price-only negotiations (Bichler, 2000). The negotiators would like to negotiate all the dimensions provided to determine the most valuable trade (Chen-Ritzo et al., 2005). Chen-Ritzo et al. (2005) claim that; *while the proposed mechanisms in the literature may provide higher theoretical utility to the negotiator, it is not clear that these improvements will be realized in practice*. Moreover, they also claim that *it is not clear whether a multi-issue negotiation mechanism can be designed that effectively achieves, in theory and practice*.

Chen-Ritzo et al. (2005) summarise the characteristics that an effective multi-issue negotiation mechanism should possess as follows: First, *negotiator must be able to effectively assess the value of a multi-issue offer*. Second, *negotiator must be able to effectively bargain on several attributes/issues simultaneously*. It is well worth to pointing out that this chapter proposes a mechanism satisfying all of above mentioned expectations from an effective multi-issue negotiation mechanism.

Multi criteria decision making (MCDM) methods play an important role in many of multi-issue negotiation developments (Wallenus et al., 2008). Value assessing of multi-issue offer i.e. revealing the utility is the main difficulty of multi-issue negotiation. MCDM methods do not allow generally decision makers to play active roles in decision making. Some information is entered by the decision makers at the beginning, and the MCDM methods use the given information to assess the alternatives. However, we strongly believe in that information which is given by decision makers can change in accordance with the closeness/proximity to final solution. Decision makers can make more robust reasoning when come closer to the final solution because, the effect of the reasoning can be perceived more clearly. Even-Swaps method employed in this work provides this property. Therefore, Even-Swaps method can be an appropriate method to solve the utility revealing problem, which is considered to be one of the main difficulties in multi-issue negotiation process. Moreover, if Even-Swaps method can be embedded to a multi-issue negotiation mechanism, it is possible to contribute to both theoretical and practical literature corresponding to automated negotiation since it is a well-known trade-off methodology which is clear, rational and easy-to-use (Hammond et al., 1998). With this purpose in mind, in this chapter, we propose a novel mechanism for automated negotiation through the modification of Even-Swaps method for bargaining where the issues are classified into two groups; bargainable issues and unbargainable issues. The proposed method enables negotiators to calculate the utility in terms of pre-determined bargainable issues.

Rau et al. (2009) claims that there is more than one issue to be considered for negotiation in a proposal, and each issue has a negotiation range formed by the initial value and reservation value. If buyer and seller can make concessions from their initial proposals, an agreement exists (Rau et al., 2009). Specification of these initial and reservation values of corresponding offers are considerably problematic in bargaining process where the buyer should know where to stop generating counter-offers for which alternative. Modified Even-Swaps proposed in this chapter solves above mentioned problem as well by providing identification of acceptable and unacceptable areas that is crucial to specify agreement areas to realize a rational negotiation process.

6.3 Proposed modification

Consideration of more alternatives and pursuing more issues are possible with making more trade-offs. Even-Swaps is a multi-criteria-decision-making method which provides a practical way of making trade-offs that are called even swaps among any set of issues across a range of alternatives (Hammond et al., 1998). By simplifying and codifying the mechanical elements of trade-offs, the method lets decision makers focus all their mental energy on the most important work of decision making: deciding the real value to decision makers and their organization of different courses of action (Luo and Cheng, 2006; Hammond et al., 1998). Main steps of Even-Swaps are as follows.

Step1- Problem initialization

Step2- Eliminate "*dominated*" alternatives

Step3- Eliminate "*irrelevant*" issues

Step4- More than one remaining alternative?

If yes, then go to *Step5*

Else, go to *Step7*

Step5- Determine alternatives and issue to perform "*even-swap*" on them

Step6- Determine the required change and perform swap

Then, go to *Step2*

Step7- The most preferred alternative is found

Even-Swaps method allows not only consideration of one offer to be better or worse than another, but also it allows us to find the difference between them (Wachowicz, 2007). However, this advantage could not been used because of structure of the method. Objective of the method is to determine the most preferred alternative. Actually, negotiators do not only want to know what the best option is but also the differences among alternatives (Li & Ma, 2008). With the method, negotiator selects one of the offers, but he/she does not use the differences among the offers for bargaining. What is more, in this method, trade-offs are performed with only one-sided by invoking the decision maker. Although bargaining can be possible on some issues, owners of the offers are not informed while performing issue trade-offs. In this chapter, some modifications on the method have been performed to overcome above mentioned obstacles. Main steps of modified Even-Swaps method are as follows:

Step1-	Problem initialization
Step2-	Determine "*bargainable*" issue
Step3-	Determine a bargaining range for bargainable issue
Step4-	Eliminate "*dominated*" alternatives
Step5-	Eliminate "*irrelevant*" issues
Step6-	Is there any relevant unbargainable issue?
	If yes, then go to *Step7*
	Else, go to *Step9*
Step7-	Determine alternatives and issue to perform "*even swap*" on them
Step8-	Determine the required change and perform swap.
	Then, go to *Step4*
Step9-	The most preferred alternatives are found
Step10-	Determine "*acceptable*" and "*unacceptable*" areas

Step1- *Problem initialization*

$$A_{ij} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix} \tag{1}$$

Decision matrix (*Aij*) is used to describe an MCDM problem. In this matrix (see equation 1), there are *"n"* alternative options, and each alternative needs to be assessed on *"m"* criteria. Before beginning to make trade-offs, a decision matrix, i.e., consequences table is needed to have a clear picture of the all alternatives and the consequences for each issue.

Step2- *Determining "bargainable" issue*

In this step, negotiator decides the issue which he/she is able to bargain on (e.g., price). All even swaps will be performed on this issue in the method.

Step3- *Determining a bargaining range for bargainable issue*

A bargaining range for bargainable issue is determined by the negotiator. This range is concerned with the bargainable issue which is determined in the *Step2*. The range affects the amounts of alternatives which remain in the decision matrix in the end. If the range is wide, the amount of alternatives (which decided to start bargain) will be more, but if it is tight, the amount will be less.

Step4- *Eliminating "dominated" alternatives*

Dominated alternative

$$\begin{bmatrix} a_{11} & \cancel{a_{12}} & \cdots & a_{1n} \\ a_{21} & \cancel{a_{22}} & \cdots & a_{2n} \\ \cdot & \cancel{\cdot} & & \cdot \\ \cdot & \cancel{\cdot} & & \cdot \\ \cdot & \cancel{\cdot} & & \cdot \\ a_{m1} & \cancel{a_{m2}} & \cdots & a_{mn} \end{bmatrix} \qquad (2)$$

If alternative "*x*" is better than alternative "*y*" on some issues and no worse than "*y*" on all other issues, "*y*" is dominated by "*x*". However, we can say that alternative "*x*" is better than alternative "*y*" on *bargainable issue*, if the difference between the issue values of the alternatives is greater than the *range* that is determined in *Step3*. The columns of dominated alternatives can be eliminated from decision matrix since these alternatives have disadvantages without any advantage (see equation 2).

[Hammond et al. (1998)](#) also introduced "*practical dominance*" concept in order to accelerate the process through eliminating unnecessary even swaps. In case of practical dominance, alternative "*x*" practically dominates alternative "*y*", if "*y*" is slightly better than "*x*" on only one or few issues; but "*x*" clearly outranks "*y*" on several other issues (Mustajoki & Hamalainen, 2007). However, experience as well as manual intervention of decision maker is essential for an effective performance. Moreover, identification of *practically-dominated* alternatives is typically harder than *dominated* ones (Mustajoki & Hamalainen, 2007). This chapter does not use *practical dominance* concept. Therefore, it performs all possible combinations of even swaps in order to identify the *dominated* alternatives. In further chapters of this thesis, we also propose a novel practical dominance concept to make it even-easier.

Step5- *Eliminating irrelevant issues*

$$\begin{array}{c} \textbf{Irrelevant issue} \\ \begin{bmatrix} \cancel{a_{11}} & \cancel{a_{12}} & \cancel{\cdots} & \cancel{a_{1n}} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix} \end{array} \qquad (3)$$

If an issue has equal consequence for all alternative options, it is believed that this issue is *irrelevant*. The rows of irrelevant issues can be eliminated from decision matrix (see equation 3).

Step6- *Is there any relevant unbargainable issue?*

If there is unbargainable issue in the decision matrix, go to *Step7*. If not, then continue with the *Step9*.

Step7- *Determining alternatives and issue to perform even swap on them*

$$\begin{bmatrix} \boxed{a_{11}} & \boxed{a_{12}} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix} \qquad (4)$$

While comparing any two alternatives, it can be possible sometimes that former one is better than the latter one on some issues, but it is worse than the latter one on some other issues. These two alternatives are determined and then the issue which has different consequence on these alternatives is selected to perform even for them (see equation 4).

Step8- *Determining the required change and performing swap*

$$\begin{bmatrix} \boxed{a_{12}} & \boxed{a_{12}} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & & \vdots \\ \boxed{?} & a_{m2} & \cdots & a_{mn} \end{bmatrix} \qquad (5)$$

Assessing what change in this issue would compensate for the change the value from ***a11*** to ***a12***

The Even-Swap method provides a way to adjust the values of different alternatives' consequences in order to render them equivalent and thus irrelevant (Hammond et al., 1998). In this stage, the decision maker is invoked to reflect his/her subjective assessment what change in other issue would compensate for the change needed (see equation 5).

Step9- *The most preferred alternatives are found*

The process continues with eliminating alternatives and irrelevant issues until only bargainable issue remains. The alternatives which remain in the decision matrix at the end of the process reflect the subjective preference of the decision maker, i.e., negotiator, by considering bargaining range.

Step10- *Determining "acceptable" and "unacceptable" areas*

Having performed *Step9*, only the bargainable issue will remain in the decision matrix. The difference between the issue values reflects the decision maker's preference. Therefore, the calculated difference can be used to specify agreement area-limits for each alternative remained in the decision matrix. In order to find the limit of unacceptable area, calculated difference is subtracted from the issue value that we have in the initial decision matrix. Having calculated the limit of unacceptable area, the limit of acceptable area is calculated by subtracting the predefined bargaining range from the unacceptable area limit. Figure-6.1 shows equations that are used for specifying agreement area limits. After finding acceptable and unacceptable areas for each alternative, bargaining among the negotiators can start by generating offers for each alternative.

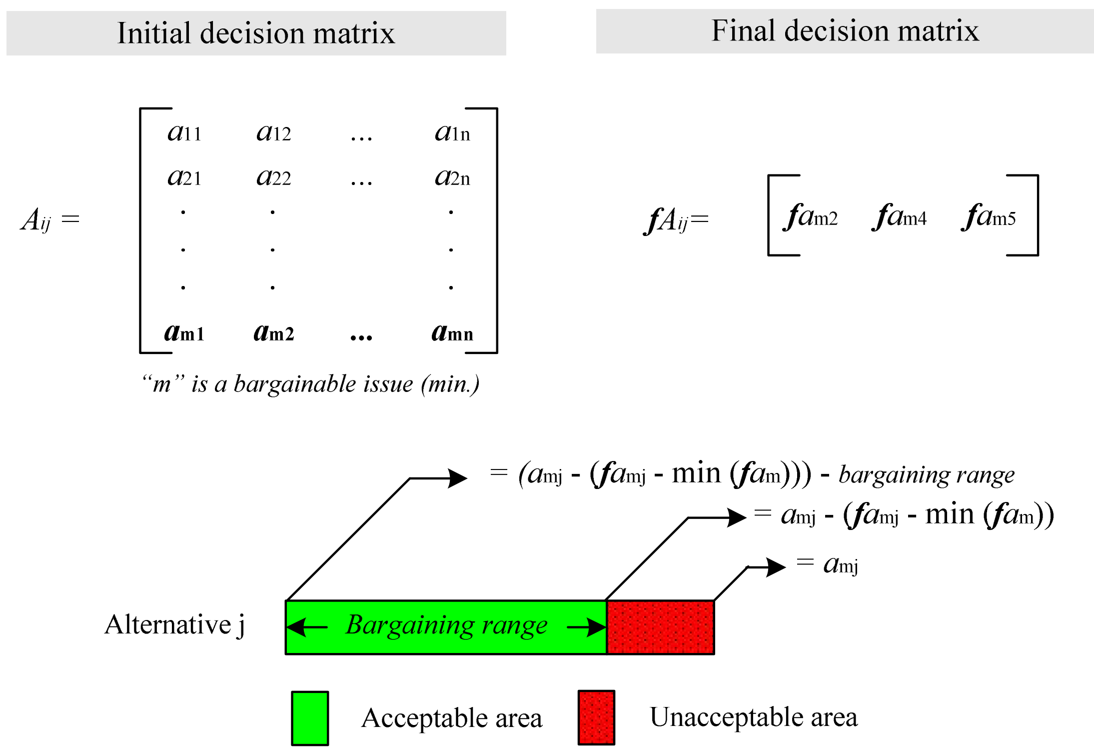


Figure 6.1 Specifying the agreement area limits

An example is given in the following for better understanding above-mentioned steps of the proposed methodology. *Issue-4* is determined as bargainable issue. Therefore, all even swaps are performed on this issue. In the next step, it is assumed that the range for bargaining on the issue is "*1000*". Afterward, it is observed that *alternative-1* is dominated by *alternative-3*. The column of *alternative-1* is eliminated from the decision matrix (see Figure-6.2a). An even swap is performed by adjusting *Issue-1 – alternative-2* value to *Issue-1 – alternative-4* value, and by changing *Issue-4 – alternative-2* value in accordance with the decision maker's assessment (see Figure-6.2b). Since there is no dominated alternative on the revised decision matrix, an even swap is needed (see Figure-6.2c). An even swap is performed by adjusting *Issue-1 – alternative-3* value to *Issue-1 – alternative-4* value, and by changing *Issue-4 – alternative-3* value. After the change, it is observed that *Issue-1* values for any alternatives are equal. The row of *Issue-1* is eliminated from decision matrix since the issue is irrelevant (see Figure-6.2d). An even swap is performed by adjusting *Issue-2 – alternative-3* value to *Issue-2 – alternative-4* value, and by changing *Issue-4 – alternative-3* value (see Figure-6.2e). The row of *Issue-2* is eliminated from decision matrix since it is irrelevant. An even swap is performed by adjusting *Issue-3 – alternative-3* value to *Issue-3 – alternative-4* value, and by changing *Issue-4 – alternative-3* value (see Figure-6.2e). After the change, it is observed that *alternative-3* is dominated by *alternative-4*. The column of *alternative-4* is eliminated from the decision matrix (see Figure-6.2f). After that, it is observed that *Issue-3* is irrelevant. The row of *Issue-3* is eliminated from decision matrix (see Figure-6.2f). Only bargainable issue remains in the decision matrix after the elimination (see Figure-6.2f). The alternatives which remain in the decision matrix reflect the decision maker's subjective preference. The differences between the bargainable-issue values of the alternatives will be used to specify unaccepted area (see Figure-6.2g). In the example, the difference between *alternative-2* and *alternative-4* is *"500"*. For this reason, *alternative-2* is acceptable if its *Issue-4* value is less than "*19500 (20000 – 500)*" (see Figure-6.2g). With the modified Even-Swaps method, the negotiator is able to assess the alternatives by considering bargaining and to select the most preferred ones. The modified Even-Swaps method proposed in this study provides also the identification of *acceptable and unacceptable areas* of the issue values of alternatives to bargain. Moreover, the proposed method helps selecting the most suitable alternative, once the negotiator has reached an agreement for each alternative (see Figure-6.2g).

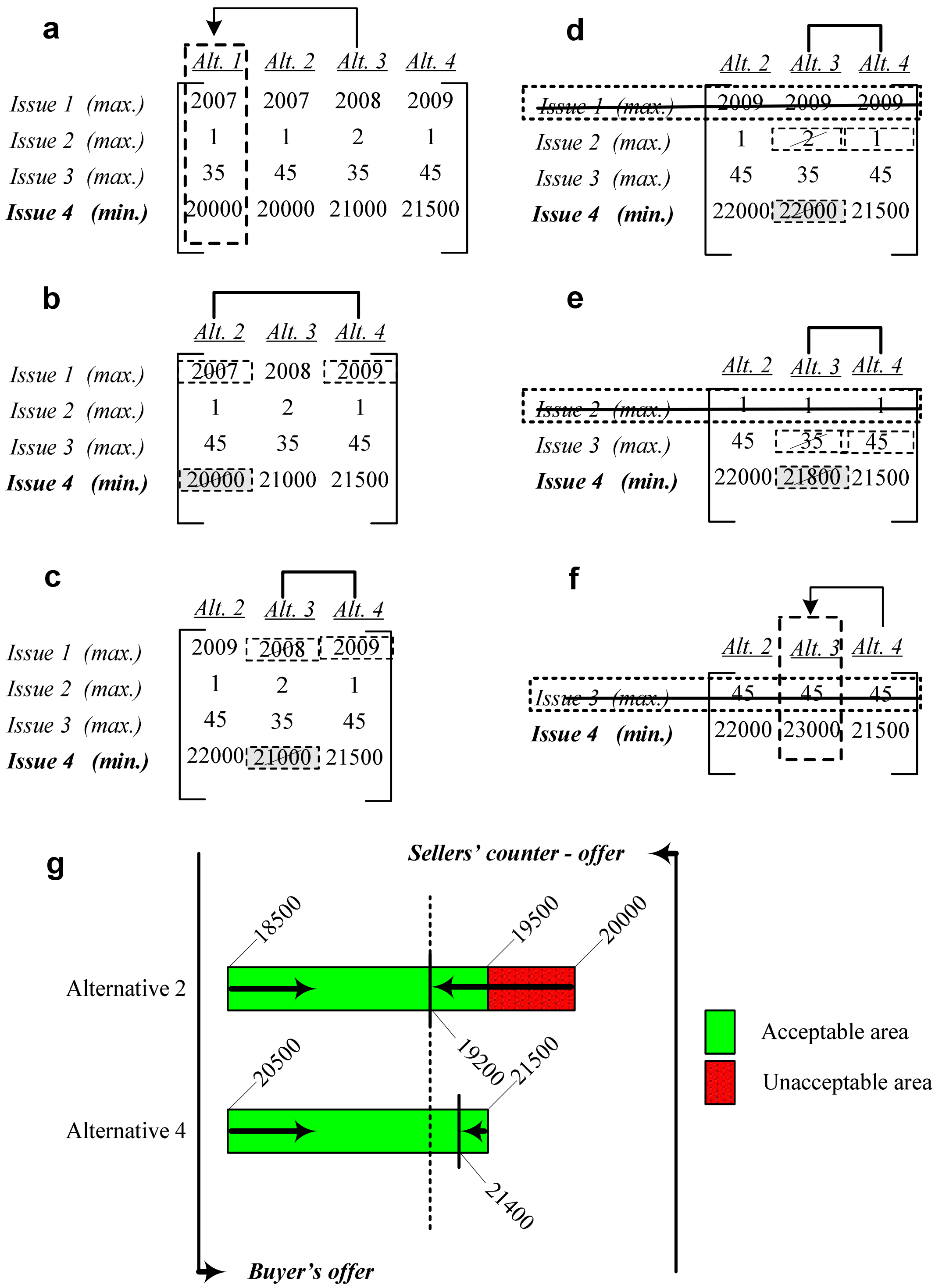


Figure 6.2 The Modified Even-Swaps

Trade-offs performed (i.e. even swap operations) in the example are shown in Table-6.2. In order to demonstrate the modifications more effectively, the same example is also solved with conventional (original) Even-Swaps method. Table-6.3 shows the trade-offs performed in the conventional Even-Swaps method. In the first trade-off operation of the conventional Even-Swaps method, *alternative-1* is dominated by *alternative-2*. However, in the modified Even-Swaps, this trade-off does not create a resulting situation as domination because the domination is possible if the difference between the issue values of the alternatives is greater than the bargaining range. While conventional Even-Swaps method searches condition of remaining one alternative for ending, the modified structure searches condition of remaining only bargainable issue. This modification is essential to generate the differences between bargainable alternatives those are required to determine the limits of the agreement areas (as in Figure-6.2g) as an outcome.

Table 6.2 Trade-offs performed in the Modified Even-Swaps

	Even Swap		
Number	Change	Compensation	Resulting situations
Issue 4 is determined as bargainable issue Bargaining range is “1000” Initial scanning through the consequence table			*Alternative 1* is dominated by *alternative 3*
1 – *Alternative 2*	*Issue 1* 2007→2009	*Issue 4* 20000→22000	-
2 – *Alternative 3*	*Issue 1* 2008→2009	*Issue 4* 21000→22000	*Issue 1* is irrelevant
3 – *Alternative 3*	*Issue 2* 2→1	*Issue 4* 22000→21800	*Issue 2* is irrelevant
4 – *Alternative 3*	*Issue 3* 35→45	*Issue 4* 21800→23000	*Issue 3* is irrelevant *Alternative 3* is dominated by *alternative 4*
(*Ending condition is the remaining only bargainable issue*) ***Alternative 2*** and ***alternative 4*** are the remaining alternatives → They are the most preferred ones → Difference between the remaining alternatives is “500” (=22000-21500) (Difference is calculated in terms of bargainable issue)			

Table 6.3 Trade-offs performed in the Even-Swaps method

Number	Even Swap: Change	Even Swap: Compensation	Resulting situations
Initial scanning through the consequence table			*Alternative 1* is dominated by *alternative 2*
1 – *Alternative 2*	*Issue 1* 2007→2009	*Issue 4* 20000→22000	*Alternative 2* is dominated by *alternative 4*
2 – *Alternative 3*	*Issue 1* 2008→2009	*Issue 4* 21000→22000	*Issue 1* is irrelevant
3 – *Alternative 3*	*Issue 2* 2→1	*Issue 4* 22000→21800	*Issue 2* is irrelevant
4 – *Alternative 3*	*Issue 3* 35→45	*Issue 4* 21800→23000	*Issue 3* is irrelevant *Alternative 3* is dominated by *alternative 4*
(*Ending condition is the remaining one alternative*) ***Alternative 4*** is the remaining alternative → It is the most preferred one			

6.4 Modified Even-Swaps Agent (MESA)

Automated negotiation researches can be considered to contend with two broad subject matters. The former has been focused on the communication between corresponding agents. It includes the studies on agent-based languages and protocols that enable the message interchange between different agents. The latter has been focused on agents' decision making models utilized in order to achieve their objectives. This study is relevant with the latter topic. Using an MCDM method can be helpful in multi-issue negotiation for developing capabilities of negotiators on offer assessment and for assisting them to find out what they really want. Correspondingly, developing supplementary decision-aid tools which utilize an MCDM method can also be helpful for an efficient automated negotiation.

In order to accomplish the steps of the proposed mechanism, a supplementary semi-automated decision-aid tool, namely; Modified Even-Swaps Agent (MESA) is developed. The MESA has been developed on Borland Delphi 7.0 which runs on 32-bit Microsoft Windows platform. The users can interact with the MESA through its user interface shown in Figure-6.3. The users firstly specify the issues as well as alternatives and then click to "*generate consequences matrix*" button. MESA creates consequence matrix and then the users fill the cells of decision matrix. Having filled the consequence matrix, the users use "*specify dominated alternative(s)*" button to see the dominated alternatives. MESA informs the users through a message-box about which alternative is dominated by which alternative(s). In order to eliminate the dominated alternative(s), the users can use "*eliminate dominated alternative(s)*" button. Subsequently, the consequence matrix is revised by MESA. If there is not any dominated alternative, "*Even-Swaps*" button is used by the users to start an even-swap operation. MESA generates a hypothetical question as `"What would change in 'price' of alternative-2 to compensate for the change the value of 'year' from 2007 to 2009?"` to the users via an input-box. According to the input data, the consequence matrix is revised by MESA. The process continues until one bargainable issue remains in the consequence matrix. "*Start bargaining*" button generates the agreement area for each remaining alternative by using the ultimate consequence matrix.

MESA provides procedural support in making trade-offs. It specifies agreement areas which help the negotiator where he/she starts to generate counter-offers. These agreement areas are also helpful to evaluate which alternative is the most suitable at the end of the negotiation process. The negotiator can only make efforts on the thinking process related to preferences since MESA takes care of the technical tasks of the modified Even-Swaps mechanism.

In multi-issue negotiation, the importance of issues (to be considered in the bargaining) can change from negotiator to negotiator. Therefore, values of each alternative can change from negotiator to negotiator as well. As a result, counter-offers for alternatives may show some dissimilarity. Each of the self-interested sides negotiates with many negotiators for finding the most suitable alternative whereas each of the self-interested sides negotiates with many negotiators for finding the most suitable offer. The negotiator can also consider more than one issue (e.g. profit and payment method) to assess the offers. So, MESA tool can be used as a powerful bargaining assistant by both of negotiation sides.

