DECISION MAKING METHODOLOGY FOR SOFTWARE DEVELOPMENT OUTSOURCING

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LIST OF SYMBOLS

ACS	: Access Control Server
AHP	: Analytic Hierarchy Process
ATM	: Automated Teller Machine
CAVV	: Cardholder Authentication Verification Value
CNP	: Card Not Present
DS	: Directory Server
ECI	: Ecommerce Indicator
EDAS	: The Evaluation Based on Distance from Average Solution
EMV	: Europay Mastercard Visa
IS	: Information Systems
IT	: Information Technologies
ITF2	: Interval Type 2 Fuzzy Sets
MCDM	: Multi Ctieria Decision Making
MPI	: Merchant Plug-In
PAN	: Primary Account Number
PCI-DSS	: Payment Card Industry Data Security Standards
PSP	: Payment Service Provider
SLA	: Service Level Agreement
SDO	: Software Development Outsourcing
UAT	: User Acceptance Test
UML	: Unified Modelling Language
VPOS	: Virtual Point of Sale
XID	: Transaction Id

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ABSTRACT

Payment is an important part of people's daily lives, and although both online and offline transactions made by credit cards increase everyday with the growing interest in e-commerce, a huge number of worldwide payment transactions are still made by cash. However, the banks, giant payment institutions like Visa and MasterCard, and Payment Service Provider companies aim to increase the number of card transactions with enhancing their platforms by supporting a wide range of channels with digital solutions, improving the security and providing value-added services.

Lately, IT Outsourcing is a business strategy of lots of companies due to focusing the core business, keeping up with technological innovations, decreasing the costs, and offering high quality. Having the user friendly and secure payment platforms, easy and quick integration opportunities with the merchants, operational efforts, security concerns are quite critical for the banks; and shift them to outsource Virtual Point of Sale platform to third parties.

In this study, Payment Service Provider selection of a bank will be evaluated based on Interval type-2 Fuzzy EDAS method. Three alternatives and seven main criteria will be assesed with the three decision makers, and the best option will be decided.

ÖZET

Ödeme insanların günlük hayatının önemli bir parçasını oluşturuyor ve kredi kartı ile yapılan çevrimiçi ve çevrimdışı işlemlerin sayısının e-ticaretin gelişmesi ile her geçen gün artmasına rağmen; dünya genelindeki ödeme işlemlerin büyük çoğunluğu hala nakit olarak yapılıyor. Ancak, bankalar, Visa, Mastercard gibi dev ödeme kuruluşları ve ödeme sağlayıcıları, platformlarını dijital kanallar ve geniş bir işlem kanalı seçeneği sunarak ve katma değer ve güvenlik hizmetlerini iyileştirerek hizmetler kredi kartı ile yapılan işlemlerin sayısının artırılmasını hedefliyor.

Son yıllarda, Bilgi Teknolojileri dış kaynak kullanımı firmaların ana faliyet konusuna odaklanabilmeleri, teknolojik gelişmelere ayak uydurabilmeleri, maliyetleri azaltlamaları ve yüksek kalitede hizmet vermeleri için sebebpleriyle bir çok firmanın iş stratejisi haline geldi. Kullanıcı dostu ve güvenli ödeme platformlarına sahip olmak, üye iş yerleri ile hızlı ve kolay entegrasyon fırsatları, operasyonel yükler ve güvenlik konuları bankalar için oldukça önemli ve onları Sanal POS platformlarını dış kaynak kullanımı ile üçüncü şahıslara vermeye itiyor.

Bu çalışmada, bir bankanın ödeme hizmeti sağlayıcısı seçimi aralık değerli tip-2 bulanık EDAS yöntemi ile değerlendirilecek. Üç adet alternatif ve yedi ana kriter üç adet karar verici tarafından değerlendirilecek ve en iyi alternatife karar verilecek.

1. INTRODUCTION

The payment world is becoming more digitalized everyday, although a large percent of purchases are still made by cash. Visa and MasterCard are still the biggest payment institutions those are also founders of EMV, however the card brands of countries with high population such as Union Pay of China have also grown excessively and arecompeting with them. All the banks and card schemes aim to decrease the cash transactions and making people prefer card transactions more both in virtual and physical environments. 3D Secure, which was introduced as Verified is a milestone in online purchases. The time's importance, the companies' improved delivery services, the easiness of refunds and the technological innovations also push individuals make online purchases more and more. That makes a strong Virtual Payment Gateway infrastructure a major issue for the banks.