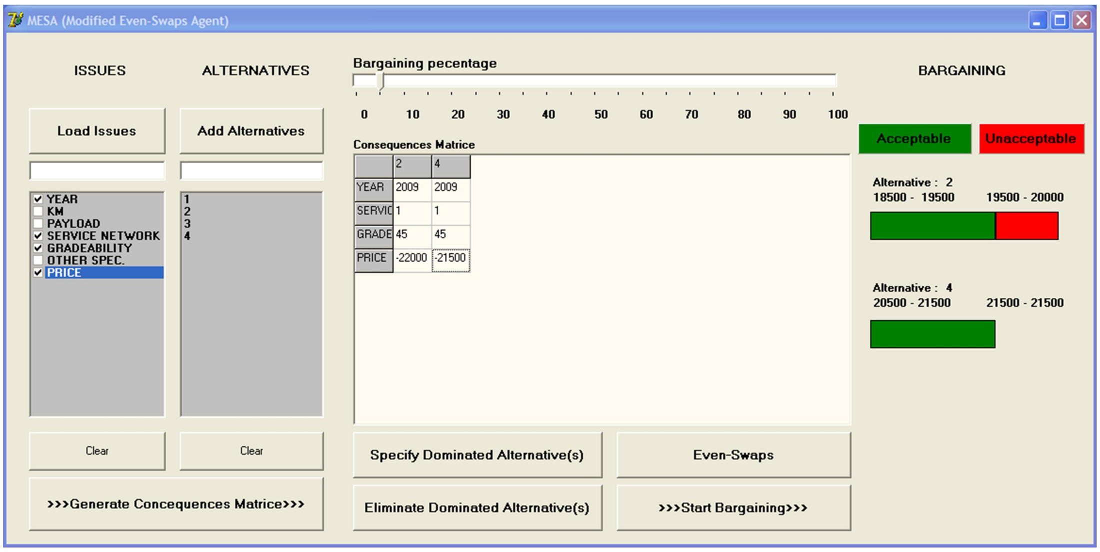


Figure 6.3 **M**odified **E**ven-**S**waps **A**gent (MESA)

6.5 Use of modified Even-Swaps in case of multi-bargainable-issue

In case there is one bargainable issue, the modified Even-Swaps method helps to select the most suitable alternative, once the negotiator has reached an agreement for each alternative. However, if there is more than one bargainable issue, the use of modified Even-Swaps cannot help the negotiator to find the best alternative, alone. In case of multi-bargainable issue, the negotiator should determine the utility of each bargainable issue. For example, the negotiator can clarify that "*delivery time*" is more important than "*price*". If "*delivery time*" is sooner, paying "*higher price*" can be possible. Correspondingly, such an offer can be acceptable from the point of view of the negotiator. In these circumstances, a negotiator can intrinsically use linguistic variables to clarify the utilities. Negotiator can then generate basic rules for evaluation of offers. Therefore, computing with words (CWW) via a Mamdani-type fuzzy inference system (FIS) can be an appropriate approach. Development of an autonomous tool can also be possible through the use of FIS.

Figure-6.4 shows the proposed approach in case of multi-bargainable-issue. The bargaining process in case of *multi-bargainable-issue* can be designed as follows.

Step1- Evaluate the offers made by sellers with modified Even-Swaps method for each bargainable issue. The differences of alternatives in terms of each bargainable issue will be determined in this step (see Figure-6.4).

Step2- Evaluate each offer by using Mamdani-type FIS. Then, create a ranking list for offers in accordance with the crisp output values which are obtained after defuzzification steps. The first alternative will be acceptable and the rest of them will be unacceptable (see Figure-6.4).

Step3- The sellers whose offers are unacceptable are prompted via messages with content like following: `"Your offer is not acceptable in our alternatives. Would you like to upgrade issue X (bargainable issues) of your product to be in the list of acceptable alternatives?"` Generate a counter-offer for the seller whose offer is acceptable.

Step4- Wait for the responses from the sellers in a pre-defined period of time. Update the acceptable and unacceptable agreement areas in accordance with the responses for each alternative by using the FIS. If the time is available, go to *Step 3* for a new bargaining cycle; otherwise terminate the bargaining process and select the most suitable offer.

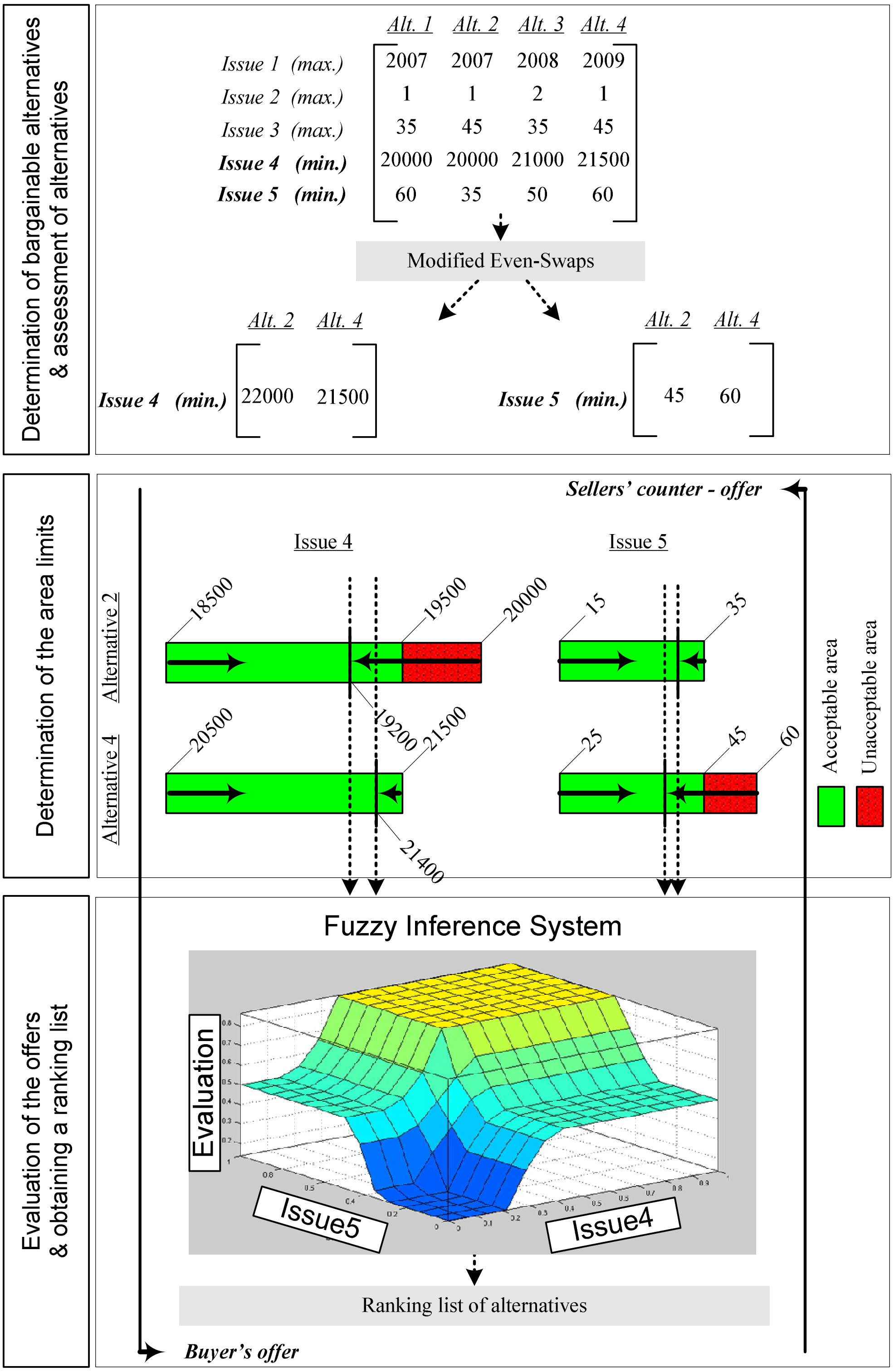


Figure 6.4 The case of multi-bargainable-issue

6.5.1 Specifying parameters of the input fuzzy sets

Fuzzy sets are formed by assigning a membership value to each object in the interval of [0, 1]. Membership values represent the degree to which an object belongs to a fuzzy set (Celikyılmaz & Turksen, 2009). A fuzzy set is characterized by its membership function (Celikyılmaz & Turksen, 2009). In the proposed multi-issue-negotiation system, input fuzzy sets are designed by considering the degree of "*acceptability*" of the offers through triangular membership functions. The acceptability values are classified into three groups as "*low*", "*middle*" and "*high*". The triangular membership functions (TMFs) have been frequently used in many applications of fuzzy sets because of their striking simplicity (Pedrycz, 1994). In this study, TMFs are employed in the design of input fuzzy sets, as well. The values limiting these clusters (*low*, *middle* and *high*) are used to define fuzzy membership functions for an offer. The agreement area limits of the alternative that has the largest area, i.e. the worst alternative for the buyer, are standardized to make range from start (0) to end (1) in order to observe the utility in the interval [0,1]. This standardization is required to perform fuzzy inference system (FIS). The agreement areas of the rest of the alternatives are scaled by considering the width of agreement area of the worst alternative. Figure-6.5 shows the operations and equations that are used to perform the transformation of agreement areas into fuzzy sets through an example.

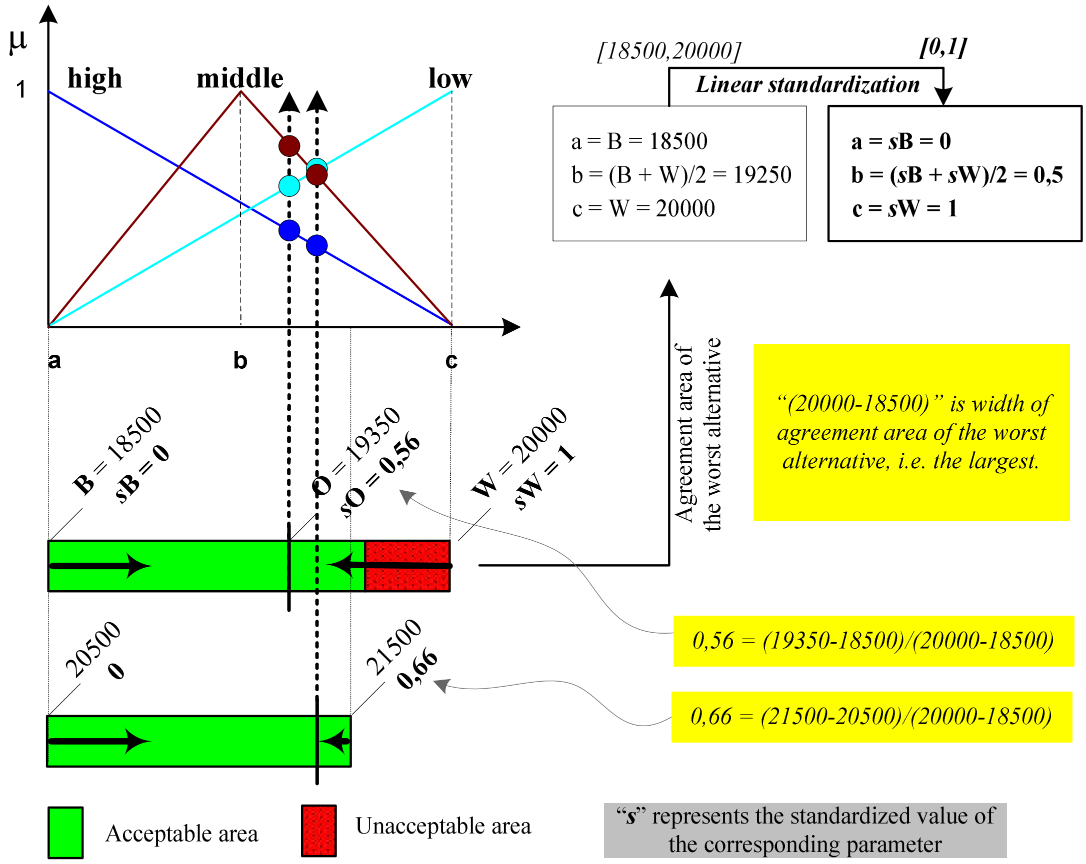


Figure 6.5 Fuzzy sets for input variables

6.6 Experimental work

Performance of the modified Even-Swaps mechanism depends significantly on the number of trade-offs. Therefore, in this section, a factorial experiment is carried out to study the factors thought to influence the number of trade-offs performed (as the *response values in Table-6.4*) in the modified Even-Swaps mechanism proposed in this work. Four main factors are taken into consideration in this experimental study. It is assumed that each factor has two levels because 2^k design provides the smallest number of runs and is useful when there are many factors to be investigated. Figure-6.6 shows the main factors and their levels. The levels of *number of alternatives* (*A*) are assumed to be ***8*** and ***14***. The levels of *number of criteria* (*B*) are assumed to be ***4*** and ***6*** as well. The levels of *compensation* (*C*) are two-folds: i) ***proportional*** *compensation* (according to previous compensations) and ii) ***independent*** *compensation* (from the previous compensations). The levels of *bargaining range*

(*D*) are determined as ***10%*** and ***20%*** of the biggest value of bargainable issue in initial decision matrix.

There are four factors and each factor has two levels. Therefore, 16 (= 2^4) trials are needed in order to conduct a full factorial design. The runs are made in random order as illustrated in Table-6.4 which also shows the average response values of five replications of the experiment.

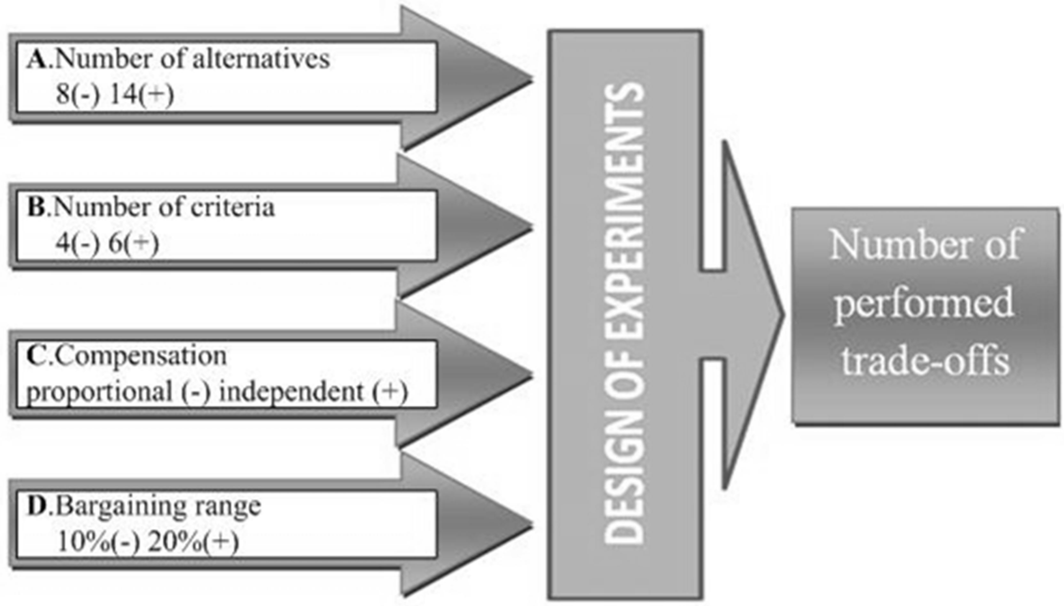


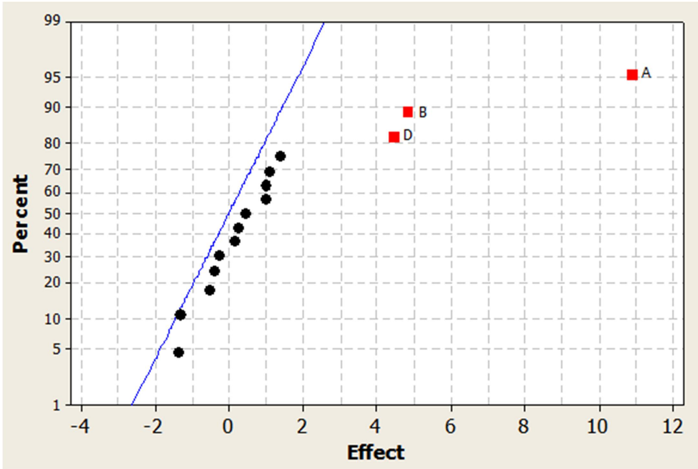
Figure 6.6 Main influential factors and their levels

Table 6.4 Design layout of the experiment with average response values

Std Order	Run Order	Factor *A*	*B*	*C*	*D*	*AB*	Treatment Combination	*Response (avrg of 5 replications)*
6	1	+1	-1	+1	-1	-1	AC	20.8
1	2	-1	-1	-1	-1	+1	(1)	11.8
4	3	+1	+1	-1	-1	+1	AB	25.6
11	4	-1	+1	-1	+1	-1	BD	19.2
7	5	-1	+1	+1	-1	-1	BC	12.6
9	6	-1	-1	-1	+1	+1	D	17
5	7	-1	-1	+1	-1	+1	C	9.2
14	8	+1	-1	+1	+1	-1	ACD	23.4
12	9	+1	+1	-1	+1	+1	ABD	31.8
16	10	+1	+1	+1	+1	+1	ABCD	31.6
15	11	-1	+1	+1	+1	-1	BCD	18.4
3	12	-1	+1	-1	-1	-1	B	17.8
2	13	+1	-1	-1	-1	-1	A	22
8	14	+1	+1	+1	-1	+1	ABC	28.2
10	15	+1	-1	-1	+1	-1	AD	26
13	16	-1	-1	+1	+1	+1	CD	16.2

Since the design of experiment is constructed over the assumption that observations are normally distributed, first of all, the response values are checked for normality. *Shapiro-Wilk (SW)* normality test is more reliable than *Kolmogorov-Smirnov* test in cases where the sample size is less than *50*. *SW* test is therefore performed and *p-value* is found greater than "*0.1*". The data follow a normal distribution according to the test result. Therefore, *data transformation* is not necessary and *parametric statistics* can be used on the data.

a.



b.

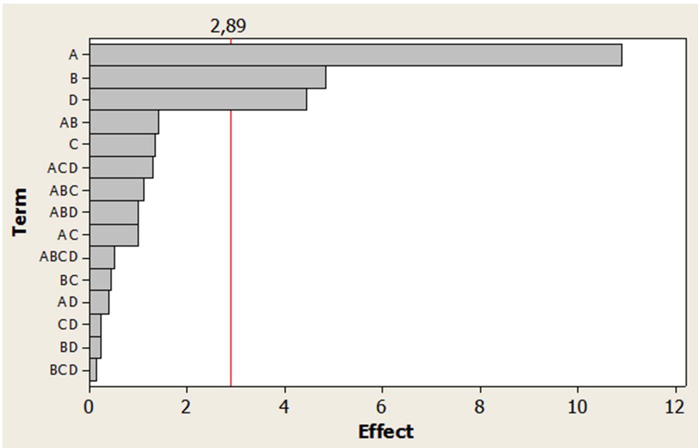


Figure 6.7 Analysis of factor effects: (a) Normal probability plot (b) Pareto plot

After performing normality test, a normal probability plot is constructed to specify the factor effects that are statistically significant (see Figure-6.7a). "*A*", "*B*" and "*D*" points are at the upper right corner of the plot. Moreover, these points also fall far away from the imaginary line. This indicates that "*A*", "*B*", and "*D*" factors are statistically significant. The rest of the points lie along the line and represent the effects of interaction factors. The important effects that emerge from this analysis are the main effects of "*A*", "*B*" and "*D*". Figure-6.7b also shows the analysis of the factor effects through Pareto plot. This plot shows that effect of "*AB* interaction factor" has more impact on the response than the impact of "*C*" that is a main factor. For that reason, it is also appended to Table-6.4 in order to examine the magnitude of impact of the factor although its effect is not statistically significant.

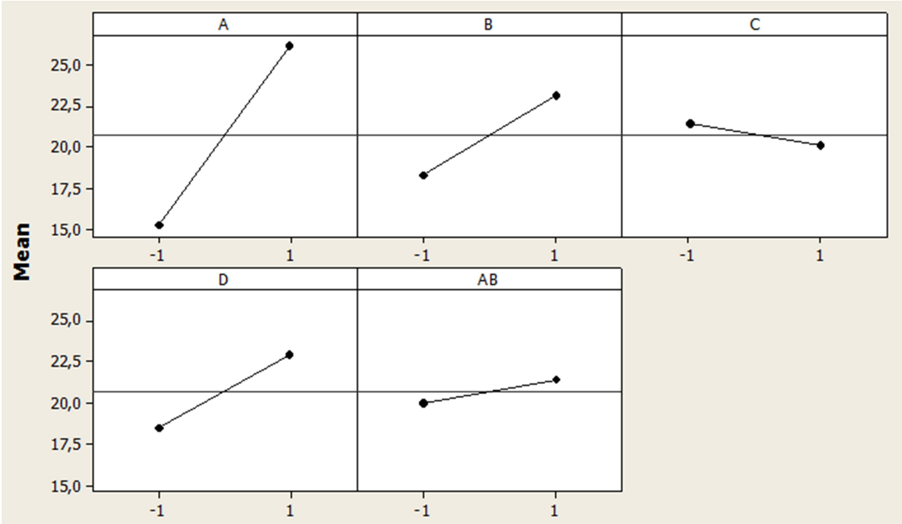


Figure 6.8 Main effect plots

Figure-6.8 shows main effects of the factors. The effects of "*A*", "*B*", "*D*" and "*AB*" are positive whereas that of "*C*" is negative. It can also be seen from these plots that the *number of alternatives* and the *number of criteria* greatly affect *the number of trade-offs*. The results are clear and meaningful since the number of alternatives and criteria specify dimension of the consequence matrix. The *bargaining range* is also one of the most influential factors according to the results. It is also obvious that the larger range causes the higher number of the trade-offs since makes difficult the "domination condition" explained in step 4 of modified Even-Swaps method (see Section-4). However, the effect of the compensation is not clear. It is generally thought that the negotiator should be consistent with the previous trade-offs in decision making processes. Making proportional compensations can assure the consistency. However, as we discussed in previous sections of this chapter, the decision maker can make more robust reasoning when he/she comes closer to the final solution since the effect of the reasoning can be perceived more explicitly. Therefore, the negotiator can change his thoughts contrary to his/her previous reasoning towards the end of the negotiation process. It should be noticed that proportional compensations (in the modified Even-Swaps mechanism) do not mean that the negotiators are consistent. So, a more robust way needs to be employed to test the consistency of the compensations. Lastly, the independent compensations can reduce the number of trade-offs and hence accelerates the negotiation process as it can be seen from the experiment results.

6.7 Conclusion

In this study, a novel multi-issue negotiation mechanism is proposed. This mechanism is based on a modified Even-Swaps method and fuzzy inference system (FIS). The usage of modified Even-Swaps method provides negotiators to assess the value of multi-issue offers effectively. The differences between the offers are produced as outcome of this assessment process in terms of *bargainable issues* under consideration. These differences are used to generate *agreement areas of the offers*. The proposed negotiation mechanism helps the negotiators to specify *initial and reservation values of the offers* by providing those agreement areas. The use of FIS enables the negotiators simultaneously bargaining on several issues under consideration, as well.

It is clear that the performance of the mechanism depends significantly on the number of trade-offs performed in the negotiation process. An experimental evaluation is also carried out to examine the factors thought to influence the number of trade-offs. The most influential factors are thoroughly discussed in the corresponding section.

With the modified Even-Swaps mechanism proposed in this work, negotiators can calculate *the real value of the products & services* through making *trade-offs* between the *issues* under consideration. Hence, they can bargain over multiple issues simultaneously. A restriction of the proposed mechanism is that it considers bargaining over a single item/product. Future research may potentially address how to extend the proposed *modified Even-Swaps mechanism* for multi-items.

CHAPTER 7

EVEN EASIER MULTI-ISSUE NEGOTIATION THROUGH MODIFIED EVEN-SWAPS CONSIDERING PRACTICALLY DOMINATED ALTERNATIVES

7.1 Introduction

"*Even-Swaps*" is a multi-criteria decision making method known as rational and easy-to-use trade-off methodology. Hammond et al. (1998) developed this method by following a kernel idea in a letter written in 1772 by Benjamin Franklin to Joseph Priestly (Franklin, 1956). In context of this method, the term "*even*" has a meaning of "*equivalence*" and the term "*swap*" represents "*exchange*" (Li & Ma, 2008). This method is based on even-swaps operations. In this method, trade-offs are performed by even-swaps, hypothetically changing consequence of an alternative in an issue and compensating this change with a preferentially equal consequence change in another issue (Mustajoki & Hamalainen, 2005; Elahi & Yu 2012).

These even-swaps enable decision makers to think about issue weights implicitly by representing value of an issue in terms of another one. Basically, these even-swaps aim to make issues "*irrelevant*" and to make alternatives "*dominated*". If an issue has equal consequence for each alternative, it is said that this issue is an "*irrelevant issue*". Such an issue can be ignored since it does not make a sense on the decision made for specification of the most preferred alternative. If an alternative is worse than any another alternative on some issues and not better than on all other issues, it is said that this alternative is a "*dominated alternative*". Such an alternative can be ruled out as well since it has disadvantages without providing any advantage over others. The method tries to reach to the most preferred alternative through even-swaps aiming at each phase to create irrelevant issues and dominated alternatives until one alternative, i.e. the most preferred one remains in the ultimate decision-matrix.

Multi-issue negotiation can be defined as a negotiation process aiming to reach a mutual agreement between parties by considering more than one negotiable issue all at once. Multi-issue negotiation can be accomplished through a well-defined agreement area in order to perform main negotiation activities such as evaluation of multi-dimensional offers appropriately and generation of counter-offers rationally. Even-Swaps method allows finding difference among alternatives in terms of any issue. This feature can be really helpful to clarify agreement area in a multi-issue negotiation environment. However, existing version of Even-Swaps method has a rigid structure trying to reveal only the best alternative. Other than this useful feature, Even-Swaps method performs trade-offs by generating hypothetical questions to decision maker. These questions can be transformed to automated negotiation messages through some modifications. With these features of this method in mind, we proposed an automated multi-issue negotiation mechanism, namely; "*Modified Even-Swaps*" in previous chapter of this thesis. Instead determination of the most preferred alternative only, modified structure of the Even-Swaps method provides a pool of negotiable alternatives that negotiator will decide which one is the best in a negotiation environment. Modified Even-Swaps mechanism can intrinsically improve the total utility by raising reciprocal solutions as a result of rational multi-issue negotiation.

Performance of the Modified Even-Swaps mechanism depends significantly on the number of trade-offs performed. It can be said that performing trade-offs by even-swaps provides more reliable reasoning in decision making when compared to methods based on explicitly weighting. Because assigning a weight for issues under consideration may not be suitable or possible to reflect decision makers' judgments straightforwardly. Some kind of trade-offs (e.g. design trade-offs) are generally tacit and therefore they are generally hard to articulate, capture and disseminate. Besides, performing trade-offs by even-swaps enables decision makers/negotiators to play active role and to make their reasoning when required. In such an environment, decision makers/negotiators can make more robust reasoning because they make their reasoning in an iterative way rather than at the beginning solely as in many multi-criteria decision making methods. Corresponding reasoning can be better extracted when decision makers/negotiators see the effects of their reasoning in updated decision-matrix in other words when they come closer to the final solution. Although even-swaps enable decision makers /negotiators to make more robust reasoning, they become unreasonable when the decision-matrix includes lots of alternatives and decision issues. In those cases, other methods above-mentioned seems more practical although even-swaps provide more robust trade-offs. Although performing even-swaps provides more robust reasoning as a result of its special structure that is iterative and not requires explicit weightings, it does not seem practical reasonably when decision-matrix includes high variation among consequences.