IT Outsourcing has been a major preference for lots of companies since Kodak effect (Loh&Venkantraman, 1992). Providing higher quality and service, decreasing the costs, focusing on core business to generate more revenue, keeping up with technological innovations are the main reasons for outsourcing Information Technologies. Companies prefer to outsource a part of a product/service or the whole.

In a Payment Service Provider company, three significant teams are software development, oepration, and security teams. Software development team makes the development of new requests, and fixes the bugs those are realized in the production environment. Operation department is responsible for the use of the current product/service accurately by the customers, and support them via telephone or email. In addition to that, when there is a new merchant of an Acquirer Bank, during the creating of the merchant and its integration process, operation department supports the merchant employee. Providing a high quality support service is significant for both the customer satisfaction and following Service Level Agreement.

When a bank has an agreement with a PSP, the scope of the product/service is decided before the integration process stars up. The bank tells what kind of transactions and which card brands to support, which integation models and which channels to use, will it support 3d secure, the campaings will be offered to the cardholders. Later the integation process is completed, and once a bank is integrated with a PSP; then direct integration with a merchant is not required since the merchant can access to PSP.

In this study, PSP selection of will be evaluated based on seven different criteria including initial cost, development cost, quality, reliability, availability, service and security. Three different alternatives will be assessed to choose the best option utilizing Interval Type-2 fuzzy EDAS method.

2. LITERATURE REVIEW

2.1. IT Outsourcing

2.1.1. Definition and Background

"Outsourcing" word means "to obtain goods or a service by contract from an outside supplier", and "Information Technology" means "the study or use of systems for storing, retrieving, and storing information" according to the Oxford English Dictonary. A comprehensive definition for Information Technology Outsourcing is an organization's decision to contract out part of or all software development activities to a third party supplier who in return is responsible for providing and managing software development activities and services to its customer for monetary returns over a decided time period based on service level agreements (Kern&Willcocks, 2000). It is also defined as "the practice of transferring IT assets, leases, staff, and management responsibility for delivery of services from internal IT functions to third-party vendors" which relies on a contract-based relationship (Hirscheim&Lacity, 2000).

The improvement of IT Outsourcing started in 1963 with the settlement between Electronic Data Systems (EDS) Company and Blue Cross of Pennsylvania which relies on EDS's processing the data on behalf of its client (Dibber, et al., 2004). Although this was the first example of a major company's transfer of the whole data; the prominent rise on the interest in IT Outsourcing eventuated with the 'Kodak Effect' in 1989 which was an agreement based on IBM's constructing and operating a Data Center for Eastman Kodak (Loh&Venkantraman, 1992). In accordance with that agreement, IBM took over the data operating business by four data centers and transferring 150 employees of Kodak to its own constitution. The expected result of this change was a 50% decrease in the operational costs of Kodak, and due to the increasing popularity in a considerable extent; 'Kodak Effect' is still considered as a milestone in IT Outsourcing (Loh&Venkantraman, 1992).

The IT Outsourcing project phases were stated in Figure 1.1:

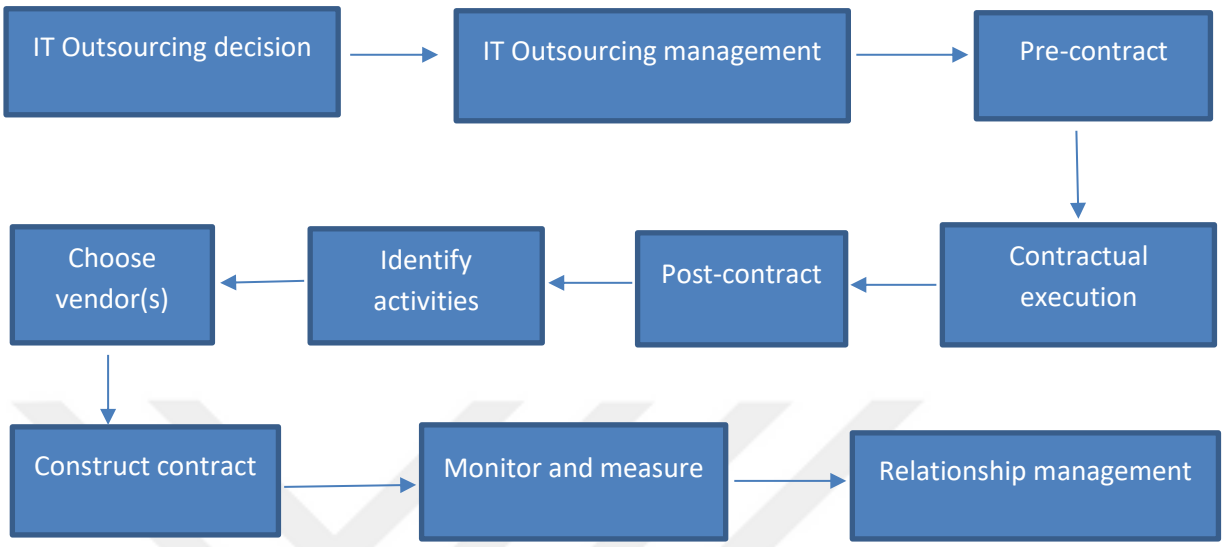


Figure 1.1: IT Outsourcing Project Phases (Mahnke, V. et al., 2005)

An illustravite study was made in 1994, to evaluate how the firm size, industry type, and information density affect the outsourcing decision for Information Systems functions including Systems Operations, Appplications Development&Maintenance, Telecommunications Management&Maintenance, Systems Planning and Management, End User Support (Grover et. al., 1994). The industries investigated are defined as manufacturing, healthcare, banking/finance/insurance, and other, whereas the firm size is specified by the number of employees, the number of IS employees, and the number of total sales revenue for a year. Information density is calculated by dividing IS Budget to Sales indicator (IS Budget/Sales indicator) which was essentially suggested by Nolan (Drury, D.H., 1983). Based on this study, it was proven that large companies are also prone to outsourcing, and company size has no relation with the outsourcing type. Also, it was shown that healthcare companies are more inclined to outsource any of IS functions due to their weak technological structure, where manufacturing and particularly finance companies are more tend to in-house there is functions. Other results obtained by the examination were the correlations between IS budget and end user support/systems planning&management functions. The first correlation showed that companies those have higher IS budgets were more likely to outsource end user support

function; which could be derived from the perception of end user support's being a non-core IS function (Loh&Venkatraman, 1992). The second correlation indicated that the companies with smaller IS expenditures when compared to sales presumably outsourced their systems planning&management functions.

The vendors and vendor selection of companies was examined by V. Michell and G. Fitzgerald, and the client and vendor's approach to an outsourcing project was investigated (V. Michell&G. Fitzgerald, 1997). It was mentioned that the stagnancy in the market and low margins pushed the vendors to avoid short-term dealings and try to establish long lasting relationships with their clients. Also, it was stated that hardware and software outsourcing had to be differentiated from each other to be be able to evaluate them objectively since they are separate expertise areas. Another point stressed in that study was the number of the candidate vendors which should be around four and no more than six. Moreover, the expectations of both clients and vendors were evaluated, which showed there were huge differences; and that was remarked as an opportunity to get better for both sides. Another evidence of this research was that during the vendor election, the qualitative criteria was much more significant than quantitative criteria for the clients. A key finding was about the vendors's lack of understanding the needs of the clients, and orienting them to a direction based on their own expertise and past experience (Michell, V.A., 1994). Moreover, clients paied attention to having close relationships with vendors, and they care about how much the vendors struggle to comprehend their business changes and requested targets whereas vendors seemed to underestimate these matters. Besides, it was emphasized that clients needed to improve themselves in understanding the vendors' capabilities in terms of their skills and background to assess them more successfully. The last indication of this article was the inadequate attention during the agreement process, and it was stressed that the contract should be prepared after a detailed research to make sure it contains accurate service levels.

B.A. Aubert, S. Rivard, and M. Patry made an illustrative research by proposing a transaction cost model by four different hypotheses based on bounded rationality and optimism assumptions (Aubert, B.A.&Rivard, S.& , Patry, M., 2003). In these assumptions, bounded rationality represents the uncertainty and opportunism is

explained as “self-interest seeking with guile” (Williamson, O.E., 1989). The authors stated that combining these two assumptions created an information asymmetry considering that both the seller and the buyer would conceal their negative sides from each other. The determinants in this study were defined as the asset specificity, the uncertainty, business skills and technical skills. After two surveys and ranking exersices, four different criteria were used in reliability assessment. The results were as follows; uncertainty has a negative impact in outsourcing decision which can be explained by the contradiction of the outsourcing’s nature. The companies aiming to handover their business did not want to deal with the ambugity. Technical skills had a positive impact, since in a competitive environment time is too valuable and training an employee or hiring an experienced person is not correct practically. Business skills had a negative impact, because information is too important to entrust and external party, and lack of the knowledge would harm the company in the future. Asset specificity findings did not provide clear results and required further research.