There is a trade-off between "robustness of trade-offs performed" and "being practical". This study aims to strike a happy medium between them. We therefore propose a hybrid approach to make even-swaps more practical in this chapter. This approach adapts a simple multi-criteria decision making method, namely; "*Simple Additive Weighting*" (SAW) method (also known as "*weighted linear combination method*" or "*scoring method*") for issues which have high variation among their consequences. By using SAW method, a combined consequence of the issues having high variation is obtained for each alternative. Decision-matrix is revised by taking these combined consequences into account. Phase of the mechanism which aims to identify dominated alternatives is executed by using revised decision-matrix including consequences of the issues having high variation as combined. This revision enables decision makers /negotiators to identify dominated alternatives more practically.

The reminder of this chapter is organized as follows. Section-7.2 gives a comprehensive review on Even-Swaps applications and realized theoretical contributions. The proposed approach is presented in Section-7.3. Conclusions are given in the final section.

7.2 Literature review

7.2.1 Applications of Even-Swaps

Diverse applications of Even-Swaps method are available in the literature. Kajanus et al. (2001) utilized Even-Swaps method while strategy selection in a rural enterprise. Kangas et al. (2008) used it while supporting decisions on forest management. Luo (2008) and Luo & Cheng (2006) applied while analyzing the resignation decisions of eleven nurses who have experience with the care of SARS patients. Even-Swaps method was also utilized while selecting an Unmanned Aerial Surveillance and Target Acquisition System (UASTAS) (Hurley & Andrews, 2003). It was especially preferred in this selection process due to its characteristic that most intelligent decision makers can easily understand it. Gregory & Wellman (2001) used it on environmental planning for simplification a policy choice by making sequential trade-offs between pairs of objectives to establish equivalences on one dimension (to make an irrelevant dimension). Baykasoglu et al. (2011) applied Even-Swaps method while making decision on buying used-trucks. Wakshull (2002) demonstrated the useful application of Even-Swaps to project risk management. Elahi & Yu (2009) used Even-Swaps in security requirements engineering. They adapted Even-Swaps method to incorporate the consequences of the mistrust condition for the trust trade-off analysis. Keser (2005) developed an interactive approach for multi-criteria sorting problems. Even-Swaps method was utilized in this approach for both making an estimation of the underlying utility function and generating possible dominance among the alternatives under consideration. Wachowicz (2010) proposed the use of Even-Swaps method for eliciting preferences of negotiator in the pre-negotiation phase. Geslin (2006) also used the Even-Swaps method in pre-negotiation phase in collaborative engineering design.

Therewithal some studies highlight the importance and usefulness of the Even-Swaps method as well. Kask et al. (2011) find useful Even-Swaps method in modeling tourist and community decision making for especially communities with limited expertise. Gregory & Keeney (2002) addressed importance of Even-Swaps method for making smarter environmental management decisions. The importance of Even-Swaps was also addressed while making sense of site selection by Augustin (1999). Dolan (2010) discussed advantages and potential problems of using Even-Swaps method in multi-criteria clinical decision support to promote evidence-based, patient-centered healthcare.

7.2.2 Theoretical contributions to Even-Swaps

Despite the fact that Even-Swaps method provides some useful features to decision makers, it also has some inadequacies. Li & Ma (2008) reported these inadequacies item by item as follows:

- Only the most preferred alternative is found. In an actual decision environment, decision maker may also want to know the second or the third preferred alternative.

- Some trade-offs of criteria values, as specified by the decision maker, may not be consistent with each other. Current methods have no mechanism to check the consistency of these trade-offs.

- The similarities among alternatives are not taken into account. Actually, the decision maker does not only want to know what the best option is but also the differences (or similarities) among alternatives.

Li & Ma (2008) and Ma & Li (2011) contributed Even-Swaps method by proposing a visualization approach, so called: *Decision Ball* model, which would display differences (or similarities) among alternatives and would assist in ranking alternatives under consideration. The model also tries to assess consistency of trade-offs by checking the latitude of alternatives after each even swap. They conclude that a trade-off is the most inconsistent when it causes the largest latitudinal shift of a given alternative. Keeney (2002) identifies important mistakes frequently made in making value trade-offs. It is stated that there is a tendency to linearly (proportionally) extrapolate value trade-offs over the entire range. Such an extrapolation is reasonable only if each successive unit change in the different measures has the same values as the previous change (Keeney, 2002). However, Even-Swaps method allows decision makers to play active roles in decision making. Expectation of proportional extrapolation in decision making may therefore not compatible when such a method is utilized. As we discussed in the previous chapter (that is also discussed in Dereli & Altun, 2012), we think that the information given by decision makers can change in accordance with the closeness to final solution. Keeney & Raiffa (1993) discuss that proportional extrapolation based consistency checking is not reasonable when there is risk aversion or diminishing marginal utility. Decision makers can make more robust reasoning when come closer to the final solution since the effect of the reasoning can be perceived more clearly. Therefore, the decision maker can change his/her thoughts contrary to the previous reasoning towards the end of the decision making process. As a result it can be stated that consistency checking may not be thought as an inadequacy of the method since its nature is different than other MCDM methods which generally use the information given by decision maker at the beginning solely and/or do not allow decision maker to play an (inter)active role in decision making process.

Mustajoki & Hamalainen (2005) contributed Even-Swaps to make it practical by adapting a preference programming approach to the method. This adaptation makes the even-swap process easier by giving helpful suggestions during decision making. They also developed “Smart-Swaps” that is a decision support system providing a platform for carrying out the elimination process and implementing the preference programming approach (see Mustajoki & Hamalainen, 2007). Moreover, Elahi & Yu (2012) developed an algorithm supporting Even-Swaps by providing a capability of accurately measuring or estimating costs and benefits of alternatives through the reuses of value trade-offs performed in the previous iterations.

7.3 Proposed approach

SAW method is one of the best known and the easiest multi-criteria decision-making methods. It is a proportional linear transformation of the raw data which means that the relative order of magnitude of the standardized scores remains equal (Afshari et al., 2010; Monakaran et al., 2011). Total score for each alternative is calculated as follow.

$$S_j = \sum_{j=1}^{k} w_j r_{ij} \; ; \; i = 1,2,\ldots,m \tag{1}$$

Where r_{ij} values are obtained from normalized consequences and w_j values are the issue weights. Calculation of the total scores (S_j) clearly demonstrates the main concept, the integration of the issue values and weights into a single magnitude (Podvezko, 2011).

Procedure of the method shows slight differences in existing applications although they are essentially based on multiplying issue weights with the normalized consequences of the alternatives. In this study, issue weighting is realized through pair-wise comparison that is based on Saaty's 1-9 scale of pair-wise comparisons. Besides, in order to express all consequence in same unit, corresponding consequences are scored by units from a 10-point scale, from 1(worst) to 10 (best). This study proposes the use of SAW method for determination of practically dominated alternatives in Modified Even-Swaps mechanism. Adaptation of SAW method to the mechanism is realized through following procedure.

Step1- Problem initialization

Step2- Determination of "bargainable" issue

Step3- Determination of a bargaining range for corresponding bargainable issue

Step4- Elimination of "dominated" alternatives

Step5- Elimination of "irrelevant" issues

Step6- Checking the existence of any relevant unbargainable issue

- If there is, check the existence of relevant unbargainable issues including high variation among consequences

    - If there are, use SAW method to obtain priority degrees as combined consequences of corresponding issues.

        - Then, eliminate dominated alternatives by considering combined consequences.

    Else, go to *Step7*

  Else, go to *Step9*

Step7- Determination of alternatives and an issue in order to perform an even-swap

Step8- Determination of required change and performing swapping operation

Then, go to Step4

Step9- The most preferred alternatives are found

Step10- Determination of agreement area limits

After elimination of dominated alternatives, SAW method is used to obtain combined consequences for the issues if relevant unbargainable issues having high variation are detected in the decision-matrix. Subsequently, mechanism checks the existence of any dominated alternatives by taking combined consequences into account. If there is, dominated alternative is excluded from the decision-matrix. This alternative can be considered as an alternative that is practically dominated. The mechanism follows its usual steps in else conditions.

7.3.1 An illustrative example

This section presents an illustrative example to demonstrate how the proposed approach improves the mechanism in terms of practicability. This example is adapted from Dereli & Altun (2012). Table-7.1 shows consequence matrix representing the example. There are fourteen alternatives and seven issues that have to be considered to make decision.

Prices of the alternatives are determined as bargainable issue. Therefore, even-swap operations will be performed for *Issue#7* (price) consequences. It is assumed that bargaining range is "2000". Initial scanning through the consequence table shows that alternative #1, #2, #3, #4, #7, #9 and alternative #11 are dominated alternatives. Dominated alternatives detected in this initial scanning are eliminated from the matrix. It is observed that all the issues are relevant in this phase. In existing version of Modified Even-Swaps mechanism, procedure goes on by making alternatives dominated or issues irrelevant by performing all of the even-swaps required. Table-7.2 shows the trade-offs performed through Modified Even-Swaps mechanism without practical dominance reinforcement.

Table 7.1 Consequence matrix corresponding to the case under consideration

Alternatives	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Issue#1	2008	2009	2009	2008	2008	2007	2007	2009	2007	2008	2007	2007	2008	2008
Issue#2	3	3	3	3	3	3	3	3	2	2	2	2	1	1
Issue#3	1	1	1	1	1	1	1	1	3	3	3	3	2	2
Issue#4	27	35	35	27	27	35	27	35	64	64	64	64	45	45
Issue#5	249	180	182	308	240	210	290	114	220	225	230	200	291	230
Issue#6	33400	32615	32615	33400	33400	32615	33400	32615	36400	36400	36400	36400	35650	35650
Issue#7	78	91,5	94	78	76	78	79	84,5	122	128	125	119	117	117

Table 7.2 List of the realized trade-offs when executed even-swaps method only

Number	Even Swap Change	Even Swap Compensation	Resulting situations
Issue#7 is determined as bargainable issue			
Bargaining range is "2000"			
Initial scanning through the consequence table			1 is dominated by 5; 3 is dominated by 2; 2 is dominated by 8; 4 is dominated by 5; 7 is dominated by 5; 11 is dominated by 9; 9 is dominated by 12
	Issue#1	*Issue#7*	
1 – *Alternative 6*	2007→2008	78000→80000	
2 – *Alternative 8*	2009→2008	84500→82500	
3 – *Alternative 12*	2007→2008	119000→121000	*Issue#1* is irrelevant; 10 is dominated by 12
	Issue#2	*Issue#7*	
4 – *Alternative 12*	2→3	121000→122500	
5 – *Alternative 13*	1→3	117000→120000	
6 – *Alternative 14*	1→3	117000→120000	*Issue#2* is irrelevant
	Issue#3	*Issue#7*	
7 – *Alternative 12*	3→1	122500→113000	
8 – *Alternative 13*	2→1	120000→115000	
9 – *Alternative 14*	2→1	120000→115000	*Issue#3* is irrelevant
	Issue#4	*Issue#7*	
10 – *Alternative 5*	27→35	76000→77800	
11 – *Alternative 12*	64→35	113000→106500	
12 – *Alternative 13*	45→35	115000→112800	*Issue#4* is irrelevant; 13 is dominated by 12;
13 – *Alternative 14*	45→35	79000→112800	14 is dominated by 12
	Issue#5	*Issue#7*	
14 – *Alternative 6*	210→240	80000→79500	
15 – *Alternative 8*	114→240	82500→70000	
16 – *Alternative 12*	200→240	106500→105500	*Issue#5* is irrelevant ; 6 is dominated by 8
	Issue#6	*Issue#7*	
17 – *Alternative 8*	32615→33400	70000→72500	*Issue#6* is irrelevant; 5 is dominated by 8; 12
18 – *Alternative 12*	36400→33400	105500→100500	is dominated by 8
(*Ending condition is the remaining only bargainable issue*)			
Alternative 8 is the remaining alternative			
→ Other alternatives are not negotiable.			

In order to find the most preferred alternative(s), 18 even-swaps have been performed. Alternative #8 only remains in the final decision-matrix and therefore there is no need to perform a negotiation process because the rest of the alternatives are not negotiable.

Modified Even-Swaps with practical dominance reinforcement proposed in this study is applied in the following. When Table-7.1 is reviewed, it is seen that "*Issue#4* (grade ability)", "*Issue#5* (km)" and "*Issue#6* (payload)" have high variation among the consequences of the alternatives. Firstly, a pair-wise comparison matrix is constructed for issues having high variation among consequences by using Saaty's 1-9 scale of pair-wise comparisons. Priority of each issue is calculated through normalization of pair-wise comparison matrix and then through finding the row averages (i.e., synthesization). Figure-7.1 shows pair-wise comparison matrix constructed and priority weights calculated. Calculated consistency index is at an acceptable level (calculated as 0.025 < 0.10).

Having found priorities of the issues having high variation, their consequences are scored by using 10-point scale, from 1 (for the worst) to 10 (for the best). Scores of the consequences of issues having high variation are shown in Table-7.3. Subsequently, combined consequences are calculated by multiplying issue priorities with corresponding consequences. These combined consequences are given in Table-7.4.

$$\begin{array}{l} \textit{Grade ability} \\ \textit{Km} \\ \textit{Payload} \end{array} \begin{bmatrix} 1 & 1/5 & 1/3 \\ 5 & 1 & 3 \\ 3 & 1/3 & 1 \end{bmatrix} \xrightarrow{\textit{Synthesization}} \begin{array}{c} \textit{Priority} \\ \begin{bmatrix} 0.10 \\ 0.64 \\ 0.26 \end{bmatrix} \end{array}$$

$$CI = \frac{\lambda \max - n}{n - 1} = \frac{3.03 - 3}{3 - 1} = 0.015$$

$$CR = \frac{CI}{RI} = 0.025 < 0.10$$

Figure 7.1 Pair-wise comparison matrix and priority weights

Table 7.3 List of the consequence scores of issues having high variation

Alternatives	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Issue#1	-	-	-	-	2008	2007	-	2009	-	2008	-	2007	2008	2008
Issue#2	-	-	-	-	3	3	-	3	-	2	-	2	1	1
*Issue#3** **(0.10)**	-	-	-	-	5	7	-	7	-	10	-	10	7	7
*Issue#4** **(0.64)**	-	-	-	-	7	9	-	10	-	8	-	9	5	8
*Issue#5** **(0.26)**	-	-	-	-	7	5	-	5	-	10	-	10	9	9
Issue#6	-	-	-	-	1	1	-	1	-	3	-	3	2	2
Issue#7	-	-	-	-	76	78	-	84,5	-	128	-	119	117	117

* Issue consequences are scored by using 10-point scale, from 1 (worst) to 10 (best)

Table 7.4 List of the combined consequences of issues having high variation

Alternatives	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Issue#1	-	-	-	-	2008	2007	-	2009	-	2008	-	2007	2008	2008
Issue#2	-	-	-	-	3	3	-	3	-	2	-	2	1	1
Issue#3	-	-	-	-	1	1	-	1	-	3	-	3	2	2
Combined consequences	-	-	-	-	6.80	7.76	-	8.40	-	8.72	-	9.36	6.24	8.16
Issue#7	-	-	-	-	76	78	-	84,5	-	128	-	119	117	117

* Issue consequences are scored by using 10-point scale, from 1 (worst) to 10 (best)

Table 7.5
List of the realized trade-offs when considered practically domination concept

Number	Even Swap Change	Compensation	Resulting situations
Issue#7 is determined as bargainable issue			
Bargaining range is "2000"			
Initial scanning through the consequence table			1 is dominated by 5; 3 is dominated by 2; 2 is dominated by 8; 4 is dominated by 5; 7 is dominated by 5; 11 is dominated by 9; 9 is dominated by 12
	Issue#1	*Issue#7*	
1 – *Alternative 6*	2007→2008	78000→80000	
2 – *Alternative 8*	2009→2008	84500→82500	
3 – *Alternative 12*	2007→2008	119000→121000	*Issue#1* is irrelevant; 10 is dominated by 12
	Issue#2	*Issue#7*	
4 – *Alternative 12*	2→3	121000→122500	
5 – *Alternative 13*	1→3	117000→120000	
6 – *Alternative 14*	1→3	117000→120000	*Issue#2* is irrelevant
	Issue#3	*Issue#7*	
7 – *Alternative 12*	3→1	122500→113000	*Issue#3* is irrelevant; 13 is **practically dominated** by 8; 14 is **practically dominated** by 8
8 – *Alternative 13*	2→1	120000→115000	
9 – *Alternative 14*	2→1	120000→115000	
	Issue#4	*Issue#7*	
10 – *Alternative 5*	27→35	76000→77800	
11 – *Alternative 12*	64→35	113000→106500	*Issue#4* is irrelevant
	Issue#5	*Issue#7*	
12 – *Alternative 6*	210→240	80000→79500	
13 – *Alternative 8*	114→240	82500→70000	
14 – *Alternative 12*	200→240	106500→105500	*Issue#5* is irrelevant ; 6 is dominated by 8
	Issue#6	*Issue#7*	
15 – *Alternative 8*	32615→33400	70000→72500	*Issue#6* is irrelevant; 5 is dominated by 8; 12 is dominated by 8
16 – *Alternative 12*	36400→33400	105500→100500	
(*Ending condition is the remaining only bargainable issue*)			
Alternative 8 is the remaining alternative			
→ Other alternatives are not negotiable.			

After calculation of combined consequences, dominated alternatives are specified by considering them as combined instead considering one by one. In this phase, detected dominated alternatives are named as "practically dominated". Table-7.5 shows trade-offs realized by means of even-swaps and SAW method supporting the mechanism to eliminate unnecessary even-swaps. Through this reinforcement, it is seen that alternative #13 and alternative #14 are dominated in the earlier phase of the process. Thus, fewer amounts of even-swaps (16 even-swaps) are needed to be performed to draw a conclusion. This example aims to demonstrate how practical dominance reinforcement improves the mechanism by executing the trade-offs, step by step.

7.3.2 Demonstration in a large-scale case

This section aims to demonstrate that proposed approach becomes more reasonable for large-scale cases dealing with bigger and complicated decision-matrices. This section includes a large-scale case derived from example given in the previous section of this chapter. It should be highlighted here that Even-Swaps is a method that is sensitive about "*path dependency*" (Lahtinen & Hamalainen, 2014). Therefore, path dependency needs to be taken into account while working on Even-Swaps method in especially comparison based examples. Therefore, illustrative example given in the previous section is extended systematically in order to assure that decision maker/negotiator will follow same path while performing trade-offs to specify the negotiable alternatives.

Table-7.6 shows the extended consequences matrix including four times more alternatives when compared to the previous example. This matrix includes additional three different alternatives for each alternative considered in the previous example. This matrix is derived from the previous example by expanding it generating three alternatives for each alternative considered in the previous example. Each of these additional three alternatives has different consequence for one of the issues which have high variation (they are "grade ability", "km" and "payload" in the previous example) and this change has been balanced by changing consequence of the negotiable issue as well. While doing that, we have changed consequence of the negotiable issue by considering that this change does not create a dominated alternative by means of dominance concept discussed in the first section, and also does not create a better option when considered total utility roughly. This kind of systematic approach enables us to follow same path while performing trade-offs.

Table-7.7 shows the trade-offs realized by means of even-swaps only for the large-scale case. Initial scanning shows that "28" alternatives are dominated, and when the table reviewed, it can be seen that procedure specifies negotiable alternatives (they are "A081", "A082", "A083", and "A084") by performing "60" times even-swaps operation.

Table 7.6 Consequence matrix for a large-scale case

Alternatives	A011	A012	A013	A014	A021	A022	A023	A024	A031	A032	A033	A034	A041	A042
Issue#1	2008	2008	2008	2008	2009	2009	2009	2009	2009	2009	2009	2009	2008	2008
Issue#2	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Issue#3	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Issue#4	27	35	27	27	35	27	35	35	35	27	35	35	27	35
Issue#5	249	249	219	249	180	180	150	180	182	182	152	182	308	308
Issue#6	33400	33400	33400	32615	32615	32615	32615	33400	32615	32615	32615	33400	33400	33400
Issue#7	78	80	80	77	91,5	90,5	93,5	94,5	94	93	96	97	78	80
Alternatives	A043	A044	A051	A052	A053	A054	A061	A062	A063	A064	A071	A072	A073	A074
Issue#1	2008	2008	2008	2008	2008	2008	2007	2007	2007	2007	2007	2007	2007	2007
Issue#2	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Issue#3	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Issue#4	27	27	27	35	27	27	35	27	35	35	27	35	27	27
Issue#5	278	308	240	240	210	240	210	210	190	210	290	290	260	290
Issue#6	33400	32615	33400	33400	33400	32615	32615	32615	32615	33400	33400	33400	33400	32615
Issue#7	80	77	76	78	78	75	78	77	80	81	79	81	81	78
Alternatives	A081	A082	A083	A084	A091	A092	A093	A094	A101	A102	A103	A104	A111	A112
Issue#1	2009	2009	2009	2009	2007	2007	2007	2007	2008	2008	2008	2008	2007	2007
Issue#2	3	3	3	3	2	2	2	2	2	2	2	2	2	2
Issue#3	1	1	1	1	3	3	3	3	3	3	3	3	3	3
Issue#4	35	27	35	35	64	35	64	64	64	35	64	64	64	35
Issue#5	114	114	84	114	220	220	190	220	225	225	195	225	230	230
Issue#6	32615	32615	32615	33400	36400	36400	36400	32615	36400	36400	36400	32615	36400	36400
Issue#7	84,5	83,5	86,5	87,5	122	120	124	121	128	126	130	127	125	123
Alternatives	A113	A114	A121	A122	A123	A124	A131	A132	A133	A134	A141	A142	A143	A144
Issue#1	2007	2007	2007	2007	2007	2007	2008	2008	2008	2008	2008	2008	2008	2008
Issue#2	2	2	2	2	2	2	1	1	1	1	1	1	1	1
Issue#3	3	3	3	3	3	3	2	2	2	2	2	2	2	2
Issue#4	64	64	64	35	64	64	45	35	45	45	45	35	45	45
Issue#5	200	230	200	200	170	200	291	291	161	291	230	230	200	230
Issue#6	36400	32615	36400	36400	36400	32615	35650	35650	35650	32615	35650	35650	35650	32615
Issue#7	127	124	119	117	121	118	117	116	119	116,5	117	116	119	116,5

Table 7.7 Trade-offs realized by means of even-swaps only for the large-scale case

Number	Even Swap Change	Compensation	Resulting situations
Issue#7 is determined as bargainable issue			
Bargaining range is "2000"			
Initial scanning through the consequence table			Following alternatives are dominated: A011, A012, A013, A014, A021, A022, A023, A024, A031, A032, A033, A034, A041, A042, A043, A044, A071, A072, A073, A074, A091, A092, A093, A094, A111, A112, A113, A114
	Issue#1	*Issue#7*	
1 - *Alternative A061*	2007→2008	78000→80000	
2 - *Alternative A062*	2007→2008	77000→79000	
3- *Alternative A063*	2007→2008	80000→82000	
4- *Alternative A064*	2007→2008	81000→83000	
5- *Alternative A081*	2009→2008	84500→82500	
6- *Alternative A082*	2009→2008	83500→81500	
7- *Alternative A083*	2009→2008	86500→84500	
8- *Alternative A084*	2009→2008	87500→85500	
9- *Alternative A121*	2007→2008	119000→121000	
10- *Alternative A122*	2007→2008	117000→119000	
11- *Alternative A123*	2007→2008	121000→123000	*Issue#1* is irrelevant; Following alternatives
12- *Alternative A124*	2007→2008	118000→120000	are dominated: A101, A102, A103, A104
	Issue#2	*Issue#7*	
13- *Alternative A121*	2→3	121000→122500	
14- *Alternative A122*	2→3	119000→120500	
15- *Alternative A123*	2→3	123000→124500	
16- *Alternative A124*	2→3	120000→121500	
17- *Alternative A131*	1→3	117000→120000	
18- *Alternative A132*	1→3	116000→119000	
19- *Alternative A133*	1→3	119000→121000	
20- *Alternative A134*	1→3	116500→119500	
21- *Alternative A141*	1→3	117000→120000	
22- *Alternative A142*	1→3	116000→119000	
23- *Alternative A143*	1→3	119000→121000	
24- *Alternative A144*	1→3	116500→119500	*Issue#2* is irrelevant
	Issue#3	*Issue#7*	
25- *Alternative A121*	3→1	122500→113000	
26- *Alternative A122*	3→1	120500→111000	
27- *Alternative A123*	3→1	124500→115000	
28- *Alternative A124*	3→1	121500→112000	
29- *Alternative A131*	2→1	120000→115000	
30- *Alternative A132*	2→1	119000→114000	
31- *Alternative A133*	2→1	121000→116000	
32- *Alternative A134*	2→1	119500→114500	
33- *Alternative A141*	2→1	120000→115000	
34- *Alternative A142*	2→1	119000→114000	*Issue#3* is irrelevant; Following alternatives
35- *Alternative A143*	2→1	121000→116000	are dominated: A131, A132, A134, A141,
36- *Alternative A144*	2→1	119500→114500	A142, A143
	Issue#4	*Issue#7*	
37- *Alternative A051*	27→35	76000→77800	
38- *Alternative A053*	27→35	78000→79800	
39- *Alternative A054*	27→35	75000→76800	
40- *Alternative A062*	27→35	79000→80800	
41- *Alternative A082*	27→35	81500→83300	
42- *Alternative A122*	64→35	113000→106500	
43- *Alternative A123*	64→35	115000→108500	
44- *Alternative A124*	64→35	112000→105500	*Issue#4* is irrelevant; Following alternatives
45- *Alternative A133*	45→35	116000→113800	are dominated: A064, A122, A124, A144
46- *Alternative A144*	45→35	114500→112300	
	Issue#5	*Issue#7*	
47- *Alternative A053*	210→240	79800→79300	
48- *Alternative A061*	210→240	80000→79500	
49- *Alternative A062*	210→240	80800→80300	
50- *Alternative A063*	190→240	82000→80500	
51- *Alternative A081*	114→240	82500→70000	
52- *Alternative A082*	114→240	83500→71000	
53- *Alternative A083*	84→240	84500→71500	
54- *Alternative A084*	114→240	85500→73000	
55- *Alternative A121*	200→240	106500→105500	*Issue#5* is irrelevant ; Following alternatives
56- *Alternative A123*	170→240	108500→106000	are dominated: A051, A052, A053, A054,
57- *Alternative A133*	161→240	113800→110300	A061, A062, A063, A133

Table 7.7 (Continued)

Number	Even Swap Change	Compensation	Resulting situations
	Issue#6	*Issue#7*	
58- *Alternative A084*	33400→32615	73000→70500	
59- *Alternative A121*	36400→32615	105500→98000	*Issue#6* is irrelevant; Following alternatives are dominated: A121, A123
60- *Alternative A123*	36400→32615	106000→98500	

(*Ending condition is the remaining only bargainable issue*)
Following alternatives are negotiable: **A081**, **A082**, **A083**, **A084**
→ Other alternatives are not negotiable.

Modified Even-Swaps considering practically dominated alternatives by means of the adaptation of SAW method has also been applied to this large-scale case. For issues having high variation among the consequences of the alternatives, i.e. "*Issue#4* (grade ability)", "*Issue#5* (km)" and "*Issue#6* (payload)" have been scored. Table-7.8 shows these scores and the calculated combined consequences for each alternative.

List of trade-offs realized by means of the proposed approach considering practically dominated alternatives are given in Table-7.9. When compared to the approach not considering dominated alternatives, this time the mechanism allows us to eliminate five more alternatives even at initial scanning phase (they are "A063", "A083", "A101", "A104", and "A123") and also allow us to eliminate some other alternatives at earlier phases of the procedure. By the help of this earlier detection of the dominated alternatives, the proposed approach enables us to reach the result with less amount of even-swaps operation. When practically dominated alternatives are considered in the mechanism, negotiable alternatives are found by performing "43" times even-swaps operation. Remind that we need to 60 times even-swaps operation to reach the result when we do not consider the practically dominated alternatives (see Table-7.7). However, it is seen that when Table-7.9 is reviewed, list of negotiable alternatives is as "A081", "A082" and "A084". This approach eliminates alternative "A081" even if it is found as a negotiable alternative when not considered practically domination. As we discussed in the first section, this is because of the trade-off between "robustness of trade-offs performed" and "being practical". It can be seen that striking a happy medium between them can be possible with the proposed approach when results of these examples are reviewed.

Table 7.8
Scoring consequences of issues having high variation for the large-scale case

Alternatives	A011	A012	A013	A014	A021	A022	A023	A024	A031	A032	A033	A034	A041	A042
Issue#1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Issue#2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Issue#3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Issue#4 ***(0,1)***	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Issue#5 ***(0,64)***	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Issue#6 ***(0,26)***	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Combined consequences	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Issue#7	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Alternatives	A043	A044	A051	A052	A053	A054	A061	A062	A063	A064	A071	A072	A073	A074
Issue#1	-	-	2008	2008	2008	2008	2007	2007	2007	2007	-	-	-	-
Issue#2	-	-	3	3	3	3	3	3	3	3	-	-	-	-
Issue#3	-	-	1	1	1	1	1	1	1	1	-	-	-	-
Issue#4 ***(0,1)***	-	-	5	7	5	5	7	5	7	7	-	-	-	-
Issue#5 ***(0,64)***	-	-	7	7	9	7	9	9	9	9	-	-	-	-
Issue#6 ***(0,26)***	-	-	7	7	7	5	5	5	5	7	-	-	-	-
Combined consequences			6,8	7	8,08	6,28	7,76	7,56	7,76	8,28				
Issue#7	-	-	76	78	78	75	78	77	80	81	-	-	-	-

Alternatives	A081	A082	A083	A084	A091	A092	A093	A094	A101	A102	A103	A104	A111	A112
Issue#1	2009	2009	2009	2009	-	-	-	-	2008	2008	2008	2008	-	-
Issue#2	3	3	3	3	-	-	-	-	2	2	2	2	-	-
Issue#3	1	1	1	1	-	-	-	-	3	3	3	3	-	-
Issue#4 ***(0,1)***	7	5	7	7	-	-	-	-	10	7	10	10	-	-
Issue#5 ***(0,64)***	10	10	10	10	-	-	-	-	8	8	9	8	-	-
Issue#6 ***(0,26)***	5	5	5	7	-	-	-	-	10	10	10	5	-	-
Combined consequences	8,4	8,2	8,4	8,92					8,72	8,42	9,36	7,42		
Issue#7	84,5	83,5	86,5	87,5	-	-	-	-	128	126	130	127	-	-

Alternatives	A113	A114	A121	A122	A123	A124	A131	A132	A133	A134	A141	A142	A143	A144
Issue#1	-	-	2007	2007	2007	2007	2008	2008	2008	2008	2008	2008	2008	2008
Issue#2	-	-	2	2	2	2	1	1	1	1	1	1	1	1
Issue#3	-	-	3	3	3	3	2	2	2	2	2	2	2	2
Issue#4 ***(0,1)***	-	-	10	7	10	10	7	7	7	7	7	7	7	7
Issue#5 ***(0,64)***	-	-	9	9	9	9	5	5	9	5	8	8	9	8
Issue#6 ***(0,26)***	-	-	10	10	10	5	9	9	9	5	9	9	9	5
Combined consequences			9,36	9,06	9,36	8,06	6,24	6,24	8,8	5,2	8,16	8,16	8,8	7,12
Issue#7	-	-	119	117	121	118	117	116	119	116,5	117	116	119	116,5

Table 7.9

Trade-offs realized for the large-scale case when considered practically domination

	Even Swap		
Number	Change	Compensation	Resulting situations
Issue#7 is determined as bargainable issue			
Bargaining range is “2000”			
Initial scanning through the consequence table			Following alternatives are dominated: A011, A012, A013, A014, A021, A022, A023, A024, A031, A032, A033, A034, A041, A042, A043, A044, A071, A072, A073, A074, A091, A092, A093, A094, A111, A112, A113, A114; Following alternatives **practically dominated**: A063, A083, A101, A104, A123
	Issue#1	*Issue#7*	
1 - *Alternative A061*	2007→2008	78000→80000	
2 - *Alternative A062*	2007→2008	77000→79000	
3- *Alternative A064*	2007→2008	81000→83000	
4- *Alternative A081*	2009→2008	84500→82500	
5- *Alternative A082*	2009→2008	83500→81500	
6- *Alternative A084*	2009→2008	87500→85500	
7- *Alternative A121*	2007→2008	119000→121000	*Issue#1* is irrelevant; Following alternatives
8- *Alternative A122*	2007→2008	117000→119000	are **practically dominated**: A061, A102,
9- *Alternative A124*	2007→2008	118000→120000	A103, A124
	Issue#2	*Issue#7*	
10- *Alternative A121*	2→3	121000→122500	
11- *Alternative A122*	2→3	119000→120500	
12- *Alternative A131*	1→3	117000→120000	
13- *Alternative A132*	1→3	116000→119000	
14- *Alternative A133*	1→3	119000→121000	
15- *Alternative A134*	1→3	116500→119500	
16- *Alternative A141*	1→3	117000→120000	
17- *Alternative A142*	1→3	116000→119000	
18- *Alternative A143*	1→3	119000→121000	
19- *Alternative A144*	1→3	116500→119500	*Issue#2* is irrelevant
	Issue#3	*Issue#7*	
20- *Alternative A121*	3→1	122500→113000	
21- *Alternative A122*	3→1	120500→111000	
22- *Alternative A131*	2→1	120000→115000	
23- *Alternative A132*	2→1	119000→114000	
24- *Alternative A133*	2→1	121000→116000	
25- *Alternative A134*	2→1	119500→114500	
26- *Alternative A141*	2→1	120000→115000	
27- *Alternative A142*	2→1	119000→114000	*Issue#3* is irrelevant; Following alternatives
28- *Alternative A143*	2→1	121000→116000	are **practically dominated**: A131, A132,
29- *Alternative A144*	2→1	119500→114500	A133, A134, A141, A142, A143, A144
	Issue#4	*Issue#7*	
30- *Alternative A051*	27→35	76000→77800	
31- *Alternative A053*	27→35	78000→79800	
32- *Alternative A054*	27→35	75000→76800	
33- *Alternative A062*	27→35	79000→80800	*Issue#4* is irrelevant; Following alternatives
34- *Alternative A082*	27→35	81500→83300	are **practically dominated**: A064, A122
35- *Alternative A121*	64→35	113000→106500	
	Issue#5	*Issue#7*	
36- *Alternative A053*	210→240	79800→79300	
37- *Alternative A062*	210→240	80800→80300	
38- *Alternative A081*	114→240	82500→70000	
39- *Alternative A082*	114→240	83300→70800	
40- *Alternative A084*	114→240	85500→73000	*Issue#5* is irrelevant ; Following alternatives
41- *Alternative A121*	200→240	106500→105500	are dominated: A051, A052, A053, A054, A062
	Issue#6	*Issue#7*	
42- *Alternative A084*	33400→32615	73000→70500	
43- *Alternative A121*	36400→32615	105500→98000	*Issue#6* is irrelevant; Following alternative is dominated: A121
(*Ending condition is the remaining only bargainable issue*)			
Following alternatives are negotiable: **A081**, **A082**, **A084**			
→ Other alternatives are not negotiable.			

7.4 Conclusion

Automated negotiation is an emerging area in the field of autonomous agents and multi-agent systems, which are the popular research direction of advanced information and communication technologies (ICTs). The most important challenging factor in automated negotiation is the complexity caused by number of issues, dependencies between considered issues, representation of utilities, etc. (see Ito et al., 2012). Development and implementation of sophisticated ICTs to multi-issue negotiation is especially therefore an active research direction in multi-agent systems. Modified Even-Swaps mechanism is a clear, rational and an easy-to-use mechanism for multi-issue negotiation that is highly complicated to realize. It can be said that any improvements aiming to make these mechanisms even easier to implement make the genuine contribution to this area.

In line with this purpose, this study addresses the development of a practical dominance reinforcement to make Modified Even-Swaps mechanism even easier. This study proposes an adaptation of SAW method to the Modified Even-Swaps mechanism in order to identify and then to eliminate dominated alternatives more practically. By means of these improvements, Modified Even-Swaps mechanism becomes more reasonable for the cases dealing with bigger and complicated decision-matrices. Magnitude of the improvements can be shown better in cases having bigger decision-matrices. Therefore, future studies can potentially address the use of the proposed approach in cases having bigger and complicated decision-matrices.

CHAPTER 8

HANDLING TYPE-2 FUZZINESS IN MULTI-ISSUE NEGOTIATON BY MEANS OF THE MODIFIED EVEN-SWAPS

It can be said that consequence of a negotiable issue is not exact although a value has assigned to define it since it will change if you negotiate for it. Furthermore, this change depending on negotiation capability does not completely depend on the competitive environment.

Modified Even-Swaps mechanism proposed in Chapter-6 of this thesis assumes that both sides of negotiation are rational and thus the negotiation mechanism tries to find a reciprocal solution by taking competitive environment into account.

However, in our daily life, we can see that, especially in negotiation cases realized between buyers and sellers, buyers are generally rational and intend to perform a negotiation process that is reasonable when taken other alternatives into account. On the other side, sellers intend to realize a negotiation process with offers those are still unreasonable when considered other alternatives provided by competitors. Negotiation is considered as a marketing trick in general by sellers (it is like using 2.99 instead of 3).

According to Wu & Mendel (2009), there are at leat two types of uncertainities associated with a word: "*intra-personal uncertainity*" and "*inter-personal uncertainity*".

By Wallsten & Budescu (1995), "*Intra-personal uncertainity*" is pointed out as "*except in very special cases, all representations are vague to some degree in the minds of the originators and in the minds of the receivers*". And it is suggested modeling this kind of uncertainity by type-1 fuzzy sets and systems.

On the other hand, "*inter-personal uncertainity*" is pointed out by Wallsten & Budesco (1995) as "*different individuals use diverse expressions to desccribe identical situations and understand the same phrases differently when hearing or reading them*". Use of type-2 fuzzy sets and systems is suggested for the cases including such kind of words that can mean different things to different people. From this point of view, we can say that negotiation process includes "*inter-personal uncertainty*" in its definition because the word, "*negotiable*" can mean different things to each side of negotiation.

Bargaining range is determined roughly for each negotiable issue while using the Modified Even-Swaps. In the duration of eliminating dominated alternatives, for bargainable issues, one alternative dominates another one if the difference betwen them is bigger than the bargaining range specified in the beginning of the process. By this way, negotiable alternatives are not eliminated from the final decision-matrix. After finding negotiable alternatives and differences between them in terms of negotiable issues, agreement area limits are specified for each negotiable issue of corresponding alternatives. Subsequently, the largest agreement area limits are used to define fuzzy input membership functions. It can be said that this efforts is to handle uncertainities in the competitive environment. Current version of the Modified Even-Swaps allows us to handle this uncertainty.

Inputs of this fuzzy system are the consequences of these negotiable issues of each alternative and they are exact values. However, the process starts with a bargaining range that is specified roughly. It is just needed to eliminate dominated alternatives that will not be acceptable even after a perfect negotiation process.

It is certain that we can get the most reliable bargaining ranges for each alternative while performing negotiation. Uncertainity in definition of bargaining ranges of each alternative is the second type fuzziness that needs to be taken into account as well. When alternatives has uncertain bargaining ranges, this uncertainty has to be taken into account while executing the fuzzy inference system (see Figure-8.1). At this phase, the Modified Even-Swaps mechanism has to revise the fuzzy sets at each round of the negotiation process. This revision creates footprint of uncertainty and it requires a type-2 fuzzy approach as described in the Chapter-4 in detail.

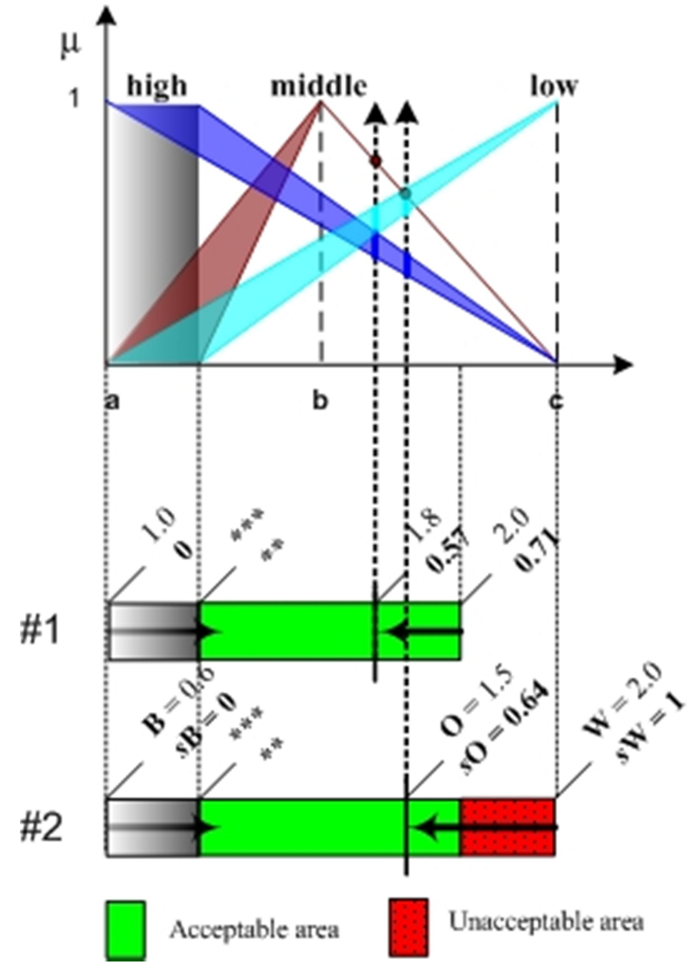


Figure 8.1 Use of type-2 fuzzy sets in the Modified Even-Swaps

CHAPTER 9

CUSTOMER CO-CREATION IN NEW PRODUCT DEVELOPMENT THROUGH THE MODIFIED EVEN-SWAPS

9.1 Introduction

The product performance is considerably related with understanding of customer needs. Better understanding of them enables product developers to engage in more directed problem-solving activities in the innovation process (Piller et al., 2011). However, these needs are often individual and tacit in nature so hard to accurately measure and coherently implement (Franke & Piller, 2004; Simonson, 2005). Therefore, customer co-creation, i.e., *collaborative NPD activities in which customers actively contribute* (Hoyer et al., 2010), through a suitable negotiation mechanism becomes inevitable to reach the success in the innovation process. Customer co-creation aims to utilize information and capabilities of customers for the innovation process. Therefore, in this chapter, we present a framework for customer co-creation in NPD through the Modified Even-Swaps.

The reminder of this chapter is organized as follows. Firstly, literature review is given in the next section. In Section-3, the proposed customer co-creation approach is presented. An illustrative example is given in Section-4. Conclusions and future study are given in the last section.

9.2 Literature review

Hauser et al. (2006) state that successful innovation rests on first understanding customer needs and then developing products to meet those needs. Two sources of information are necessary for successful NPD. The former is about customer needs and the latter is about how best to solve these needs (O'Hern & Rindfleisch, 2008).

Conventionally, customers are in the forms of either "passive" or "speaking only when spoken to" in the innovation process (Piller et al., 2011). Customer needs elicitations and evaluations are fundamental procedures and essential premises for successful NPD (Yan et al., 2002). Various techniques, (psychology based, artificial-intelligence based and knowledge-recovery based) have been used for elicitation of the customer needs. See Jia & Chen (2006) for a review study on customer needs elicitation. Various techniques have also been used for concept generation and evaluation. Using multiple criteria decision making (MCDM) methods is one of the most applied approaches for concept generation and evaluation. For instance, Ayag (2005a) and Ayag (2005b) use analytic hierarchy process (AHP) and fuzzy AHP, respectively; to evaluate conceptual design. Fuzzy analytic network process (ANP) is also used by Ayag & Ozdemir (2009). In another study, Huang et al. (2006) implement concept evaluation and decision making through fuzzy neural network to obtain an optimal concept.

However, since new products very often fail to match customer needs, improving interaction with customers during NPD process is an important challenge in order to reduce failure rates and to increase financial returns from high investments (Ernst et al., 2010). In this regard, customer co-creation in NPD process is an emergent domain. There are some research agendas for this domain in the scientific literature (see Hoyer et al., 2010; Piller et al., 2011; O'Hern et al., 2008). Customers are actively involved and take part in NPD process through co-creation (Piller et al. 2011). Especially, customer co-creation in the idea generation and concept development can improve the product performance considerably (Gruner & Homburg, 2000).

Complexity in NPD process steadily increases and represents a major challenge for any enterprise's sustainable market success (Maurer, 2007). With the increased complexity, amount of the issues/criteria taken into account also increases naturally. Thus, NPD process becomes all about trade-offs and therefore trade-off management gets an important responsibility for designers. Making robust trade-offs can be vital for determination of the contradictions and hence for solving them through inventive problem solving techniques. However, solving contradictions may generate other contradictions into the design because of the increased complexity. Besides, there can be more than one solution for the contradiction. In complex product design environments it can also be possible that the contradictions are from results of not only two issues but also triple and more interactions among issues. In those cases, concept evaluation through MCDM methods alone may not solve the problem entirely. In most cases, needs are negotiable and may conflict with one another (Jiao & Chen, 2006), and thus negotiation with issue trade-offs are often necessary to improve the product performance in terms of customer needs and technical economic availabilities. As a consequence, rather than using MCDM methods alone, use of an appropriate "multi-issue negotiation" mechanism gets more appropriate advance to customer co-creation in NPD. Developing and implementing automated negotiation mechanisms for customer co-creation in NPD will also be a part of the CAI literature since they aim to improve efficiency and effectiveness of innovation process as well.

Although studies related with concept evaluation in NPD environment through MCDM methods are increasingly popular, relevant literature on customer co-creation in NPD through negotiation is quite limited (Hoyer et al., 2010). Chen & Tseng (2005) address the use of multi-issue negotiation approach for custom products. Their study follows supplier-oriented approach rather than customer-oriented approach since backbone of customer-oriented approach lies in utility theory. They believe that utility theory is hard to implement in practice because of its subjectivity. In another study, Wijen & Duysters (2005) argue that innovation can be the result of a repetitive, multi-actor negotiation process.

The academic literature still tends to ignore the specific aspects of negotiation as an important factor in the innovation process in spite of the widespread use of customer involvement in the innovation process (Wijen & Duysters, 2005). The complex and dynamic negotiation process with contingent outcomes that leads to an innovation like the present one has not, or at least insufficiently, been highlighted in the literature (Wijen & Duysters, 2005). Of course, an essential reason for that is about negotiation mechanisms and their obstacles. Chen-Ritzo et al. (2005) claim that; *in many applications it may not be practical for a negotiator to reveal their entire utility function, either for strategic reasons, or because they are unable to express it.* For that difficulty, price-only negotiation has been considered as a reasonable approach to adopt for some researchers (e.g. Yuan & Tsao, 2010) although the overall utility achieved in multi-issue negotiation formats is considerably higher than in price-only negotiations (Bichler, 2000). Chen-Ritzo et al. (2005) also claim that; while the proposed multi-issue negotiation mechanisms in the literature may provide higher theoretical utility to the negotiator, it is not clear that these improvements will be realized in practice. An effective multi-issue negotiation mechanism should possess following properties with respect to Chen-Ritzo et al., 2005: Negotiator must be able to effectively assess the value of a multi-issue offer. Negotiator must be able to effectively bargain on several attributes/issues simultaneously.

In their study, Chen-Ritzo et al. (2005) also state that; *it is not clear whether a multi issue negotiation mechanism can be designed which effectively achieves these properties in theory and practice*. However, for the time being, there has been significant progress in multi-issue negotiation. We propose an effective multi-issue negotiation mechanism, namely; Modified Even-Swaps in the previous chapters. This mechanism has a unique feature that provides negotiators assessing the value of multi-issue offers effectively, since at this stage it uses a modified version of the Even-Swaps that is known a novel, clear, rational and easy-to-use trade-off methodology. The mechanism also enables negotiators bargaining on several issues simultaneously through a fuzzy inference system. Therefore, it can be said that the mechanism is an effective one with respect to assessment criteria of Chen-Ritzo et al. (2005). With the help of this progress on multi-issue negotiation, this study calls attention for customer co-creation in NPD through multi-issue negotiation via presenting a framework which uses Modified Even-Swaps mechanism for finding win-win solutions between customers and designers.

9.3 Proposed approach

9.3.1 Involving lead-users

Focusing groups and customer surveys are generally applied methods to understand customer needs and preferences (Gourova and Toteva, 2011). Besides, Von Hippel (1986) introduced a novel concept, namely; "*lead-users*" as an alternative to the traditional market research approaches. Lead-users are defined as users whose present strong needs will become general in a marketplace months or years in the future (Von Hippel, 1986). Lead users can provide more accurate and useful NPD data than provided by traditional market researches since lead-users have real-world experience and they are at the front of the trend. Therefore, they can provide understanding of "tomorrow's needs today" (Herstatt & Von Hippel, 1992). Furthermore, use of lead-users can accelerate the negotiation process since obtaining responses can be faster than the traditional approaches. For that reasons, we propose to entail lead-users for customer co-creation in NPD.

9.3.2 Using modified Even-Swaps for concepts evaluation

Lead-user evaluates set of design alternatives through modified Even-Swaps. While doing that first of all designer and lead-user decide bargainable issues and the other issues which will be taken into account together. Afterwards, the issues, the alternatives and their responding values are used to generate a consequence matrix. Having generated consequence matrix, the steps of the modified Even-Swaps are performed. At this stage, the software, namely; MESA, developed for performing the steps of modified Even-Swaps can be used. It grants procedural support to the lead-user in making trade-offs by generating suitable comparison statements. At the end of the process, agreement areas are specified.

9.3.3 Using agreement areas to clarify design contradictions and their emergency

Having performed concepts evaluation, acceptable and unacceptable areas in terms of bargainable issues are specified. These areas are used to generate input-fuzzy-sets of the fuzzy inference system as we mentioned before. After generating rule bases by taking into account lead-user's directions, fuzzy inference system is ready to give the utility of each alternative. Evaluate each alternative by using Mamdani-type fuzzy inference system. Subsequently, create a ranking list for alternatives with respect to the crisp output values which are obtained after defuzzification steps. Generated rule base and limits of existing agreement areas help to clarify design contradictions and their emergency.

9.3.4 Dealing with contradictions

Negotiation process should lead to exploration of a larger design space since the final agreement is only as good as the best of the agreements explored during negotiation (Jin & Geslin, 2010). Contradictions between two parties are not only the problems to deal with but also the opportunities that the parties can take to explore new solutions (Jin & Geslin, 2010). The proposed negotiation process aims to augment utility of the design alternatives through mutual solutions. Augmenting the utility is possible with making new offers through dealing with contradictions by using "40 principles" for solving contradictions accessed through the "contradiction matrix" and "separation principles" (see Gadd, 2011) and/or finding optimum levels of bargainable issues. While using contradiction matrix, a mapping/matching is required to transform the specified bargainable issues to suitable contradictions which are in the contradiction matrix. Designer tries to modify/improve the design through contradiction matrix and/or optimization techniques. Afterward, designer offers novel modified/improved design alternatives for multi-issue evaluation again.