A research addressing not “to outsource or not” question due to the unsuitability of a generalization, but rather asks for “Who should outsource”, “what is outsourcing”, “why should outsource”, “where should you outsource” and “when should you outsource” was made by a group of CIOs that has an industry perspective more than academical approach (Laplante, P.A. et al. 2004). It was stated that as well was the vendor, the organization type of the company considering the receive outsourcing service should be analyzed very well before taking the decision. Outsourcing could not be identified as a cheap activity, and it was more convenient for the companies those are medium or large scale in terms of economic size. It was also stressed that the satisfaction rates of IT outsourcing services was quite low, 33% against 70-80%, when compared with non-IT services (King, W.R., 2001). Besides, the authors mentioned that the social factors were also quite important while choosing the vendor such as vendor’s prestige, because it could damage the brand value of the company. Trust was another important factor, since losts of company entrusted precious knowledge to their vendors.

One of the appealing reasons for companies to outsource is known as the low costs, and for many companies this is achieved by reaching an agreement with a vendor from a

foreign country where the salaries are lower. It was noted that, additionally to the cost advantages, offshore vendors were in a more competitive environment and that made them follow technological innovations better, learn from their mistakes, improve themselves and create considerable value to their clients' business (Shao, B., David, J.S., 2007). However, the cultural adaptability should also be taken into account which's affects were felt strongly with the becoming popular trend of outsourcing from overseas countries. Despite being cost-effective, the distance and the differences between working cultures could make the disagreements hard to solve, and could have negative consequences.

In addition, the discrepancy between the approaches of the vendor and the client was cited as a key subject to take over. The basic difference was about the expectation of a project, clients were more focused on the future and looked for long-term relationships by considering opportunities whereas vendors were interested in gaining revenue, supporting when there was a problem with the aim of quick sales. Also, Cisco's "core versus context" model was explained. According to that model, the core activities created value for the stakeholders, and it could be destructive for a company to outsource not only the core activities, but also the activities those might have strong relation with them. However, the context was not benefit and close to the core business, and therefore convenient to outsource (Bruno, J., 2002). The IT functions considered suitable to outsource were stated as Human resources, Rayroll, Enterprise Resource Planning (ERP), Financial, Customer relationship management (CRM), Production, Inventory, and Analytics.

In a software development environment, software maintenance is often regarded as a quite item that it generally costs more than a comprehensive project or a change request. Outsourcing software maintenance was investigated by P. N. Robillard, and a Reference Maintanance Process was proposed (Robillard, P.N. et al, 2007). Fives roles included in that process were Request Manager, programmer, software engineer, user, and client. Request Manager was responsible of listing the bugs, deciding the stringency of the problem, and prioritizing them; whereas software engineers checked the list, analyzed it, and new modules were designed. Then, the programmer was responsible for making the

necessary change, and the user which was also mentioned as validator was liable for testing the development. If the tests of the requirements were successful, then configutation manager would deploy the package to the production environment. The importance of the quality management for successful maintenance process was also emphasized, and “reliability, functionality, maintainability, portability, and efficiency” was defined as primary quality crtieria for software quality. Moreover, according to the authors, the domain knowledge was significant for a request manager, software developer, or a tester which could complicate the outsourcing of the process for maintanance.