9.3.5 Updating agreement areas and performing a new negotiation round

Designed fuzzy inference system evaluates the new modifications through updated responding values of bargainable issues and updates the utility of each design alternative and hence the ranking list. The performed modifications/improvements can augment utility of modified design alternatives. In complex product design environments, these modification/improvements obtained through dealing with contradictions can cause other contradictions. For clarifying the new contradictions the process starts at the beginning by using modified/improved design alternatives. The process can stop with as soon as predefined satisfying level of lead-user needs and preferences is achieved and/or predefined time for negotiation is consumed.

9.4 An illustrative example

In this section of this chapter, an illustrative example is presented to show how the proposed customer co-creation in NPD approach works. There is one lead user and one designer in the example. There are three bargainable issues which lead user and designer will bargain for them. Besides there are three unbargainable issues which will be taken into account. The decision matrix is given in Figure-9.1. Lead-user evaluates the concept that includes four design alternatives through modified Even-Swaps method. At the end of the evaluation process, "design 1" and "design 3" are eliminated because the lead-user finds that these designs are not reasonable with the help of modified Even-Swaps method. The rest of the design alternatives are reasonable and therefore the method generates assessment results of these alternatives as an output. By using the difference between the issue values and the exact issue values of responding alternatives, acceptable and unacceptable areas for each reasonable design alternative are found as in Figure-9.1.

Fuzzy inference system is constructed having found acceptable and unacceptable areas for reasonable design alternatives. Input-fuzzy-sets are generated by using the approach discussed in previous chapters of this thesis. After generation of the fuzzy sets, a rule base is generated to design a Mamdani-type fuzzy-inference-system. Evaluation results represent the utility degree of the design alternatives. A ranking list is obtained with respect to the calculated utility degrees. Top of the list provides the most utility to the lead-user. Therefore, the rest of the design alternatives have to improve the issue values in order to be an acceptable design alternative for the lead-user. The most preferred alternative is also improved, since the aims of the new product development process is to improve product performance in terms of utility that is provided to the lead-user.

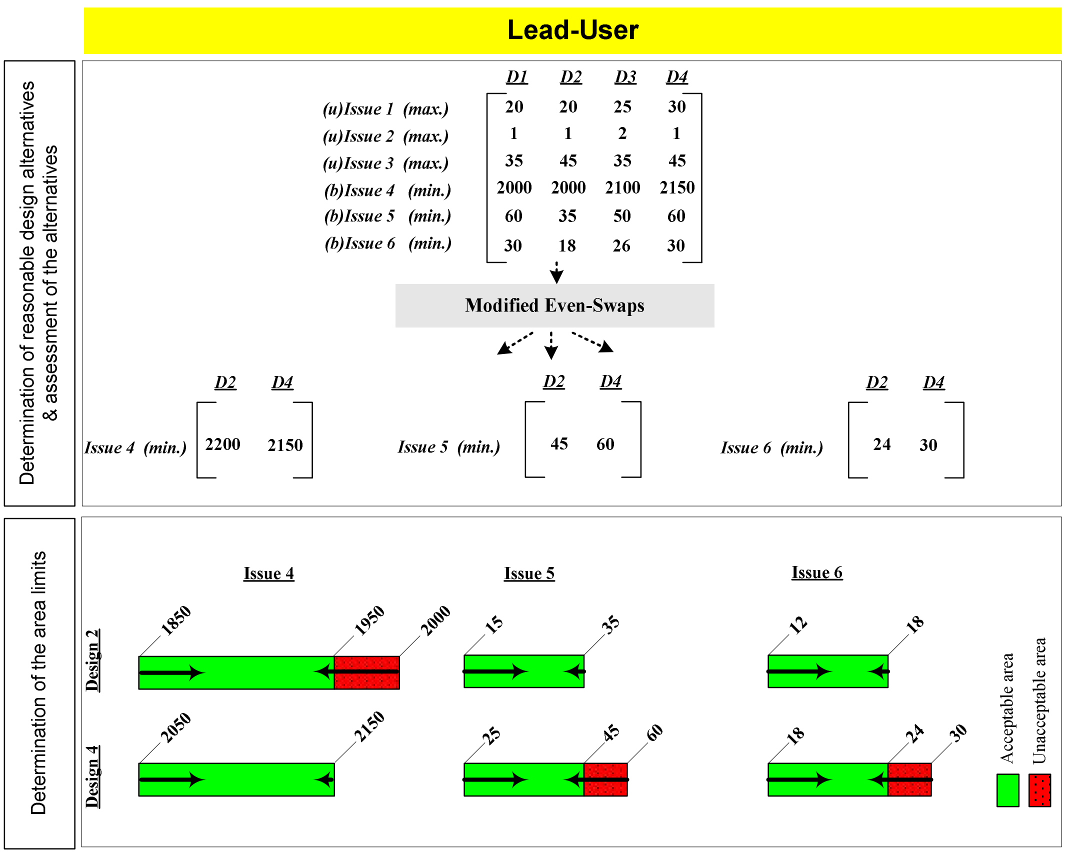


Figure 9.1 Evaluation of design alternatives before bargaining process

Figure-9.2 shows the bargaining process round by round. Firstly, provided issue values are evaluated by the lead-user and utility degrees are found through fuzzy inference system. The results show that “design 2” provides the highest utility to the lead-user. The designer makes modifications on designs by using the agreement areas to improve the utility provided by design. For “design 2”, “issue 4” is the most emerged issue to improve. The designer improves the issue value but the “issue 6” value gets worse when the modification is performed. This shows the reality of trade-off (contradiction) between these two issues for “design 2”. This awareness can help designer to solve this contradiction with the help of inventive problem solving technique and/or with optimization the issue values for the maximum utility. For “design 4”, “issue 5” and “issue 6” are the most emerged issues to improve. Therefore, designer improves the issue values but the “issue 4” value gets worse when the modifications are performed. This also shows the reality of trade-off between the issues as well. Although “issue 5” and “issue 6” are improved the utility is decreased because the declination on the “issue 4” is greater than the improvements. In our example, two rounds are executed. The process can carry on until satisfactory improvements are provided to the lead-user.

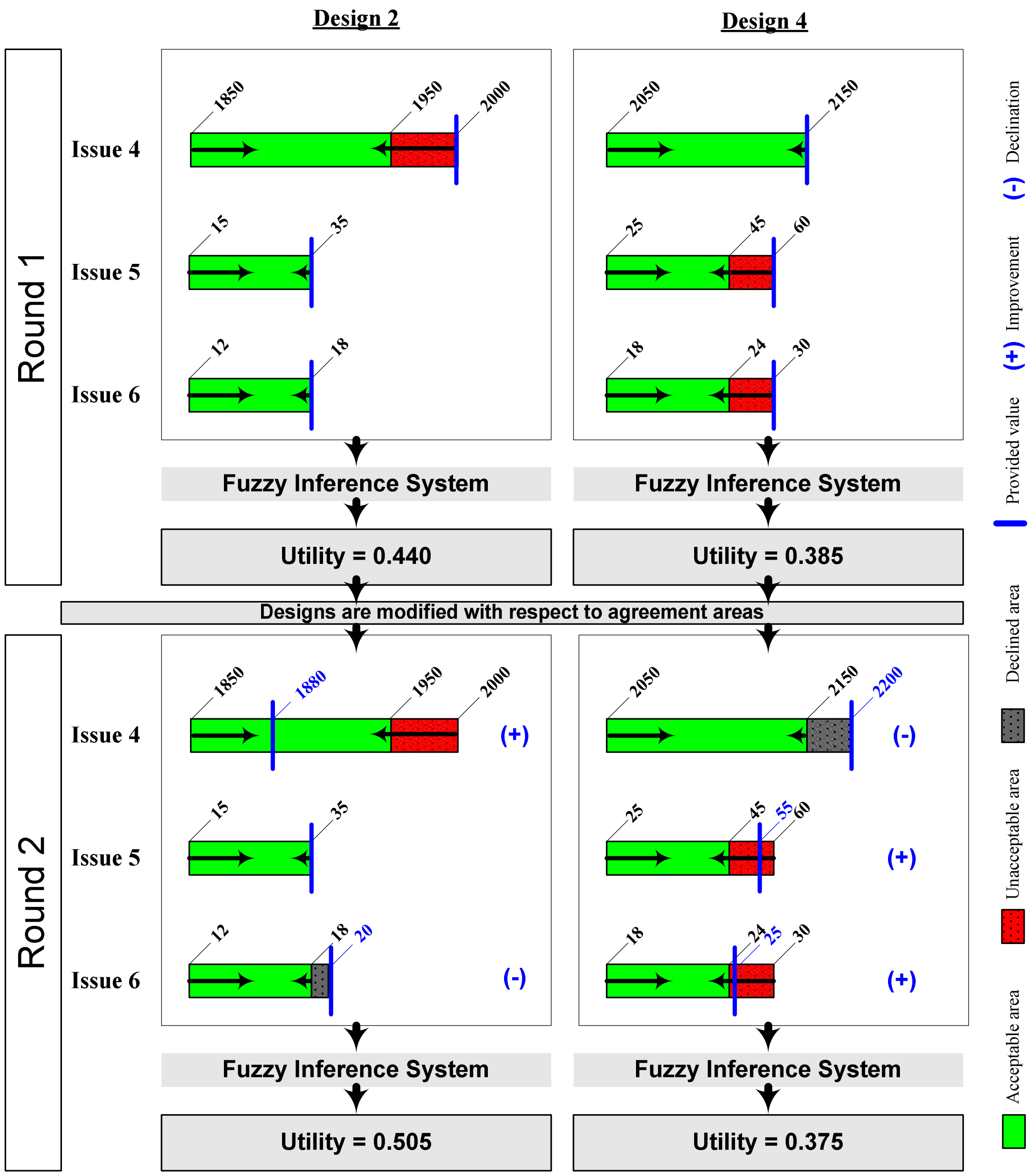


Figure 9.2 Bargaining process

9.5 Conclusion

"Trade-off" can be considered as an implicit weighting method which the weights are represented in terms of any specified issue. Making robust trade-offs can be vital for determination of the contradictions and hence solving them through inventive solutions in complex product design environments. Therefore, trade-off management is getting an important duty for the designers. Collaboration for evaluation, prioritization and selection of customer requirements in concept evaluation phase of NPD process requires a well-designed trade-off methodology because of existence of contradictions between requirements. Besides, collaboration requires a negotiation mechanism. However, customer co-creation in NPD through multi-issue negotiation with issue trade-offs hasn't been addressed in any study.

Therefore, in this chapter, we proposed a framework for customer co-creation in NPD through a multi-issue negotiation mechanism. This framework provides firstly multi-issue evaluation of design alternatives and then clarifying their contradictions with the help of agreement areas generated through the used negotiation mechanism. Moreover, before releasing the product to market, designer can see whether the modifications, which are performed for trying to solve the contradictions, improve or decline product performance in terms of customers' utility.

CHAPTER 10

ADAPTATION OF MULTI-ISSUE NEGOTIATION TO QUALITY FUNCTION DEPLOYMENT BY USING THE MODIFIED EVEN-SWAPS

10.1 Introduction

"*Increasing complexity in NPD*" is frequently highlighted in the corresponding literature and design trade-offs are considered as useful and fruitful means to study decision-making (see Altun et al., 2013; Maurer, 2007; Belecheanu et al., 2006).

As a result of increasing complexity, elicitation of design trade-offs relating to customer requirements becomes even harder to articulate, to capture and to disseminate. And therefore, Quality Function Deployment (QFD), a common methodology providing a systematic procedure for assuring product designs and production processes are driven by customer requirements, becomes unreasonable because one of major influential factors of a successful QFD application is the "*accuracy of customer requirements*".

Through recent developments on ICTs, especially in multi-agent technologies and multi-issue negotiation mechanisms, discovering reciprocal solutions by means of a process that is rational and providing better understanding of partner's interests and expectations can be possible in complex cases. Adaptation of these new ICTs to NPD is also needed to sustain success in NPD being disturbed by some technical obstacles mostly induced by increasing complexities, dynamism on customer requirements and decentralization of NPD. This adaptation is required to better understand customer requirements and hence to develop better products meeting those needs.

Adaptation of these ICTs to QFD also can be considered as a remedy to overcome challenges of QFD revealing while making design trade-offs in complex cases. Through this adaptation, customers can play active roles in NPD while eliciting design trade-offs and while evaluating and developing design alternatives by handling contradictions more efficiently and effectively. Furthermore, adaptation of these ICTs can allow "*customer co-creation in decentralized NPD*" as well.

Correspondingly, this chapter addresses adaptation of multi-issue negotiation to QFD and presents a novel methodology adapting a recently-developed multi-issue negotiation mechanism (namely; Modified Even-Swaps) to QFD methodology. According to the best knowledge of authors, this is the first attempt in this research direction that is emerging as a next step of the improvements.

The reminder of this chapter is organised as follows: Section-9.2 presents a literature review on QFD methodology. A multi-issue negotiation based QFD methodology is introduced in Section-9.3 and an illustrative example addressing washing machine development is given in Section-9.4. Finally, conclusions and discussion are presented.

10.2 Literature review

10.2.1 Challenges and Improvements

Success on NPD processes rests on first understanding customer requirements and then trying to develop products to meet those requirements. In this regard, QFD is a common methodology providing a systematic procedure for assuring product designs and production processes are driven by customer requirements.

However, QFD becomes difficult to deal with by several challenges standing out while executing over a complicated system (Hari et al., 2007). In order to overcome these challenges, various methods have been adapted to QFD methodology (See Table-10.1 for a categorisation of these methods). One of the most important challenges faced is that it does not support *making issue trade-offs*. In order to overcome this obstacle, some studies prioritized customer requirements through multi-criteria decision making (MCDM) methods. Earlier approaches ignored interdependencies among customer requirements (e.g. Karsak, 2004; Kwong & Bai 2002, 2003) but after then following studies suggested using advanced MCDM methods considering these interdependencies such as "*analytical network process*" (ANP) and its variants to improve trade-off operations of QFD (e.g. Lee et al., 2010; Lin et al., 2010; Kahraman et al., 2006; Büyüközkan et al., 2004).

Table 10.1 Categorization of models enhancing QFD methodology

Categories	Corresponding papers
Multi-criteria decision making methods:	- Gungor et al., 2011; Felice & Petrillo, 2010; Lee et al., 2010; Lin et al., 2010; Sanayei et al., 2010; Lin et al., 2008; Das & Mukherjee, 2007; Hanumaiah et al., 2006; Kahraman et al., 2006; Bhattacharya et al., 2005; Büyüközkan et al., 2004; Karsak, 2004; Erol & Ferrell, 2003; Kwong & Bai, 2003; Hsiao, 2002; Kwong & Bai, 2002; Kim et al., 2000
Linear and Nonlinear programming:	- Chen & Ko, 2010; Chen & Ko, 2009; Chen & Ko, 2008; Luo et al., 2008
Metaheuristic methods:	- Lee & Lin, 2011; Lin et al., 2011; Wang & Xiong, 2011; Hsiao & Liu, 2004
Hybrid models:	- Liu, 2010; Ozdemir & Ayag, 2010; Sener & Karsak, 2010; Guo et al., 2009; Huang & Li, 2009; Karsak & Ozogul, 2009; Tolga & Alptekin, 2008; Wang & Chin, 2008; Muo et al., 2007; Karsak et al., 2003
Other approaches:	- Mehdizadeh, 2010; Lai et al., 2008; Hari et al., 2007; Kahraman et al., 2006

Computing fulfilment levels of process parameters respecting constraints under consideration is another important challenging factor in QFD. Various optimization methods were adapted to QFD in order to overcome this challenge (see Chen & Ko, 2010, 2009, 2008; Luo et al, 2008). Some metaheuristic methods (e.g. Lee & Lin, 2011; Lin et al., 2011; Wang & Xiong, 2011; Hsiao & Liu, 2004) and hybrid models (e.g. Liu, 2010; Ozdemir & Ayag, 2010; Sener & Karsak, 2010; Guo et al., 2009; Huang & Li, 2009; Karsak & Ozogul, 2009) also were proposed to support QFD in different stages. Some other approaches and modifications also were proposed to increase its usability in complex cases (e.g. Mehdizadeh, 2010; Lai et al., 2008; Hari et al., 2007; Kahraman et al., 2006). Please see Abdolshah & Moradi (2013) for further discussions and an analytical literature review on QFD.

10.2.2 Indispensable requirements and relevance of the study

Nevertheless, there are indispensable requirements especially faced in NPD processes, which studies corresponding to the literature are still not enough to meet them, such as; ***i)*** these studies do not take into account that design trade-offs are generally tacit and therefore elicitation of them is a concept that is hard to articulate, to capture and to disseminate. On the other hand, ***ii)*** they do not allow customers to play an active role in NPD process although it is needed to handle dynamism on customer requirements as it should be. Instead, customers are in forms of either *"passive"* or *"speaking when spoken to"* although design trade-offs are more challenging than simple decisions. Design tasks require iterative information exchanging performed cooperatively and continuously. In a typical NPD process, determining contradictions and solving them through inventive problem solving techniques are possible with making trade-offs elicited with customers taken part in the process as actively being involved.

NPD speed is considered as the most important metric of innovation process (Boston Consulting Group, 2006) because of continuous reduction in product life cycle-time and increase in competition from technological advancements and globalization (Chen et al., 2010).The time-lag from collection of customer requirements to the time when the product is ready to be launched is also considered as a major limitation of QFD methodology (Raharjo et al, 2011).

In complex cases, solution of a contradiction may cause another contradiction. Besides, it is a frequently encountered circumstance that there can be more than one option to solve contradictions. Moreover, contradictions may be from results of not only two issues but also triple and more interactions among issues. Therefore, *customer co-creation* becomes essential especially in such cases to realize reciprocal utility for both firms and customers. Furthermore, active customer involvement in

QFD may also be a remedy to the limitation corresponding to the time-lag issue above-mentioned.

Besides, ***iii)*** firms are considered as if they have centralized NPD teams while studying design trade-offs and trying to overcome complexity. However, *decentralization of NPD teams* also becomes one of the practical challenges assuring success of NPD activities as a result of globalization. Decentralized structure of NPD teams has to be considered in order to be efficient and effective in NPD.

Improvements on QFD need to follow a way satisfying above-mentioned requirements to stay convenient to NPD. Overcoming the challenge of QFD revealing while making design trade-offs in complex cases requires adaptation of supporting approaches that allow customers to play active roles in NPD in order ***i)*** to elicit design trade-offs straightforwardly and ***ii)*** to develop and/or evaluate design alternatives by handling contradictions more efficiently and effectively. On the other hand, these supporting approaches should allow customer co-creation in *decentralized NPD* as well.

Multi-issue negotiation can be considered as a process aiming to reach an agreement between parties by considering multiple issues, simultaneously. Providing multi-issue negotiation support seems one of the best remedies in such circumstances. E-commerce environment is the best example to these types of circumstance (see Balachandran, 2012; Balachandran et al., 2011; Shakun, 2005). In e-commerce environments, buyers have to evaluate so many alternatives in case some issues under consideration are negotiable. Multi-issue negotiation mechanisms have been developed to overcome this circumstance since these mechanisms can provide buyers and sellers to make rational decisions in multi-issue environment and to negotiate each other, concurrently. With utilities of multi-issue negotiation mechanisms in mind, adaptation of multi-issue negotiation to QFD methodology has a great potential as a next step to these improvements.

10.3 Proposed methodology

This section proposes a QFD methodology adapting Modified Even-Swaps mechanism, named as *NegoQFD*. How it has been adapted to QFD and how such an approach offers a possibility to dissolve the key problems discussed in previous sections of this study are addressed in this section.

QFD is a methodology enabling new product development teams to identify and prioritize customer requirements, subsequently to translate them into appropriate technical specifications, and ultimately to deploy these requirements into each stage of product development; product planning, product design, process planning, and production planning (see Figure-10.1). Although it has four stages, most enterprises use only the first stage of QFD (i.e., House of Quality), without any further steps (Yu et al., 2012). As a reason, it is discussed that especially the first phase provides a communication platform to fuse diverse opinions among cross-functional team members (Wang & Chen, 2012). Adaptation of multi-issue negotiation to QFD aims to create a platform among cross-functional and decentralized new product development teams and customers. Relation network between *voice of the customer* and *voice of the technician* turns out to be clear by executing the *house of quality* (HoQ), basic design tool of QFD. Therefore, the most appropriate phase is the first phase of QFD to adapt a multi-issue negotiation mechanism.

House of Quality can be considered as a conceptual map illustrating the relationship between customer requirements and engineering characteristics. It is sometimes called as "matrix of matrices" because of inclusion of large number of matrices. There are many forms of HoQ although it generally has eight sections (i.e., rooms) and it needs about 20 steps to be completed. Therefore, while presenting this multi-issue negotiation based QFD methodology, the process from beginning to end has been identified clearly and also similarities and modifications / improvements have been highlighted in this section.

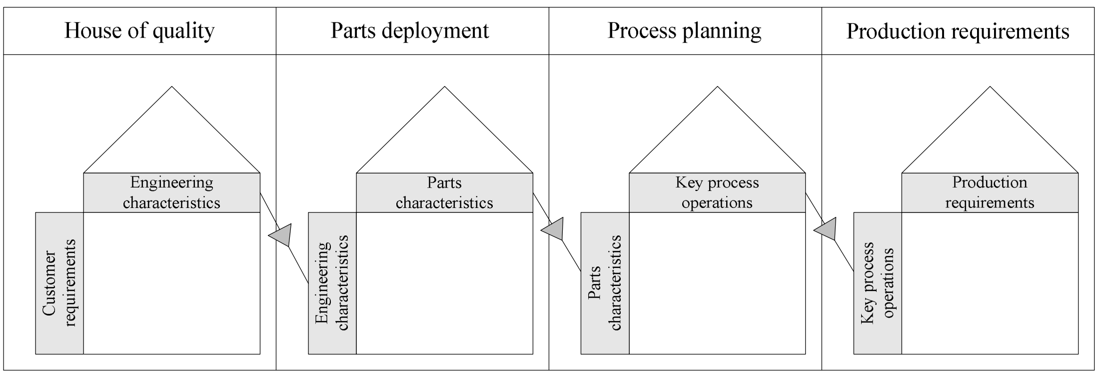


Figure 10.1 Four phases of QFD

Figure-10.2 shows general view of the proposed QFD structure. The first step (*Step-1*) is to specify target market segments and customers. Determination of the way of collecting customer requirements is considered in this step as well. Generally, customer requirements are collected by focusing groups and customer surveys (Gourova & Toteva, 2011). This study aims to propose a novel QFD methodology that is negotiation based. Therefore, target customers might be able to participate in negotiation process.

Hoyer et al. (2010) discusses four types of customer segments who can contribute to co-creation, namely as; "*innovators*", "*lead-users*", "*emergent customers*", and "*market mavens*". *Innovators* represent a customer segment including individuals who are enthusiasts of new product and technology. They are therefore the earliest adopters of new products and technologies (Moore, 1991). *Emergent customers* are individuals who can provide judgments and institutions to improve existing products (Hoffman et al., 2010). *Market mavens* are customers who have extensive information about existing products in the corresponding market (Feick & Price, 1987). *Lead-users* represent a special customer segment providing accurate and useful data by understanding of "tomorrow's needs today" (Hippel, 1986; Herstatt & Hippel, 1992).

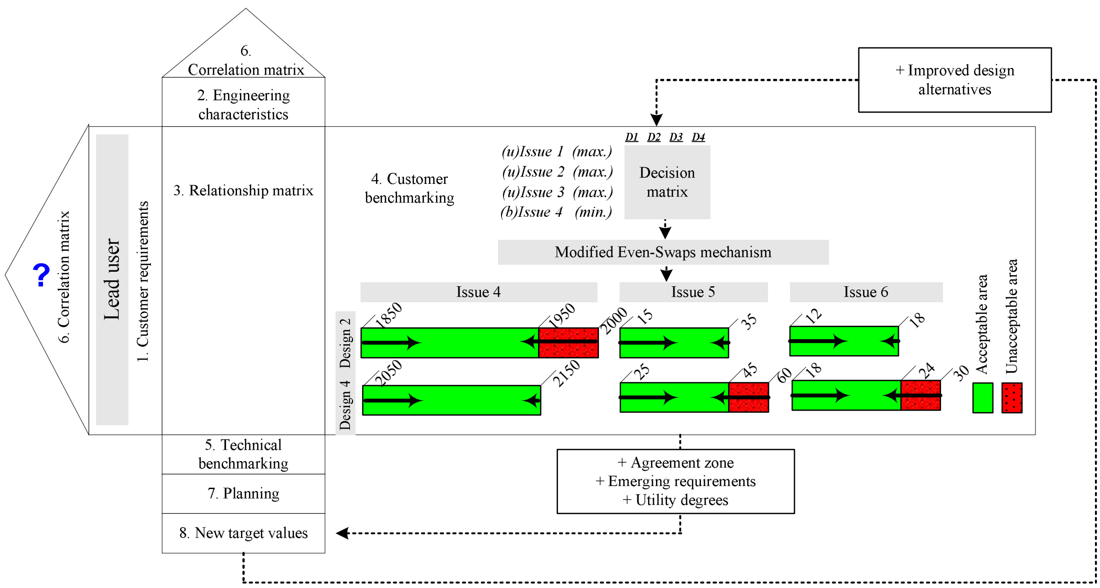


Figure 10.2 Overview of the NegoQFD methodology

Working with suitable customer segments can contribute to negotiation process in terms of cost, quality and acceleration of process. The time-lag from collection of customer needs to the time when the product is ready to be launched is considered as a major limitation of QFD methodology (see Raharjo et al., 2011). When taken today's rapidly changing market into account, this time-lag problem can cause an effort that is trying to meet dated requirements. Although all customer segments above-mentioned can contribute to clarification of customer needs, the negotiation process especially indicates emergence of the use of *lead-users* because of their abilities to understand tomorrow's needs today. With these features in mind, working with *lead-users* is suggested in while performing interviews and/or contextual inquiries (*Step-2*).

Elicitation of emotional expectations (*Step-3*) and disambiguation of collected requirements (*Step-4*) are performed similarly when compared to conventional QFD methodology. Amount of the requirements under consideration will be more influential on efficiency and effectiveness than conventional QFD because of its iterative structure. Therefore, selection of reasonable amount of requirements is essential to handle them appropriately (*Step-5*). Proposed multi-issue negotiation based QFD does not operate steps of categorisation (*Step-6*) and prioritization (*Step-7*) of customer requirements. Their functions are satisfied by using multi-issue negotiation mechanism at the customer benchmarking section.