Security has always been a major issue in Information Technologies, and it also critically important in IT Outsourcing. A two-phased approach was made by G. Dihillon, R. Chowdhuri, and F. Sá-Soares to specify the security matters among clients and vendors including a Delphi study in the first phase to define security issues, and a depth-analysis (Dihillon, G. et al, 2013). In this study, the huge difference of the parties in defining the security in IT oursourcing was stressed. For data analysis part Schmidt’s method was used, and 11 respondents were elected in that five from vendor side and six from client side. Beginning with the brainstorming phase, each was asked for listing 6 issues including a short definition, later the list was shorten, and finally they ranked 26 issues. Kendall’s Coefficient was used for scoring the issues in which 0.1 was corresponding a weak deal, and 0.9 was meaning a reasonably strong deal. After collecting the respondens’ mean ranking for every issue, it was arised that “information security competency of outsourcing vendor” has the highest importance from a vendor’s perspective, whereas a client considered that issue in the 8th rank. Also, “trust that outsourcing vendor appropriate security controls”, and “ability of outsourcing vendor to comply with the client’s security policies, standards, and processes” were the most significant two issues for the client, however the vendors did not really pay to them. These disagreements indicated that there was room to develop the quality of outsourcing security service by approximating both parties’ approaches to each other, the accordance between their perspectives was essential for a long-term and successful outsourcing relationship. Furthermore, transparency was accentuated as an indispensable issue from a client’s perspective, and vendors should be aware of this fact . Besides, the authors

pointed out that the knowledge management was another subject matter which made retention a major topic to be focused by making the employees satisfied with education opportunities, enhancing the salaries, or offering other benefits.

Another significant part of Information Technologies, which has also great importance in the IT Outsourcing is Requirements Engineering (RE). The meaning of Requirements Engineering is explained as defining the stakeholders which is any individual related to a product/service such as a customer, internal employee, or the programmer and their needs (Nuseibeh, B., Easterbrook, S., 2000). It is important because it is the way of identifying a project's scope which is the first phase and affects all the following steps including the analysis, design, coding, testing, and delivery. Any single issue that is not defined in the scope and experienced in a later phase would be harmful due to the extra time and cost needed. That is why, during the process of identifying the scope, people involved in the project should make sure they spend enough time during the requirements analysis phase. While gathering and deciding the requirements, meeting the conflicting needs of the stakeholders is a challenge of RE. Six basic stages of Requirements Engineering were stated as follows (Sawyer, P., Somemrville, I., 2004):

- Elicitation of Requirements
- Analysing and Negotiation of Requirements
- Requirements Decsription
- System Modelling
- Requirements Validation
- Requirements Management

M.A. Noor et al. made a research to rise notice to Requirements Engineering's value in Software Development Outsourcing, and stated that as a result of the absence or inefficiency of RE; the project would probably to result in a failure due to not providing the anticipated service (Noor, M.A., 2013). The research was made by interviewing people who are SDO experts from different roles including software engineers, programmers, designers, analysts, and managers. 49 practices were selected, and they were evaluated in six groups as stated below (Elicitation of Requirements, Analysing and

Negotiation of Requirements, etc.). Each was ranked with a benefit level of high, medium, low, or zero. Prominence Levels (PL) of each practice was calculated, which showed 43 practices were defined as significant, and prioritizing the requirements was stated as crucial by a very high PL. Considering the prominence of a guhe number of Requirements Engineering practices, the authors underlined that the essential time and effort should be spent for RE to take the advantages of IT outsourcing on a large scale.

N. Venkatraman brought another perspective to IT Outsourcing by looking at IT Resources as a value center (Venkatraman, N., 1997). It was splitted into four parts including service center, investment center, cost center, and profit center. The aim was to maximize the profit and investment centers while minimizing the service center, and cost center.

2.1.2. Advantages and Disadvantages

Although IT Outsourcing is a lot of companies' strategy today, and becoming more and more popular; it can't be said that an outsourcing project is always a right decision that ends successfully. Also, it would be a wrong expression to define an outsourcing agreement as advantageous, because in IT outsourcing projects there are both advantages and disadvantages those should be evaluated very carefully. The primary advantages are remarked as cost reduction, focus on core competencies, providing the flexibility, being adaptable technologically, having higher quality of service, sharing the responsibility. However, there are also many disadvantages such as poor service or product quality, project failures, disputes about the contracts, ineffective vendors, etc. Before taking an outsourcing decision, a company should understand its business very well, know the place in the market and its competitors, describe its business strategy, and identify both its goals and system requirements. After a careful analysis, the company will both know what it aims to accomplish, and what type of characteristics of a vendor is important to it. There are lots of studies in the literature, assessing the advantages, disadvantages and risks in IT outsourcing environment.

P.C. Palvia made an explaratory research interviewing two different people from different companies to judge both positive and negative sides of IT Outsourcing (Palvia,

P.C., 1995). The extent to be outsourced was divided into two categories, one is "operations" part and including data entry and simple processing, contract programming, and facilities management, and the other one is "applications" part containing system integration, and support operations. Being able to check the costs, lower budget spent on the assets and equipment, enhanced tracing of Management Information Systems without taking the responsibility, having the technology easily accessable, and being able to focus on substance competencies were stated as the advantages. Dealing with the complexity with the support of a vendor was also remarked as a positivie side. On the other hand, coordination cost was pointed out a factor needs to be considered. Because, however the the concept behind the outsourcing is summarized with "hand over and forget", the communication between the employees of the client and vendor lasts until the contract is over. One another inconvenience of IT Outsourcing was defined as not being able to follow up the operations and software development quality. Additionally to these drawbacks, the worst side of IT Outsourcing was denoted as the psychology of the employees. It was stated that, after an outsourcing decision was taken, and a contract was signed; the employees of the company generally became nervous and felt insecure which made them look for other job opportunities outside of the company. When there was a lockout, even though some employees' contracts were not terminated; they were afraid of a possible second lockout that might arise in the future. Besides, it was specified that in case of the advantages were not achieved at an expected level; that meant the service cost more than planned. The author suggested a process map including the following steps:

- Outsourcing initiation
- Formation of a task force and goal setting
- Developing and implementing a communications plan
- Requirements formulation
- Initial screening of vendors
- Solicitation of vendor proposals
- Evaluation of proposals
- Negotiating the contract
- Contract implementation
- Contract maintenance

Risk, which can be defined as the probability of the materialization of something in the future which is bad or undesirable (Oxford), is a major factor in IT Outsourcing. Before making an agreement with a vendor, the potential risks should be defined and a comprehensive risk analysis study should be made. H. Barki, S. Rivard, and J. Talbot defined the risk factors of a company as the size of the project, the technical complication, inadequate resources, lack of the domain or general knowledge/expertise of the team, and technological novelty (Barki, H., et al, 1993). The undesired outcomes were stated as software bugs harming the experience or cause the loss of the important data, the bad performance of the features those are not fault-tolerated,the delays arising from the hardware, inadequate memory of the processor, the problems related to the management of Database, bad user interfaces affecting the operation, etc. (Boehm, B.W., 1991). In that study, a risk exposure formulation was proposed as risk exposure equaled to the multiplying the propability of an undesirable outcome with the loss originated by the undesirable outcome.

B.A. Aubert, M. Patry, S. Rivard made an investigative risk assessment research in IT Outsourcing and their work was mainly on defining the risk elements, describing the possible unwanted results; and the relation between the risk elemens and possible unwanted results by integrationg two basic components stressed in the previously shared reference articles (Aubert, B.A., et al., 1998). They explained that debates and trials originated from the false measurements, and not well suited, due to the lack or knowledge or past experience, contracts. Lock-in unwanted outcome was explained as a result of the low number of the vendors in the market. Increased cost of services consequence was also stressed, as arised from the vendor's opportunist approach, insufficient expertise during the planning and agreement phase. Besides, uncertainty and technological interruption might result in costly adjustments, whereas the lack of knowledge of the product/service could result in unforeseen management and transition costs. They also stated that service quality, and service cost were primary factors in IT Outsourcing, and the delays in the response, bad return times, the updates those were not made on time, and the applications did not satisfy the requirements were also unwanted results for an IT Outsourcing project.

K. M. Gilley and A. Rasheed evaluated the affects of outsourcing on the organization's performance experimentally by comparing peripheral outsourcing and core outsourcing (Gilley, K. M., Rasheed, A., 2000). They explained that outsourcing concept was formed by two primary attributes: depth, and breadth. Breadth meant that the percentage of the amount of the outsourced operations to the total amount of the operations, and on the other hand, depth meant the part of the level of the specific outsourced operation. 4 hypothesises were proposed in that study. The first one suggested that "Peripheral outsourcing intensity had a favorable impact on the company's performance". The second one proposed "Core outsourcing intensity had an unfavorable influence on company's performance". The third one suggested the company's business strategy lightened the relations between among the outsourcing intensity and firm performance, which proposed that a cost leader, which means having the lowest prices by decreasing the manufactury costs, each favorable impact of outsourcing on performance would have a direct proportion in the company, whereas for a diffentiator, which can be defined by having the highest prices by offering the unique products or services, any positive affect would have an inverse proportion in the company's performance. The fourth and last hypothesis suggested that environmental dynamism moderated the correlation among outsourcing intensity and company performance so that as dynamism incremented; positive effects of outsourcing on company's performance became stronger, and negative impacts diminished. To measure the accurancy of the hypotheses, two-level survey was materialized. In the first level, top five managers of the companies responded the survey, and in the second level only one manager from each company responded the survey. The dimensions were "outsourcing intensity", "strategic significance of activity", "firm performance", "environmental dynamism", and "firm strategy". Based on the correlations, estimated reliabilities were calculated by coefficient alpha and the hypotheses were interpreted based on them. It was found out that the first two hypotheses were incorrect, because both for peripheral and core outsourcing there was no direct impact of outsourcing intensity to the company perfornmance. Another finding was that the third hypothesis, which was defending that there was a relation between outsourcing intensity on firm performance and the company's business strategy, was only partially correct. Furthermore, the fourth hypothesis was also not supported with the research that it was found the companies would have more profit in consistent environments.