Having performed operations of customer requirements section, engineering characteristics, (i.e., technical specifications) need to be determined. This determination process including *Step-8* to *Step-10* remains without change when compared to conventional QFD. Dissemination of customer requirements to technical specifications (*Step-8*) has to be considered. Logical categorisation (*Step-9)* and determination of methods/test plans (*Step-10*) are also needed in this section.

Relationship matrix is also needed to connect customer requirements and engineering characteristics, straightforwardly. Corresponding steps (*Step-11* & *Step-12*) in this section remains without change as well. *Step-11* includes assignment of a degree of influence between each engineering characteristic and each customer requirement. It is common to use symbols while assigning a degree. A solid circle (●) represents strong relationship that is equal to "9" in terms of value. A single circle (○)

represents medium relationship and its value is equal to “3”. Weak relationship is represented by using a triangle (∆) and its value is equal to “1”. Blank cell represents no relationship. Having performed assignment, the relationship matrix has to be confirmed. This confirmation (*Step-12*) is realized by checking some conditions such as empty row or column, and involvement of row or column that contains relationships more than a few.

Customer benchmarking section undergoes major modifications while developing a structure for a negotiation based QFD methodology. This section adapts the multi-issue negotiation mechanism, namely; *Modified Even-Swaps*. Lead-users are expected to assess existing products according to how satisfy them in terms of each customer requirement (*Step-13*). This mechanism produces some messages to product development team after assessments as how the total utility of each product alternatives can be improved. These messages are essential to realize negotiation between development teams and lead-users. In this phase, Modified Even-Swaps mechanism is executed by using the following procedure.

- *Problem initialization*

  First of all, a decision-matrix (A_{ij}) is generated (see Equation-1). This decision matrix includes “n” existing products, and these products are assessed by considering “m” customer requirements decided in customer requirements section of QFD. Consequences (a_{ij} values) for each requirement are assigned by using 1-5 scale as being a rating of “1”for the best and “5” for the worst.

$$A_{ij} = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ a_{m1} & a_{m2} & \dots & a_{mn} \end{bmatrix} \qquad (1)$$

- *Determination of “negotiable” customer requirements*

  Negotiation is possible when issues under consideration are flexible. Sides of negotiation process can reach more satisfying agreement conditions by using these flexibilities and by bargaining for them conveniently in order to reach win-win solutions. In this phase, development teams decide which customer requirements are negotiable. While making this decision, relationship matrix is essential. Development teams decide negotiable customer requirements by considering their correlated technical specifications. If they have a capability to adjust the level of correlated specifications, corresponding customer requirements are assumed as negotiable.

- *Determination of a “bargaining range” for negotiable customer requirements*

  Bargaining range needs to be known at least roughly in order to eliminate products those are dominated by other products and bargaining is not reasonable for them. Remaining products in the ultimate decision-matrix will be negotiated by development teams and amount of these products intrinsically influences speed of this negotiation process. These ranges can be specified by means of relationship matrix of QFD. Development teams can assess each engineering characteristics and their upper and lower bounds by considering available technological capabilities and constraints. Transition from engineering characteristics to customer requirements is performed through relationship matrix. While doing this transition, the biggest range should be assigned in case of existing more than one relation between characteristics and requirements to avoid unnecessary elimination.

- *Elimination of “dominated” products*

  The pair-wise dominance concept is used while identifying dominated products. If product-*x* is better than product-*y* on some customer requirements and no worse than product-*y* on all other customer requirements, product-*y* is dominated by product-*x*. However, we can say product-*x* is better than product-*y* on negotiable customer requirements, if the difference between corresponding requirement values of products is greater than bargaining range. Practical dominance concept can also be used in order to accelerate the process through elimination of unnecessary even swaps (see Altun & Dereli, 2014; Hammond et al., 1998; Mustajoki & Hamalainen, 2007). A product is practically dominated if it provides slightly better advantages for only one or few requirements; but it is clearly outranked by other products for the rest requirements. Columns corresponding to dominated and practically dominated products are excluded from decision-matrix (see Equation-2).

$$\begin{array}{c} \text{Dominated product} \\ \begin{bmatrix} a_{11} & \cancel{a_{12}} & \cdots & a_{1n} \\ a_{21} & \cancel{a_{22}} & \cdots & a_{2n} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ a_{m1} & \cancel{a_{m2}} & \cdots & a_{mn} \end{bmatrix} \end{array} \qquad (2)$$

- *Elimination of "irrelevant" customer requirements*

A customer requirement is irrelevant when its values are similar for all products. Rows corresponding to irrelevant customer requirements are excluded from decision-matrix (see Equation-3).

$$\begin{array}{c} \text{Irrelevant customer requirement} \\ \begin{bmatrix} \cancel{a_{11}} & \cancel{a_{12}} & \cancel{\cdots} & \cancel{a_{1n}} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix} \end{array} \qquad (3)$$

- *Is there any customer requirement that is relevant and not negotiable?*

  If there is a customer requirement that is relevant and specified as not negotiable, the process needs to even swaps. In the absence of any such requirement, the process goes on by interpretation of remaining products and then by specification of agreement area limits.

- *Arrangement for even swap operation*

  In this phase, any two products remained in the revised decision-matrix are determined. Subsequently, a customer requirement having different consequence for these products is determined as well to perform even swap (see Equation-4).

$$\begin{bmatrix} \boxed{a_{11}} & \boxed{a_{12}} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ a_{m1} & a_{m2} & \dots & a_{mn} \end{bmatrix} \tag{4}$$

- *Determination of required change and performing even swap operation*

  Lead-user is invoked to perform even swap. Assume that #*1* and #*2* are the products determined in set-up phase. Besides, #*m* is the customer requirement determined as well. In this phase, lead-user assesses what change in the corresponding requirement would compensate for the change the value from "a_{11}" to "a_{12}" (see Equation-5).

$$
\begin{bmatrix}
\boxed{a_{12}} & \boxed{a_{12}} & \cdots & a_{1n} \\
a_{21} & a_{22} & \cdots & a_{2n} \\
\cdot & \cdot & & \cdot \\
\cdot & \cdot & & \cdot \\
\cdot & \cdot & & \cdot \\
\boxed{?} & a_{m2} & \cdots & a_{mn}
\end{bmatrix} \tag{5}
$$

Having performed this even swap operation, process goes on by elimination of "dominated" products and "irrelevant" customer requirements. This loop breaks when only negotiable customer requirement remains in the revised decision-matrix.

- *Determination of negotiable products*

Products remaining at the ultimate decision matrix will be considered in negotiation process because these products outcome their alternatives and also they have negotiable differences when compared to each other.

- *Determination of agreement area limits*

In this phase, agreement area limits are found by using consequences of initial decision-matrix and final decision-matrix. Final decision-matrix is especially needed to specify the difference between products in terms of negotiable customer requirement. Agreement area is divided into two sections, namely; "acceptable" and "unacceptable". Limits of agreement area are calculated by using equations illustrated in Figure-10.3. Unacceptable area is bounded by two limits. Lower limit is initial matrix consequence of corresponding product. Upper limit is calculated by means of the difference between corresponding product and the best product. Acceptable area has also bounded by two limits. Lower limit of acceptable area is equal to upper limit of unacceptable area. Upper limit of acceptable area is calculated by taking bargaining range into account.

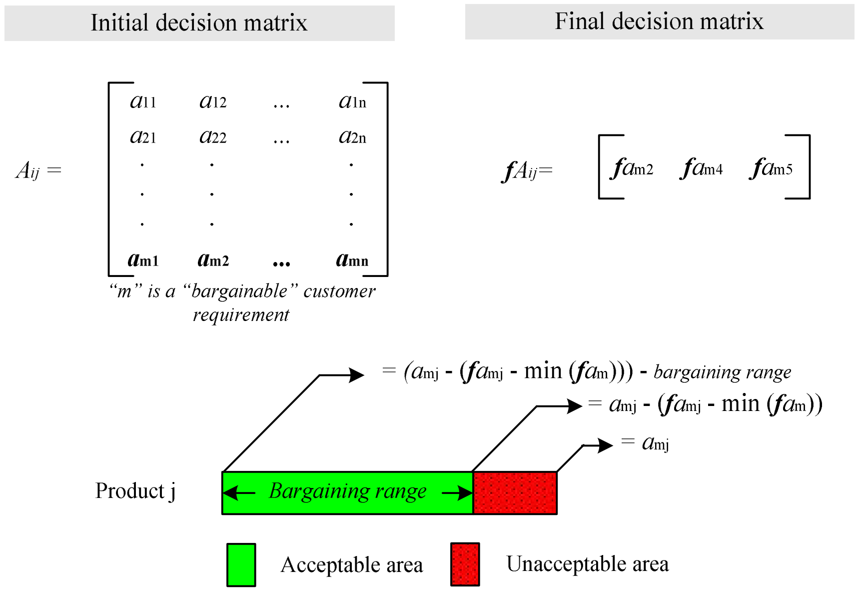


Figure 10.3 Determination of agreement area limits

An example is given for better understanding of the above-mentioned steps of methodology as follows. This example considers four customer requirements and four products as given in Figure-10.4. *Customer requirement #4* is determined as negotiable requirement. Compensations will therefore be realized for this requirement while performing even swaps operations. Bargaining range is specified as *"1"* for corresponding negotiable requirement. Dominated products are identified as a next step by using pair-wise dominance concept. It is observed that *Product #1* dominates *Product #3* and *Product #4* (see Figure-10.4a). Columns corresponding to *Product #3* and *Product #4* are excluded from decision-matrix. After this revision, it is observed that *Customer requirement #1* and *Customer requirement #2* become irrelevant to this decision process. Rows corresponding to these irrelevant requirements are excluded from decision-matrix (see Figure-10.4b). An even swap is performed by adjusting the value of *Product #2 – Customer requirement #1* to the value of *Product #1 – Customer requirement #1* (see Figure-10.4c). This adjustment is compensated by changing the value of *Product #2 – Customer requirement #2* with a change from *"2.0"* to *"2.4"* (see Figure-10.4d). After this even swap operation, *Customer requirement #3* becomes irrelevant and therefore it is excluded from decision-matrix (see Figure-10.4d). The revised matrix is our final decision-matrix because it includes only negotiable requirement and negotiable products. The difference between negotiable products is calculated as 0.4 (= 2.4 – 2.0). After calculation of the difference, agreement area limits for *Customer requirement #4* are calculated as in Figure-10.4e.

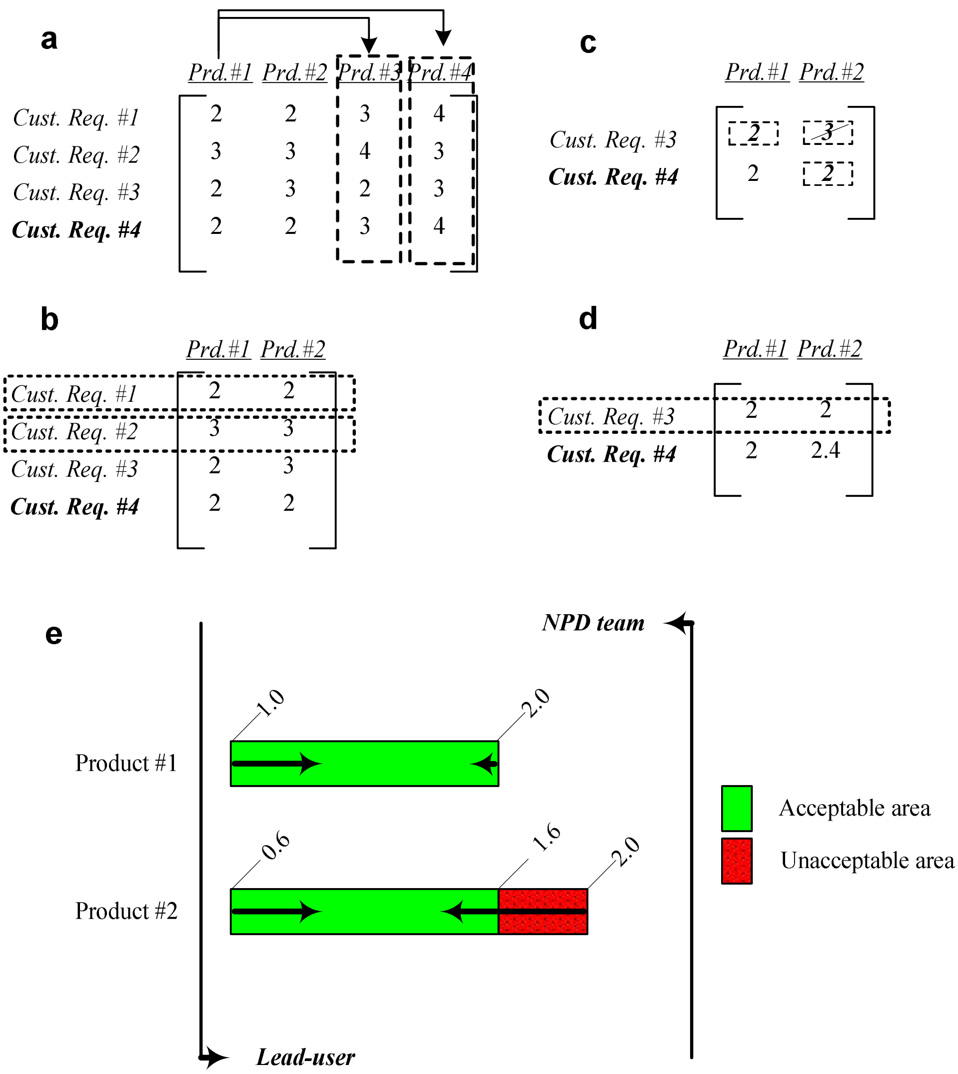


Figure 10.4 An example for determination of agreement area limits

- *Multi-issue negotiation process*

Agreement area limits for each negotiable requirement are specified by using the process above-mentioned. Agreement area limits are essential while developing new products. Through these limits, development team will direct their efforts by also considering their competencies and strategies. Having specified the limits for each requirement, a support system is required to evaluate how counter-offers affect the utility provided to lead-users. This assessment is required to generate new suggestions to development teams for possible further improvements on utilities to be provided by new products.

Modified Even-Swaps mechanism is supported by a (Mamdani-type) *fuzzy-inference system* in this phase to evaluate multi-issue offers, concurrently. Fuzzy-inference system is particularly preferred because use of linguistic variables seems more convenient while clarifying the importance of each requirement by comparison.

Modified Even-Swaps uses the degree of *"acceptability"* while designing *input fuzzy sets*. Acceptability is classified into three groups as *"low"*, *"middle"* and *"high"*. Modified Even-Swaps mechanism uses *triangular membership functions* because of their striking simplicity (see Pedrycz, 1994). Input fuzzy sets are based on agreement areas in this multi-issue negotiation mechanism. The largest agreement area limits are standardized to make range in the interval [0,1]. Agreement areas corresponding to the remaining products are scaled by taking the largest one into account. Figure-10.5 shows how agreement areas transform into input fuzzy sets in detail.

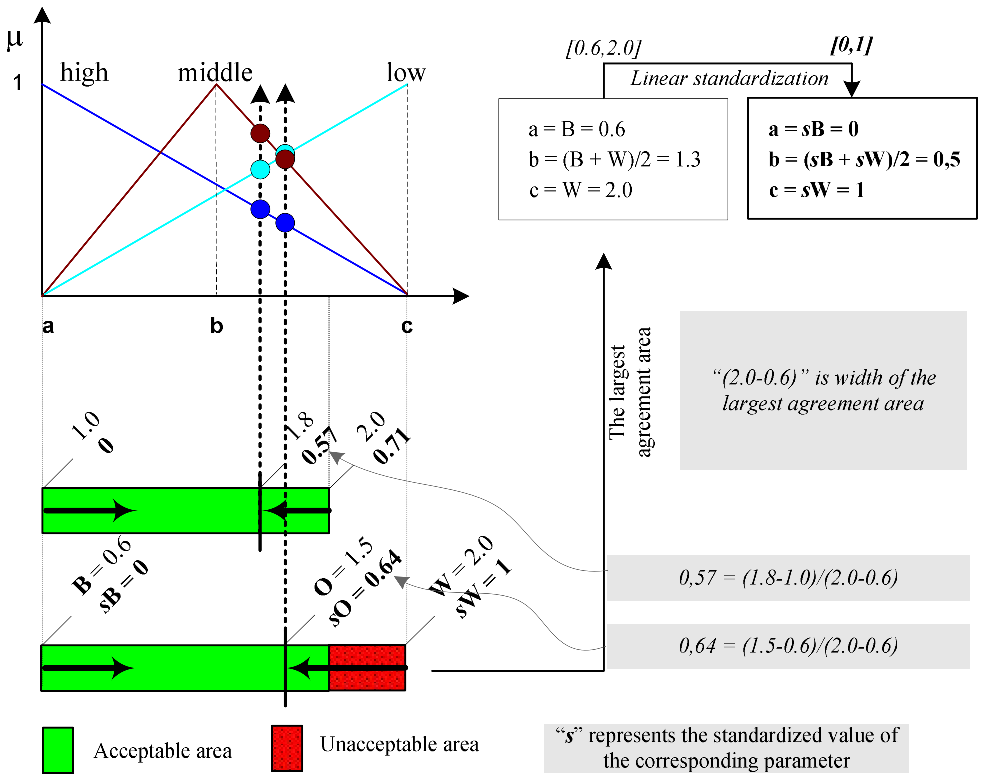


Figure 10.5 Fuzzy sets for input variables

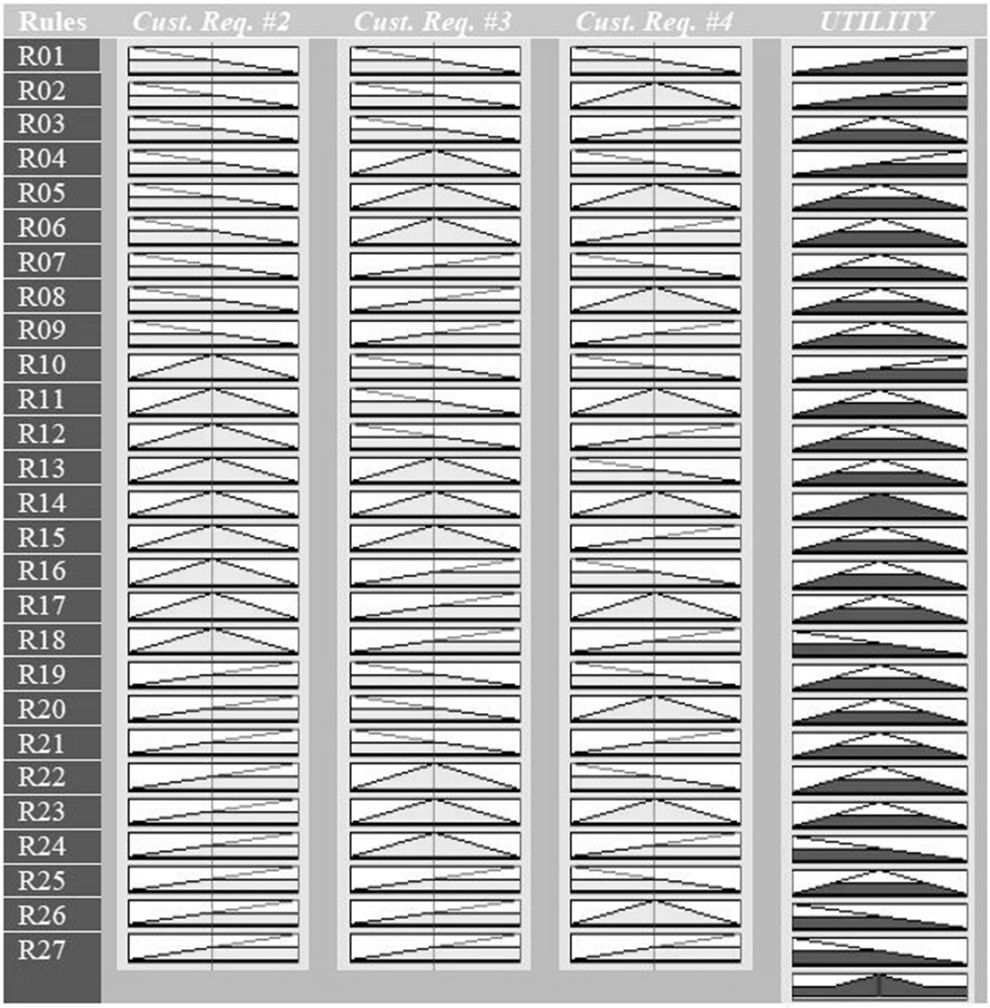


Figure 10.6 Rules indicating utility

Having generated input fuzzy sets, fuzzy-inference system requires a fuzzy rule-base to fuse multi-issue offers to utility degrees. Rules are expected to be defined by lead-user in the proposed approach. How lead-user interprets multi-issue offers is clarified by means of this rule-base. Figure-10.6 shows a rule-base in case of there are three negotiable customer requirements.

Development teams decide which customer requirements and which products should be focused by taking agreement areas into account. Relationship matrix is used to link customer requirements and engineering characteristics. Development teams adjust engineering characteristics to improve corresponding products and then offer new products expecting to increase the utility. Relationship matrix does not consider the correlations between customer requirements. As it is discussed in the first section of this study, design trade-offs related to customer requirements are generally tacit and therefore elicitation of them is a concept that is hard to articulate, to capture and to disseminate. Proposed approach aims to take corresponding trade-offs into account by negotiation instead roughly clarifying them at the beginning. Therefore, after generation of new products by considering relationship matrix, lead-user performs evaluation of products in order to update initial decision-matrix. Negotiable customer requirement values in the updated matrix are entered to the fuzzy-inference system to produce utility degrees for each product. Following rounds of this negotiation process use updated agreement areas and then revises input fuzzy sets of the inference system. Updated agreement areas and revised input fuzzy sets allow development teams to take correlations into account by another way.

Before negotiation, technical benchmarking (*Step-14*) is also needed to be performed (*Step-15*) to make sure whether customer benchmarking and technical benchmarking affirm each other. Construction of accurate relationship matrix is verified through this matching process.

Correlation matrix for engineering characteristics is constructed (*Step-16*) to handle design trade-offs corresponding to engineering characteristics. It should be noted that correlation matrix regarding to customer requirements is not constructed in this NegoQFD methodology. Design trade-offs corresponding to customer requirements are considered indirectly through the negotiation process while developing new products.

Planning section undergoes modifications in the NegoQFD. In the existing QFD, this section is used to calculate the overall importance of each engineering characteristic through considering weights of customer requirements and relationship matrix. However, weights indicating the importance of each customer requirement are not needed in the proposed methodology. Instead of weights, proposed methodology uses agreement areas indicating acceptable and unacceptable levels of each product. By considering agreement areas and relationship matrix, importance of each engineering characteristics becomes apparent (*Step-17*). Development teams have to clarify their capabilities on each engineering characteristic (*Step-18*) in order to make their plans.

New target values are assigned (*Step-19*) by considering agreement areas, their capabilities for each engineering characteristics and their strategies. As a last step, whether HoQ has enough details to develop is confirmed (*Step-20*). After these steps, negotiation process is executed round by round until reaching satisfactory utility levels.

10.4 An illustrative example

This section presents an illustrative example to give some practical insights for the use of NegoQFD methodology. This example addresses a washing machine development problem that is adapted from Yamashina et al. (2002) and Delice & Gungor (2009). It should be noted that this example is not a full case-study. It only aims to show how the NegoQFD methodology works in practice. Figure-10.7 shows HoQ corresponding to the example. In this example, *customer requirements* are represented by five language expressions (as *"through washing"*, *"quite washing"*, *"through rinsing"*, *"no damage to clothes"* and *"short washing time"*) and *engineering characteristics* are represented by five measurable standard values (as *"washing quality"*, *"noise level"*, *"washing time"*, *"rinsing quality"* and *"clothes damage rate"*). There are four products competing with each other. Engineering characteristic performances of each product are also given. Interrelationships between engineering characteristics are shown in the roof part of the HoQ. There are interrelations between customer requirements but they could not be specified because they are tacit (i.e., lead-user is unable to clarify this relations). There are two development centres as *polycentric decentralized* and associated with *Product #2*. They would like to assess position of their product in the market by considering customer utility provided and also would like to analyse magnitudes of each influencing factors in order to be aware of emerging improvements to take a better position in the market.

These centres reach to a consensus on bargaining range for the engineering characteristics by considering their technological capabilities to improve each of them. These ranges are as follows; "*washing quality"* can be improved to *87%*, "*noise level"* can be reduced to *45 db*, "*washing time"* can be reduced to *28 minutes*, "*rinsing quality"* can be increased to *85%* and "*clothes damage" rate* can be reduced to *1.6%*. Bargaining ranges corresponding to customer requirements are determined by considering bargaining ranges corresponding to engineering characteristics and relationship matrix. In this example, each customer requirement is dependent to more than one engineering characteristics. Therefore, in order to avoid unnecessary elimination in the next steps, the biggest bargaining range of the engineering characteristic corresponding to customer requirement is adjusted as bargaining range of the customer requirement.

As discussed in previous section in detail, customer benchmarking section has been undergone major modifications. In this section, modified Even-Swaps mechanism is executed to generate limits of agreement areas, to determine emerging requirements and to obtain an assessment result for the products under consideration in terms of utility degrees provided to customers. Figure-10.8a shows the decision matrix (A_{ij}) generated by customer (lead-user). This matrix consists of five rows representing the each customer requirement, respectively. There are four columns representing the four products under consideration. Consequences are assigned by lead-user using 1-5 scale indicating a gradual rating as "*1*" for the best and "*5*" for the worst. Having clarified the consequence matrix, modified Even-Swaps mechanism interacts with the lead-user through some messages generated to clarify the differences between product alternatives in terms of each negotiable issue. Figure-10.8b shows final decision matrices determined by this interaction.

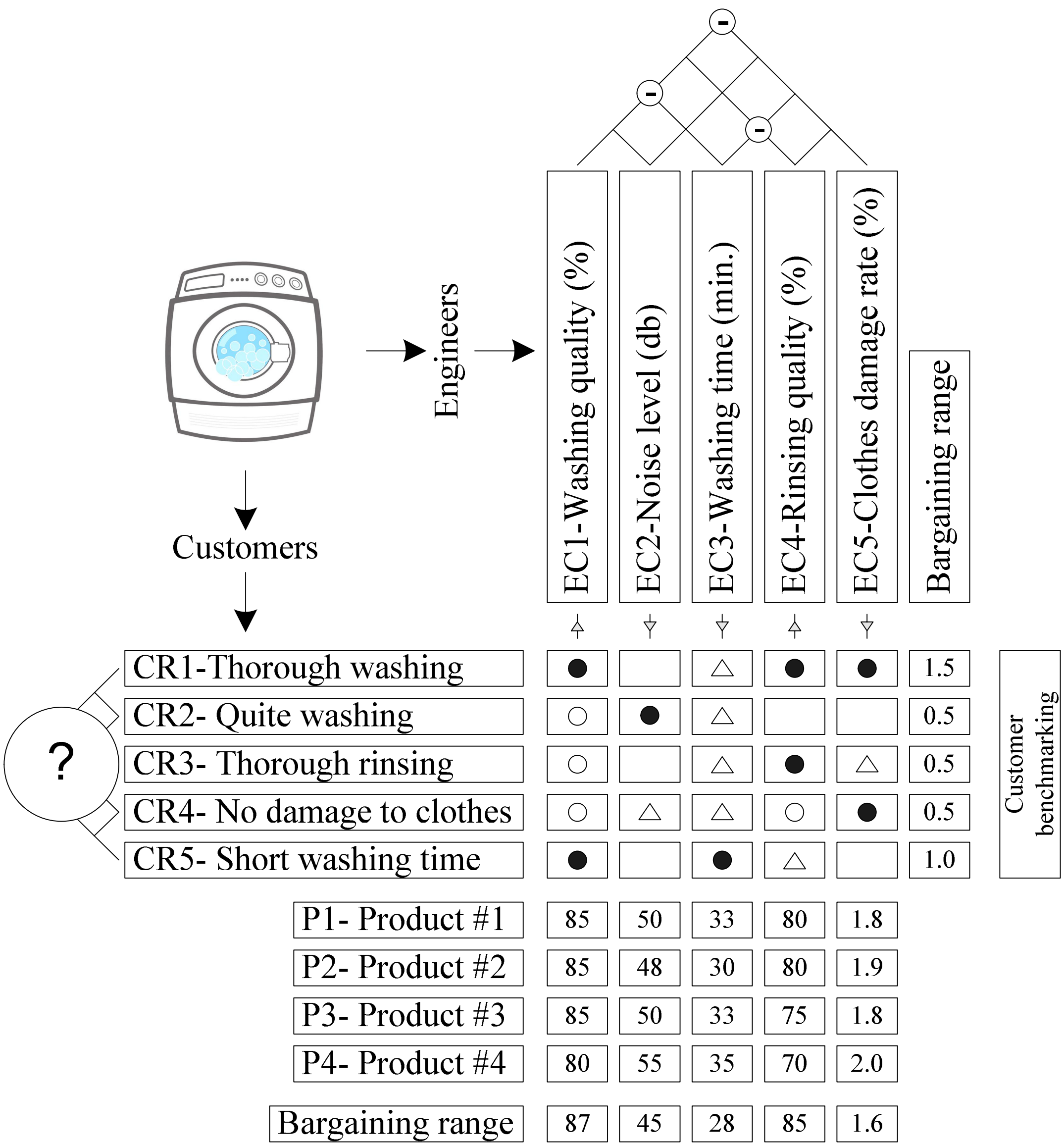


Figure 10.7 HoQ for washing machine development

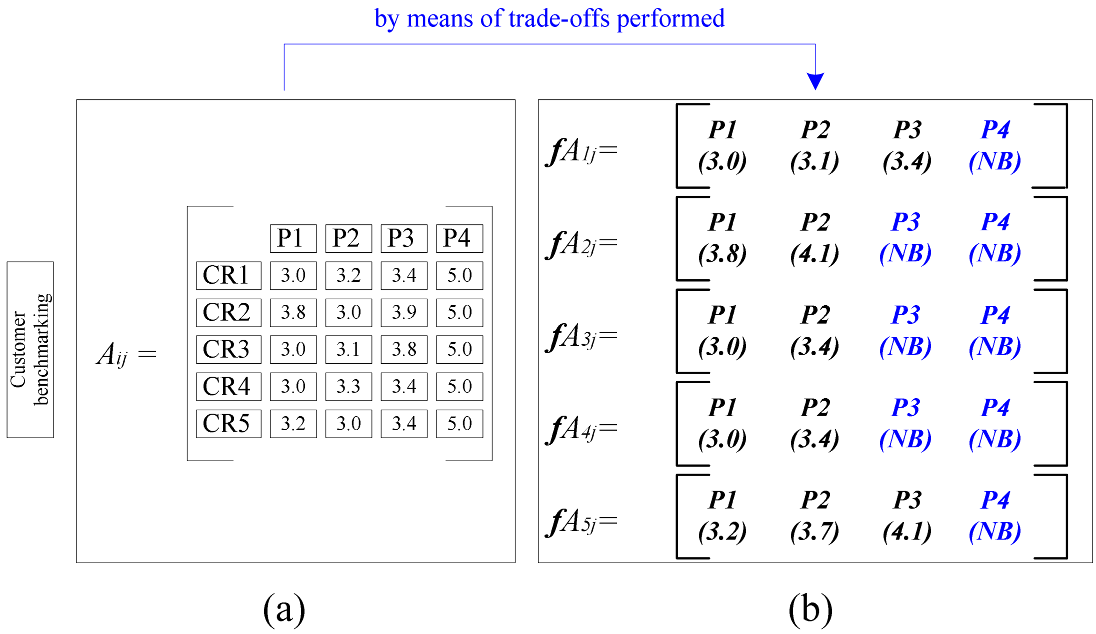


Figure 10.8 Customer benchmarking: (a) initial decision-matrix (b) final decision-matrices

(NB: Not bargainable/negotiable)

Table-10.2 shows the trade-offs performed during this interaction process. All of the customer requirements are specified as negotiable in this example. Therefore, in the end of the process, five final decision matrices are obtained. Procedure starts with specification of a negotiable issue, "*CR5-Short washing time*" with a bargaining range as "*1.0*". Initial scanning through the consequence matrix (A_{ij}) is performed to eliminate dominated alternative(s) and irrelevant customer requirement(s). This initial scanning indicates that *"Product #4"* is dominated by *"Product #1"*. Dominated product is eliminated from the consequence matrix. Trade-offs are performed by considering this updated consequence matrix. Corresponding trade-offs (aiming to make alternatives dominated and to make issues irrelevant) are performed by even-swaps, hypothetically changing the consequences of alternatives in all customer requirements except *"CR5"* and compensating this change with a preferentially equal consequence changes in *"CR5"*. Having performed these even-swaps operations, final decision matrix for *"CR5"* (fA_{5j}) is found by using last compensation result of each product alternative. This procedure is also executed for each negotiable issue and final decision-matrices corresponding to these issues are found as well.

Table 10.2 Trade-offs performed in customer benchmarking section

Number	Even Swap Change	Compensation	Resulting situations
CR5 is determined as negotiable issue; Bargaining range is "1.0"			
Initial scanning through the consequence table			*P4* is dominated by *P1*
	CR1	*CR5*	
1 – *P2*	3.2→3.0	3.0→3.4	
2 – *P3*	3.4→3.0	3.4→3.8	*CR1* is irrelevant
	CR2	*CR5*	
3 – *P2*	3.0→3.8	3.4→3.0	
4 – *P3*	3.9→3.8	3.8→3.8	*CR2* is irrelevant
	CR3	*CR5*	
5 – *P2*	3.1→3.0	3.2→3.1	
6 – *P3*	3.8→3.0	3.8→3.4	*CR3* is irrelevant
	CR4	*CR5*	
7 – *P2*	3.3→3.0	3.1→3.7	
8 – *P3*	3.4→3.0	3.4→4.1	*CR4* is irrelevant
Final decision matrix for **CR5 = [*P1*(3.2) *P2*(3.7) *P3*(4.1)]**			
CR4 is determined as negotiable issue; Bargaining range is "0.5"			
Initial scanning through the consequence table			*P4* is dominated by *P1*
	CR1	*CR4*	
9 – *P2*	3.2→3.0	3.3→3.6	
10 – *P3*	3.4→3.0	3.4→3.9	*CR1* is irrelevant; *P3* is dominated by *P1*
	CR2	*CR4*	
11 – *P2*	3.0→3.8	3.6→3.4	*CR2* is irrelevant
	CR3	*CR4*	
12 – *P2*	3.1→3.0	3.4→3.5	*CR3* is irrelevant
	CR5	*CR4*	
13 – *P2*	3.0→3.2	3.5→3.4	*CR5* is irrelevant
Final decision matrix for **CR4 = [*P1*(3.0) *P2*(3.4)]**			
CR3 is determined as negotiable issue; Bargaining range is "0.5"			
Initial scanning through the consequence table			*P3* and *P4* are dominated by *P1*
	CR1	*CR3*	
14 – *P2*	3.2→3.0	3.1→3.4	*CR1* is irrelevant
	CR2	*CR3*	
15 – *P2*	3.0→3.8	3.4→3.2	*CR2* is irrelevant
	CR4	*CR3*	
16 – *P2*	3.3→3.0	3.2→3.5	*CR4* is irrelevant
	CR5	*CR3*	
17 – *P2*	3.0→3.2	3.5→3.4	*CR5* is irrelevant
Final decision matrix for **CR3 = [*P1*(3.0) *P2*(3.4)]**			
CR2 is determined as negotiable issue; Bargaining range is "0.5"			
Initial scanning through the consequence table			*P4* is dominated by *P1*
	CR1	*CR2*	
18 – *P2*	3.2→3.0	3.0→3.7	
19 – *P3*	3.4→3.0	3.9→4.4	*CR1* is irrelevant; *P3* is dominated by *P1*
	CR3	*CR2*	
20 – *P2*	3.1→3.0	3.7→4.0	*CR3* is irrelevant
	CR4	*CR2*	
21 – *P2*	3.3→3.0	4.0→4.5	*CR4* is irrelevant
	CR5	*CR2*	
22 – *P2*	3.0→3.2	4.5→4.1	*CR5* is irrelevant
Final decision matrix for **CR2 = [*P1*(3.8) *P2*(4.1)]**			
CR1 is determined as negotiable issue; Bargaining range is "1.5"			
Initial scanning through the consequence table			*P4* is dominated by *P1*
	CR2	*CR1*	
23 – *P2*	3.0→3.8	3.2→3.0	
24 – *P3*	3.9→3.8	3.4→3.4	*CR2* is irrelevant
	CR3	*CR1*	
25 – *P2*	3.1→3.0	3.0→3.0	
26 – *P3*	3.8→3.0	3.4→3.6	*CR3* is irrelevant
	CR4	*CR1*	
27 – *P2*	3.3→3.0	3.0→3.2	
28 – *P3*	3.4→3.0	3.6→3.3	*CR4* is irrelevant
	CR5	*CR1*	
29 – *P2*	3.0→3.2	3.2→3.1	
30 – *P3*	3.4→3.2	3.3→3.4	*CR5* is irrelevant
Final decision matrix for **CR1 = [*P1*(3.0) *P2*(3.1) *P3*(3.4)]**			

After specifying final decision-matrices, differences/similarities between product alternatives in terms of any negotiable issue also become clear. By means of these differences/similarities, limits of agreement areas of negotiable products for each negotiable customer requirement are determined. Although it is discussed in previous section in detail, as an example, determination of agreement area limits of *"CR5-Short washing time"* is presented in Figure-10.9 to show how these limits are determined.

After determination of all agreement areas, fuzzy input sets are generated. Figure-10.10 shows the input fuzzy sets generated by using these agreement areas. Triangular membership functions are used while generating input fuzzy sets. These fuzzy sets consider *"acceptability"* of product alternatives. Degree of acceptability is represented by three membership functions, as; *"high", "middle"* and *"low"*. Parameters of these membership functions are assigned by considering the largest agreement area as illustrated in Figure-10.5. After generating input fuzzy sets, a rule-base is needed to obtain a utility degree for each product alternative. It is assumed that lead-user interprets his/her judgments through rules given in Table-10.3. It should be noted that the rules are generated by using "*L27 orthogonal array*" in order to reflect perception of the lead-user with a smaller and efficient amount of rules. A default rule (see R28 in Table-10.3) that can be reasoned easily is also added to the rule list. Fuzzy-inference system uses an output fuzzy set that is also triangular and representing the utility degree (within interval of [0, 1]). When parameters of the product alternatives are entered to the system, utility degrees are obtained as in Table-10.4.

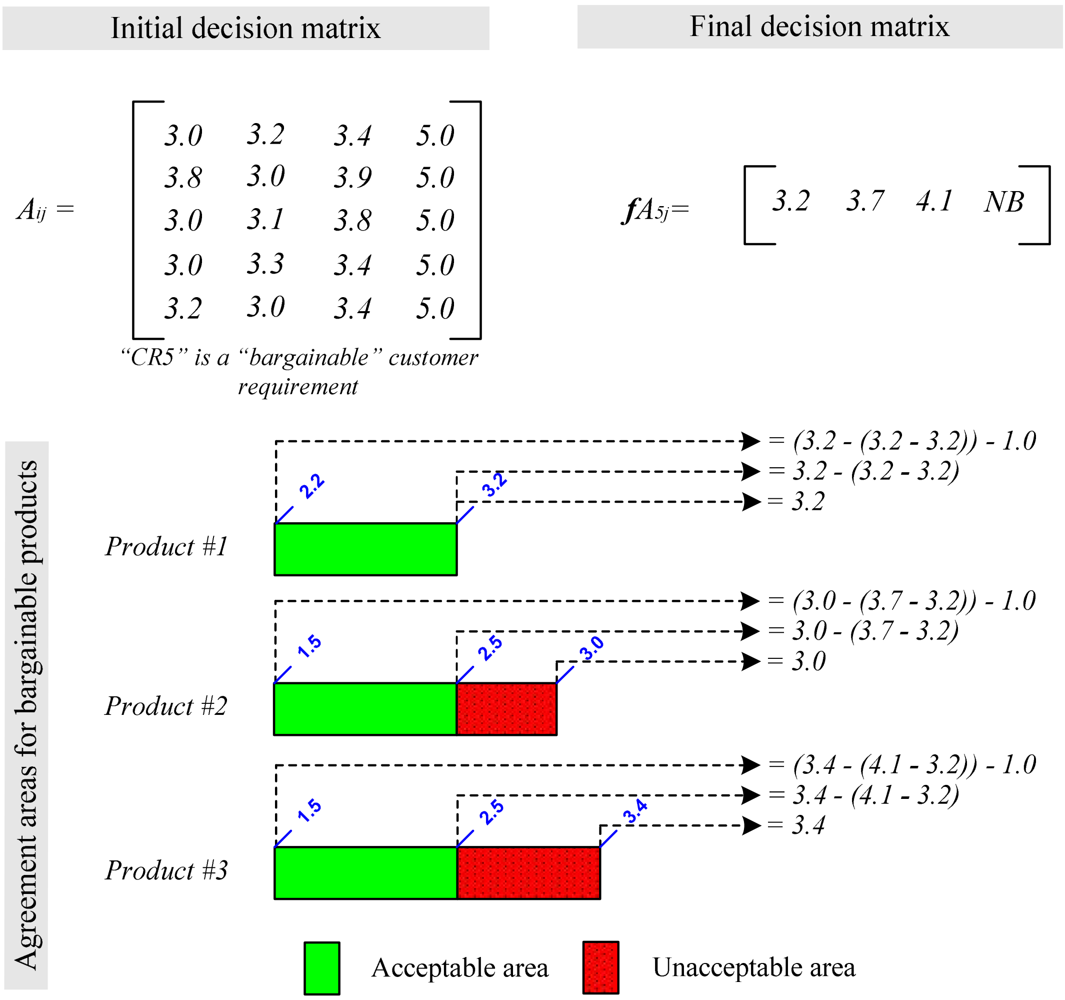


Figure 10.9 Determination of agreement area limits for CR5 – Short washing time

After determination of all agreement areas, fuzzy input sets are generated. Figure-10.10 shows the input fuzzy sets generated by using these agreement areas. Triangular membership functions are used while generating input fuzzy sets. These fuzzy sets consider *"acceptability"* of product alternatives. Degree of acceptability is represented by three membership functions, as; *"high"*, *"middle"* and *"low"*. Parameters of these membership functions are assigned by considering the largest agreement area as illustrated in Figure-10.5. After generating input fuzzy sets, a rule-base is needed to obtain a utility degree for each product alternative. It is assumed that lead-user interprets his/her judgments through rules given in Table-10.3. It should be noted that the rules are generated by using "*L27 orthogonal array*" in order to reflect perception of the lead-user with a smaller and efficient amount of rules. A default rule (see R28 in Table-10.3) that can be reasoned easily is also added to the rule list. Fuzzy-inference system uses an output fuzzy set that is also triangular and representing the utility degree (within interval of [0, 1]). When parameters of the product alternatives are entered to the system, utility degrees are obtained as in Table-10.4.

The first round evaluation results obtained from the mechanism show that *"Product #3"* and *"Product #4"* cannot be considered as competing products because they do not meet some customer requirements (see Table-10.4). They need major improvements on engineering characteristics corresponding to the unsatisfied customer requirements.

Suppose that development centres are trying to make *"Product #2"* the most preferred one in the market. By considering benefit-cost related factors for improvements on each engineering characteristic, they need to optimize level of each engineering characteristic to obtain a planned customer need score by considering relationship matrix, consequence table, agreement areas and rule-base that is roughly elicited.

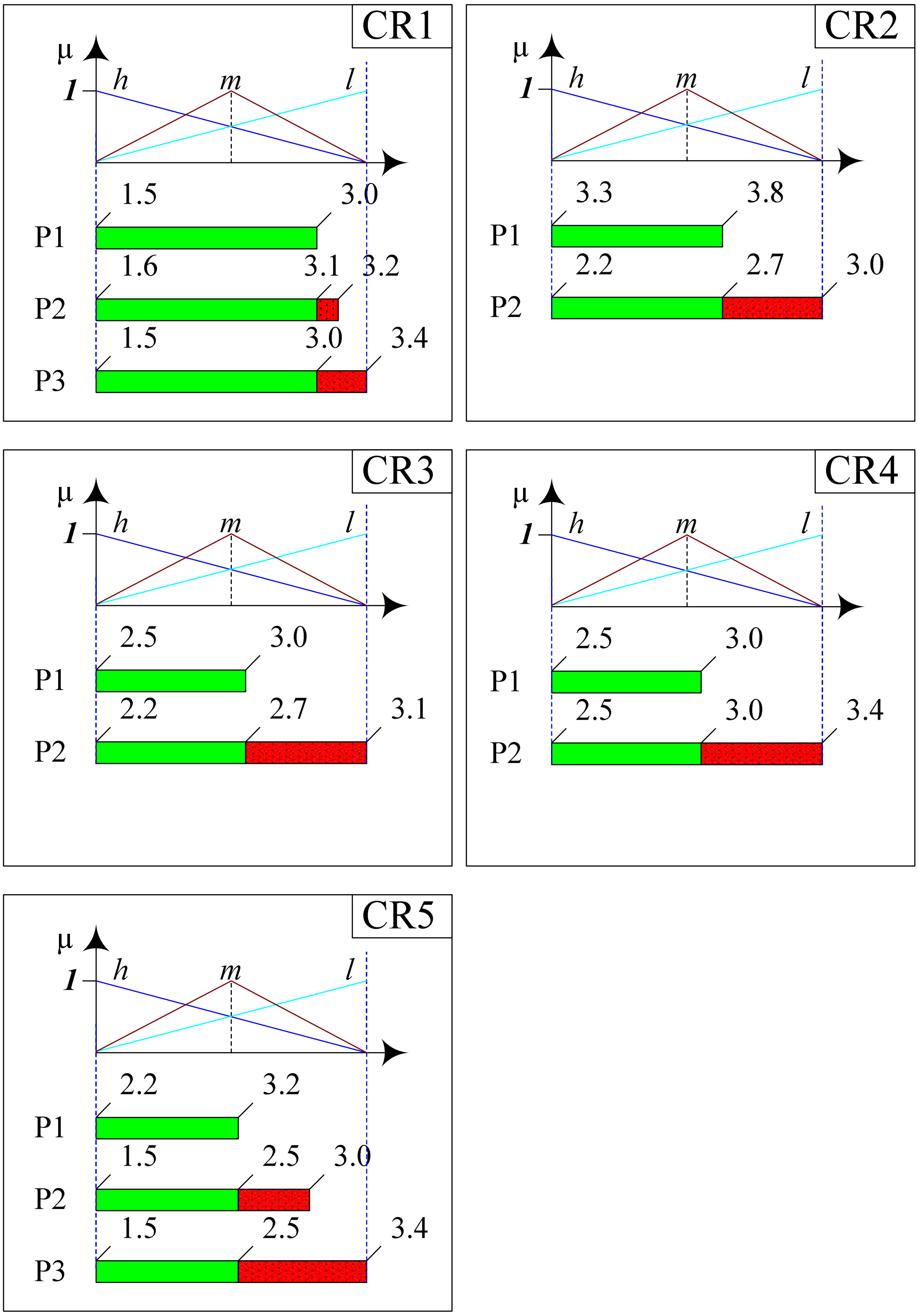


Figure 10.10 Generating input fuzzy sets from agreement areas

Table 10.3 Rule-base

	CR1	CR2	CR3	CR4	CR5	Utility
R01	High	High	High	High	High	High
R02	High	High	High	High	Middle	High
R03	High	High	High	High	Low	Middle
R04	High	Middle	Middle	Middle	High	High
R05	High	Middle	Middle	Middle	Middle	Middle
R06	High	Middle	Middle	Middle	Low	Middle
R07	High	Low	Low	Low	High	Middle
R08	High	Low	Low	Low	Middle	Middle
R09	High	Low	Low	Low	Low	Low
R10	Middle	High	Middle	Low	High	Middle
R11	Middle	High	Middle	Low	Middle	Middle
R12	Middle	High	Middle	Low	Low	Low
R13	Middle	Middle	Low	High	High	High
R14	Middle	Middle	Low	High	Middle	Middle
R15	Middle	Middle	Low	High	Low	Low
R16	Middle	Low	High	Middle	High	Middle
R17	Middle	Low	High	Middle	Middle	Middle
R18	Middle	Low	High	Middle	Low	Low
R19	Low	High	Low	Middle	High	Middle
R20	Low	High	Low	Middle	Middle	Low
R21	Low	High	Low	Middle	Low	Low
R22	Low	Middle	High	Low	High	Low
R23	Low	Middle	High	Low	Middle	Low
R24	Low	Middle	High	Low	Low	Low
R25	Low	Low	Middle	High	High	Middle
R26	Low	Low	Middle	High	Middle	Middle
R27	Low	Low	Middle	High	Low	Low
R28	Low	Low	Low	Low	Low	Low

Table 10.4 Utility degrees obtained from fuzzy-inference system

	CR1	CR2	CR3	CR4	CR5	Utility
Product #1	0.789	0.625	0.555	0.555	0.526	0.475
Product #2	0.842	1.000	1.000	1.000	0.789	0.350
Product #3	1.000	-	-	-	1.000	-
Product #4	-	-	-	-	-	-

Figure-10.11 shows the new levels of engineering characteristics determined by each development center for "*Product #2*". *Team #1* has decided to make following improvements by considering above-mentioned factors. *Washing quality* will be increased from 85% to 87%. However, this improvement will cause a declination at *washing time* from 30-min to 35-min and also a declination at *clothes damage rate* from 1.9% to 1.92%. On the other hand, the new levels of *Team #2* are as follow. They have decided to increase *rinsing quality* from 80% to 85% with a declination at *washing time* from 30-min to 35-min. The expected utilities for the new product concepts of *Team #1* and *Team #2* are reasoned as "0,499" and "0,485", respectively. Details of the reasoning process are given in Table-10.5. Direct proportion is used in the calculations of the magnitude of improvements or declinations on each customer requirements. After these calculations, corresponding scores were updated and standardized by considering agreement zones illustrated in Figure-10.10. These standardized values entered to the fuzzy inference system and new utility degrees were obtained. Lead-user is invoked to confirm that these renewed levels reflect his/her judgment reasonably. It is assumed that the lead-user agrees with the updated utility degrees. By means of this process, company can rationally decide which product concept should be focused on. In case of there is inconsistency between expected utility and perception of the lead-user, benchmarking scores are revised by lead-user. As a result of this revision, it is expected that definition of agreement areas becomes more robust and therefore fuzzy model produces more reliable outcomes.

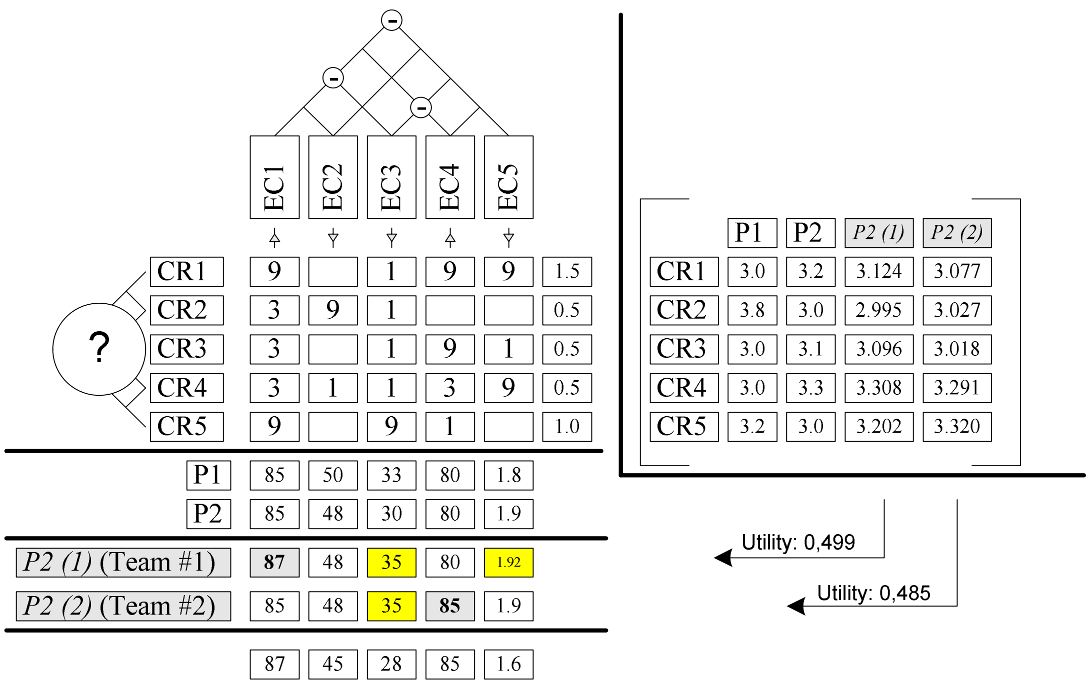


Figure 10.11 New product concepts improving the provided utility

Table 10.5 Reasoning for expected utility for new product concepts

			Team #1		Team #2	
CR1	*IF*		*THEN*		*THEN*	
	EC1: From 80 to 87	+0,482	From 85 to 87	*+0,137*		
	EC3: From 35 to 28	+0,053	From 30 to 35	*-0,037*	From 30 to 35	*-0,037*
	EC4: From 70 to 85	+0,482			From 80 to 85	*+0,160*
	EC5: From 2,0 to 1,6	+0,482	From 1,9 to 1,92	*-0,024*		
	Bargaining range:	1,5	Improvement:	*+0,076*	Improvement:	*+0,123*
			Revised score:	*3,124*	Revised score:	*3,077*
			Standardization:	*0,802*	Standardization:	*0,777*
CR2	*IF*		*THEN*		*THEN*	
	EC1: From 80 to 87	+0,115	From 85 to 87	*+0,032*		
	EC2: From 55 to 45	+0,346				
	EC3: From 35 to 28	+0,038	From 30 to 35	*-0,027*	From 30 to 35	*-0,027*
	Bargaining range:	0,5	Improvement:	*+0,005*	Declination:	*-0,027*
			Revised score:	*2,995*	Revised score:	*3,027*
			Standardization:	*0,993*	Standardization:	*1,000*
CR3	*IF*		*THEN*		*THEN*	
	EC1: From 80 to 87	+0,107	From 85 to 87	*+0,030*		
	EC3: From 35 to 28	+0,035	From 30 to 35	*-0,025*	From 30 to 35	*-0,025*
	EC4: From 70 to 85	+0,321			From 80 to 85	*+0,107*
	EC5: From 2,0 to 1,6	+0,035	From 1,9 to 1,92	*-0,001*		
	Bargaining range:	0,5	Improvement:	*+0,004*	Improvement:	*+0,082*
			Revised score:	*3,096*	Revised score:	*3,018*
			Standardization:	*0,995*	Standardization:	*0,908*
CR4	*IF*		*THEN*		*THEN*	
	EC1: From 80 to 87	+0,088	From 85 to 87	*+0,025*		
	EC2: From 55 to 45	+0,029				
	EC3: From 35 to 28	+0,029	From 30 to 35	*-0,020*	From 30 to 35	*-0,020*
	EC4: From 70 to 85	+0,088			From 80 to 85	*+0,029*
	EC5: From 2,0 to 1,6	+0,264	From 1,9 to 1,92	*-0,013*		
	Bargaining range:	0,5	Declination:	*-0,008*	Improvement:	*+0,009*
			Revised score:	*3,308*	Revised score:	*3,291*
			Standardization:	*0,897*	Standardization:	*0,878*
CR5	*IF*		*THEN*		*THEN*	
	EC1: From 80 to 87	+0,473	From 85 to 87	*+0,135*		
	EC3: From 35 to 28	+0,473	From 30 to 35	*-0,337*	From 30 to 35	*-0,337*
	EC4: From 70 to 85	+0,052			From 80 to 85	*+0,017*
	Bargaining range:	1,0	Declination:	*-0,202*	Declination:	*-0,320*
			Revised score:	*3,202*	Revised score:	*3,320*
			Standardization:	*0,895*	Standardization:	*0,957*
			Expected utility:	*0,499*	Expected utility:	*0,485*

10.5 Conclusion

Customer centric NPD requires supporting methods and tools for elicitation of customer needs and then for incorporation of them to the development processes. Although QFD is a well-known methodology in customer centric NPD, it becomes insufficient in complex and decentralized NPD environment. This study discussed major factors forcing the QFD methodology to evolve some way to stay reasonable and proposed a novel research direction, construction of a multi-issue negotiation based QFD methodology, which may help QFD to adapt this changed NPD environment.

10.5.1. Theoretical implications

This study is the first attempt adapting a multi-issue negotiation mechanism to QFD in the literature according to authors' best knowledge. The methodology proposed in this study contributes to this domain by providing following merits;

- This approach allows customers to play active role (i.e., customer co-creation) in NPD that is more than ever crucial to clarify design trade-offs and handle them with appropriate solutions.

- Besides, a negotiation based structure can be faster as it includes changing customer requirements in real-time rather than a cycle-time determined by the length of the product development process.

- Multi-issue negotiation based QFD also enables decentralized NPD teams to negotiate with each-other and with customers (lead-users), concurrently. By this achievement, this improved version of QFD is also expected to be a unique system which can be placed in "virtual R&D teams" literature, does still not include a multi-issue negotiation mechanism for supporting decentralized NPD.

10.5.2. Managerial Implications

From the results, it is clear that implementing NegoQFD is beneficial to organizations while clarifying interrelations between customer requirements when especially they are tacit, i.e., hard articulate and disseminate. Furthermore, it provides organizations a platform to manage their communication traffic for knowledge creation and sharing between decentralized teams each other and also between each team and its customers.

10.5.3. Limitations and directions for future research

Figure-10.12a shows the perceived quality of solutions by means of QFD for both in centralized and decentralized NPD environment. Furthermore, a comparison of the expected contribution of adaptation of multi-issue negotiation and the NegoQFD methodology proposed in this study is illustrated in this figure as well. When a typical NPD process funnel is reviewed (see Figure-10.12b), different forms of customer participation are required at each phase of NPD. While the first phase can be handled with passive participation (through interviews as source of ideas), further phases require active participation to satisfy customer requirements and then for their confirmations in complex NPD environments. From this illustration, it is seen that QFD allows NPD teams to participating customers only in the first phase as sources of ideas. Furthermore, this method is not able to support coordination and collaboration of decentralized NPD teams in complex cases.

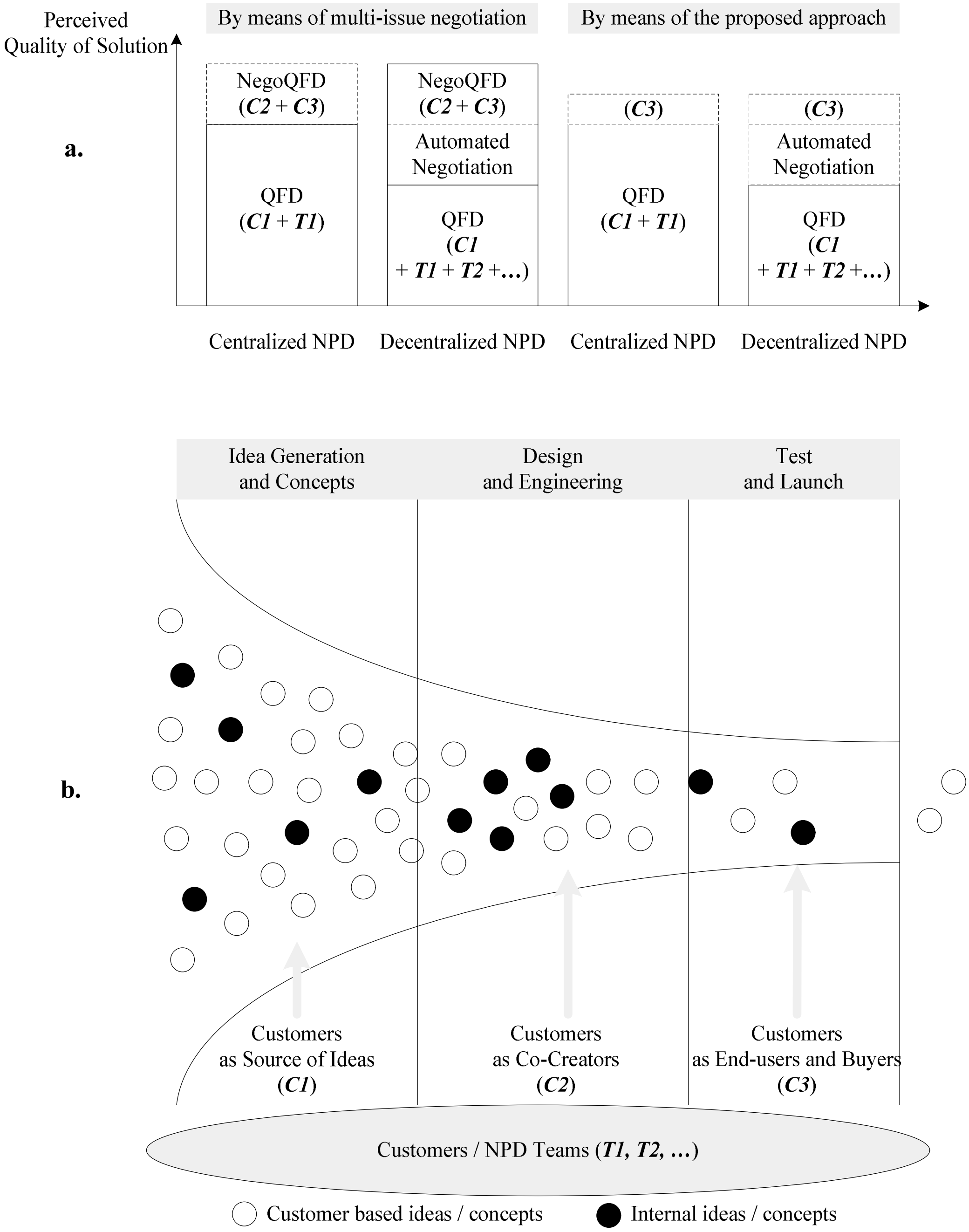


Figure 10.12 Enhancement of perceived quality of solutions by improving customer involvement

Adaptation of automated & multi-issue negotiation may contribute to QFD to solve coordination and collaboration issue. This adaptation therefore has potential to defeat the declination of perceived quality of solution while implementing QFD in decentralized NPD. Appropriate participation of customers in design & engineering phase and test & launch phase can improve the perceived quality of solution as a result of playing active role that is more than ever crucial to clarify design trade-offs and handle them with appropriate solutions in complex product development environment. As it is discussed in previous sections of this chapter, multi-issue negotiation mechanisms have a great potential to achieve this participation. However, elicitation of the preferences over the relevant issues is considered as the main difficulty underlying multi-issue negotiation (Wallenius et al., 2008). Chen-Ritzo et al. (2005) claim that in many applications revealing utility function may not be practical for negotiators either for strategic reasons or because they are unable to express it. Because of this difficulty, price-only (single-issue) negotiation is considered as a reasonable approach to implement although the overall utility that can be obtained by means of multi-issue negotiation (Yuan & Tsao, 2010). This study adapted a novel multi-issue negotiation mechanism that is known as rational, clear and easy-to-use to QFD methodology but still some improvements are required to achieve active participation in the second phase of NPD process illustrated in Figure-10.12b. Although interrelations and trade-offs between customer requirements can be expressed in a better way by means of the Modified Even-Swaps, there is still a supporting approaches/modifications to participate actively in the second phase. Correspondingly, this unsatisfied requirement can be considered as a research direction for further works in this area to design a multi-issue negotiation mechanism providing higher quality/utility in theory and practice by active participation of customers at all phases of NPD.

Multi-issue negotiation related previous works are generally extensions of corresponding price-only (i.e., single-issue) negotiation related efforts. However, consideration of multi-issue negotiation as an hybridized form of decision making (selection of the best alternative) and optimization (describing the best alternative providing optimal solution) in multi-issue environment may help to develop more convincing mechanisms for multi-issue negotiation (at first selection of the best negotiable alternatives and then optimization of negotiable issues of selected alternatives to generate offers / counter-offers providing win-win solutions). From this point of view, appropriate modifications on some multi-criteria decision making methods may provide better advances in literature corresponding to multi-issue negotiation and its adaptation to NPD.

CHAPTER 11

GENERAL REMARKS AND CONCLUDING DISCUSSION

This thesis proposed some novel approaches those are well-structured and easy-to-use CAI methods aiming to improve industrial innovation intelligence. Each chapter includes detailed discussions about the key contributions and suggested future research directions.

Most of the approaches proposed in this thesis has been published in (or submitted to) some international journals (Altun et al., 2015; Altun & Dereli, 2014; Dereli & Altun, 2013b; Altun et al., 2013; Dereli & Altun, 2013; Dereli & Altun, 2012) and presented in some conferences (Altun et al., 2014; Altun & Dereli, 2014b; Altun & Dereli, 2013; Altun et al., 2011; Dereli & Altun, 2011; Dereli & Altun, 2011b). Therefore we have an opportunity to conclude this thesis by means of some statements of other researchers corresponding to importance of the approaches proposed in this thesis.

In order to contribute innovation process in "*doing right things*", we have proposed the Quick Innovation Intelligence Process. The assessment processes aiming to evaluate and prioritize inventions according to their innovation potentials has been named as "*innovation intelligence*" in this thesis. It can be seen from the literature that "*innovation intelligence*" is now a roof name for this kind of attempts (Makkonen & Inkinen, 2014; Felekoglu & Moultrie, 2013). We have also highlighted that understanding fundamentals and life cycle of innovation process is decisive for developing appropriate frameworks aiming to improve success of innovation process. This statement directed some further studies to develop such kind of frameworks (e.g., Mutanov & Yessengaliyeva, 2013).

Moreover, the proposed innovation intelligence process is compared in a recent paper. Choi et al. (2014) compares some algorithms by considering their data requirements, forecasting speed and stability as in Table-11.1. According to their comparisons, the Quick Innovation Intelligence Process is fast one when considered its forecasting speed, and also it has high stability.

Table 11.1 Comparisons between recently developed forecasting models (Choi et al., 2014)

Papers	Data requirements	Forecasting speed	Stability	Application domain	Methods
Willis & Parks (1983)	Sufficiency is assumed	Slow	High	Control loading problems	Fourier transform model
Au et al. (2008)	Sufficiency is assumed	Slow	High	Fashion sales time series problems	ANN
Aznarte et al. (2012)	Sufficiency is assumed	Slow	High	Generic	Fuzzy model
Carpinteiroa et al. (2007)	Sufficiency is assumed	Slow	High	Control loading problems	Hierarchical neural model
Kim et al. (2012)	Sufficiency is assumed	Slow	High	Advertisement	Hierarchical Bayes model
Majhi et al. (2012)	Sufficiency is assumed	Slow	High	Finance	Wilcoxon ANN and Wilcoxon functional link ANN
Premanode & Toumazou (2013)	Sufficiency is assumed	Slow	High	Finance	Differential EMD
Shin et al. (2013)	Sufficiency is assumed	Slow	High	Network intrusion	Markov chain
Won et al. (2012)	Sufficiency is assumed	Slow	High	Finance	Genetic algorithm
Egrioglu et al. (2013)	Sufficiency is assumed	Moderate	High	Generic	Fuzzy c-means and neural networks
Park & Lee (2012)	Sufficiency is assumed	Moderate	High	Finance	Bayesian kernel method
Fan et al. (2009)	Sufficiency is assumed	Fast	Moderate	Control loading problems	Ensemble ANN
Dereli & Altun (2013)	*Sufficiency is assumed*	*Fast*	*High*	*Technology assessment problems*	*Fuzzy inference system*
Kim et al. (2012)	Sufficiency is assumed	Fast	High	Technology trend	Decision tree
Yu et al. (2011)	Sufficiency is assumed	Moderate	High	Fashion sales time series problems	Extreme learning machine
Hsu (2009)	Sufficiency is not assumed	Moderate	Low	Integrated circuit output	Genetic algorithm based multivariable grey optimization model
Hsu & Wang (2007)	Sufficiency is not assumed	Moderate	Low	Integrated circuit output	Grey model
Lei & Feng (2012)	Sufficiency is not assumed	Moderate	Low	Electricity	Grey model
Choi et al. (2014)	Sufficiency is not assumed	Fast	Moderate	Fashion sales time series problems	Extended extreme learning machine, grey model

In order to contribute innovation process in "*doing things right*", we have proposed customer co-creation in NPD through multi-issue negotiation, and also we have proposed a novel QFD methodology that is based on multi-issue negotiation, namely; NegoQFD. In order to achieve this co-creation process, we have also proposed a novel, clear, rational and an easy-to-use mechanism for multi-issue negotiation, namely; Modified Even-Swaps.

When the literature corresponding to multi-issue negotiation is reviewed, it can be seen that it is considered as an extension of single-issue negotiation. And they are not easy-to-use although they provide higher utility when compared to single issue negotiation based counterpart. For this reason, single issue negotiation is still an active research direction. However, we think that multi-issue negotiation is an extension of multi-criteria decision making. Through some modifications in some well-known multi-criteria decision making methods, they can also support its users in case of some criteria are negotiable. Modified Even-Swaps mechanism is one of such kind of attempts. Moreover, we believe in that similar successful modifications will be appeared in the literature and these attempts will dramatically increase the performance and applicability of multi-issue negotiation in theory and practice.

Lee (2013) states that when a new offer is received, its evaluation can be done by multi-criteria decision making methods however user lacks such approaches as creating new offer and confirming acceptable offer, under the traditional framework of multi-criteria decision making approaches. Lee (2013) states that the Modified Even-Swaps mechanism proposed in this thesis indicates that agent-based negotiation could effectively enhance users' bargaining power and avoid unnecessary social interaction between human agents. This high-quality interaction between customer and company and its importance in customer co-creation is also highlighted in Gadeib (2014). It is also discussed that existing deficiencies of QFD can be handled by employing such attempts (Melemez et al., 2013). NegoQFD is another attempt that is supported by the Modified Even-Swaps in order to provide a well-structured negotiation based QFD methodology solving existing deficiencies of traditional QFD.

When we review these approaches according to their possible industrial applications, the quick innovation intelligence process may be useful in strategic technology management; especially it may be useful in science and technology policy making relating to the given incentives for directing investments. Moreover, the Modified Even-Swaps mechanism proposed in this thesis is a generic mechanism and its implementations in e-commerce may also be useful and may solve some issues in buyer-seller interaction as it is discussed by Dereli & Altun (2012) in detail. We also believe in that adaptation of such kind of mechanisms to collaborative new product development has a great potential to be a hot and important research direction and implementation area in new product development domain, which is addressing how to overcome increasing complexity and how to provide a mode for collaboration in a decentralized / internationalized structure.

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RESEARCH INTERESTS

Decision Analysis; Automated (multi-issue) negotiation; Technology – Innovation – Imitation Management; Computer Aided Innovation (CAI); New product development (NPD); Virtual R&D teams; Collaborative engineering design; (Type-2) Fuzzy sets and systems

PUBLICATIONS

International Journals (SCI/SCI-E):

Altun, K., Dereli, T., Even easier multi-issue negotiation through Modified Even-Swaps considering practically dominated alternatives, Computers & Industrial Engineering 76 307-317, 2014.

Dereli, T., ***Altun, K.***, Technology evaluation through the use interval type-2 fuzzy sets and systems, Computers & Industrial Engineering, 65 (4) 624-633, 2013.

Altun, K., Dereli, T., Baykasoglu, A., Development of a framework for customer co-creation in NPD through multi-issue negotiation with issue trade-offs, Expert Systems with Applications, 40 (3) 873-880, 2013.

Dereli, T., ***Altun, K.***, A novel approach for assessment of candidate technologies with respect to their innovation potentials: Quick innovation intelligence process, Expert Systems with Applications, 40 (3) 881-891, 2013.

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Dereli, T., ***Altun, K.***, Gölec, A., Durmusoglu, A., Improvement of manufacturing productivity and responsiveness through integrated process planning and authorizing, Technical Gazette / Technicki Vjesnik, 19 (4) 871-884, 2012.

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Altun, K., von Zedtwitz, M., Dereli, T., Multi-issue negotiation in quality function deployment: Modified Even-Swaps in new product development, Submitted to an international journal, 2015.

Book Chapters:

Dereli, T., ***Altun, K.***, Imovator’s dilemma: How to decide when to be offensive and when to be defensive? Strategic Planning Decisions in the High Tech Industry (Editors: D. Cetindamar, T. Daim, N. Basoglu, B. Beyhan), Springer/Verlag, London, ISBN 978-1-4471-4886-9, 2013.

National Journals:

Altun, K., Gölec, A., A comparative simulation study of production control systems, Journal of the Institute of Science and Technology of Erciyes University, 27(2), 200-2007, 2011. (in Turkish)

Baykasoglu, A., Dereli, T., ***Altun, K.***, Used truck selection: A practical decision support approach through the use of Even-Swaps, Lojistik, 19, 18-22, 2011. (in Turkish)

International Conferences:

Altun, K., Dereli, T., Hämäläinen, R.P., Use of Modified Even-Swaps in multi-issue negotiation with fuzzy issues, INFORMS - 2014 Advances in Decision Analysis Conference, June 16-18, Georgetown University, Washington DC, USA, 2014.

Altun, K., Dereli, T., Computer-Aided Innovation for improving industrial innovation intelligence, The 5th International Conference on Systematic Innovation, July 16-18, San Jose State University, San Jose, California, USA, 2014.

Altun, K., Dereli, T., A practical dominance reinforcement to make the Modified Even-Swaps mechanism even easier, Proceedings of CIE43: The 43rd International Conference on Computers & Industrial Engineering, October 16-18, The University of Hong Kong, Hong Kong, 2013.

Dereli, T., ***Altun, K.***, Achieving manufacturing responsiveness by integrating "process planning" and "authorizing", Proceedings of IMS 2012: 8th International Symposium on Intelligent and Manufacturing Systems, September 27-28, Antalya, Turkey, 2012.

Altun, K., Dereli, T., Baykasoglu, A., Usage of Modified Even-Swaps in case of multi-bargainable-issue, Proceedings of FUZZYSS'11: 2nd International Fuzzy Systems Symposium, November 17-18, Hacettepe University, Ankara, Turkey, 87-91, 2011.

Dereli, T., ***Altun, K.***, Quick innovation intelligence process, Proceedings of FUZZYSS'11: 2nd International Fuzzy Systems Symposium, November 17-18, Hacettepe University, Ankara, Turkey, 92-97, 2011.

Dereli, T., ***Altun, K.***, Automated negotiation with issue trade-offs: Modified Even-Swaps for bargaining, Proceedings of ISCSE 2011: 2nd International Symposium on Computing Science and Engineering, June 1-4, Kusadası, Turkey, 600-606, 2011.

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National Conferences:

Altun, K., Development of a novel multi-issue negotiation mechanism and its adaptation to new product development, YEAM 2014 PhD Students Colloquium, October 24-25, Middle East Technical University (METU), Ankara, Turkey, 2014.

Dereli, T., ***Altun, K.***, Innovation Intelligence, Proceedings of YAEM 2011: 31st National Meeting on Operational Research and Industrial Engineering, July 5-7, Sakarya University, Sakarya, Turkey, 2011. (in Turkish)

Dereli, T., ***Altun, K.***, A research profiling study on Computer-Aided-Innovation (CAI), Proceedings of ÜAS'11: 11th National Symposium on Production Researches, June 23-24, Istanbul Commerce University, Istanbul, 224-233, 2011. (in Turkish)

Dereli, T., ***Altun, K.***, Durmusoglu, A., Integrated Process Planning and Authorizing, Proceedings of ÜAS'10: 10th National Symposium on Production Researches, September 16-18, Kyrenia American University, Kyrenia, TRNC, 2010. (in Turkish)

Dereli, T., ***Altun, K.***, Durmusoglu, A., Computer Aided Innovation (CAI): A review, Proceedings of YAEM 2010: 30th National Meeting on Operational Research and Industrial Engineering, June 30 – July 2, Sabanci University, Istanbul, Turkey, 2010. (Invited Talk) (in Turkish)

MEMBERSHIPS

2015 – to date	INFORMS - Decision Analysis Society
2013 – to date	GLORAD – Research Center for Global R&D Management
2013 – to date	IAENG – International Association of Engineers
2012 – to date	INFORMS – Technology Management Section
2011 – to date	UAD – National association of production researches
2010 – to date	FUZZY SYSTEMS ASSOCIATION
2010 – to date	TIRG – Technology Intelligence Research Group

PROFESSIONAL ACTIVITIES

Refereeing for : Technovation; Computers & Industrial Engineering; Computers in Industry; European Journal of Industrial Engineering; International Journal of Production Research; Journal of the Operational Research Society; Journal of Intelligent and Fuzzy Systems; Project Management Journal; Turkish Journal of Agriculture & Forestry; International Journal of E-Business Development; Academy of Management Annual Meeting (AOM 2014 & AOM 2015); American Journal of Computation, Communication and Control; American Journal of Computer Science and Information Engineering; International Journal of Management Science

AWARDS & HONORS

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2011-2014 TUBITAK, International publication encouragement awards (6 times)

2011&2013 TUBITAK, Support for attending international conference (2 times)

2011 TUBITAK, Support for attending an international doctoral summer school

2009 Ranked 1st in the graduates list of Department of Industrial Engineering, Erciyes University