In another study, black box approach was used to evaluate by reviewing 209 application development projects and a vendor-client knowledge conformity assessment framework was proposed to answer “outsource or inhouse” question (Tiwana, A., 2004). To decide how much novel the project was, conceptual novelty including design concept, system design, system functionality, and business application problem domain, and process novelty, consisting of development methodology and software development tools measures were scored. Later, the technical and domain expertise of both the client and vendor were measured to understand the overall situation. The company’s internal technical knowledge was assesed by an elaborate system design, identifying the limitations of the technical design, which programming languages will be used, the expertise on a wide range of methodologies, development procedure’s for test and debugs, and how familiar the team with the software coordination instruments. The vendor’s expertise was evaluated by the business processes, application problem domain, daily business routines, business rules of the system, the aims and expectations from the project, and the familiarity with its own product/service to be outsourced. Regression model was applied to the scores, which had a very high confidence level. The study showed that, when there was a routine project, the client’s business knowledge and the vendor’s technical knowledge could be more balanced. However, when the project was conceptually novel; the business knowledge of the vendor had to be higher, whereas, working with the novel processes the technical knowledge of the client should be considerably high. Also, when there was a novel process, too much business domain knowledge of the vendor could be a disadvantage to the development process due to the blindness. The agile metholodogy or pair programming, which became popular metholodogies after the waterfall were also stated as remarkable for the companies, however it was stressed that beginning to using these methodologies were also process novelties, and the companies should both be well-prepared before starting to use them and evaluate the feasibility of those methodologies due to their interactive attribute.

A goal driven Software Development Risk Manegement Modelling (GSRM) was proposed by S. Islam, A. A. Joarder, and S. H. Houmb which consists of three phases and four layers using Delphi survey process offsore outsourced IT projects (Islam, S.,

Joarder, A.A., Houmb, S.H., 2009). It was stressed that to be able to manage the risk, describing, reviewing, and clarifying the objectives were required, and in the first phase both objectives and risk factors were explored after making a quick company overview of the five vendors those would attend the survey. The company overview included employee number, sharing the portion of the outsourced activity such as coding, testing, maintenance, or overall with a percentage, people those will participate in survey with their roles, and experiences. In the second phase, the risk factors were stated in detail, and in the third phase; the risk factors were ranked in the order of importance. The risk factors were connected to the goals, and top three risk factors were the lack of interference of client in development phases, unsteady requirements, and the low coordination and communication abilities. KAOS goal modelling was used in this study, and the model was constructed on the requirements phase. GSRM was configured based on goals and impediments, and impediments were stated with their reverse impact on the goals. Later, the model evaluated the risks and proposed dealing approach for the risks management. The four layers were goal, risk obstacle, assessment, and treatment layers respectively. In the goal layer, the business aims were identified such as error minimization, estimation for the budget, the grade of the employee those should be accomplished and preserved. The second layer was risk obstacle, which was relevant to the goals and included the adverse of them. In the assessment layer, which was the third layer; the risk obstacles were criticized implicitly and the “likelihood” and “severity” of every risk factor was estimated. The final layer was treatment layer, to address each risk factor with a solution strategy such as hindering, decreasing, refrain, transfer, or seize the risk. It was noted that the first action to a possible risk had to be decreasing its likelihood or the severity of it; however if obstructing it was not possible; then the risk should have been accepted or transmitted, and how to manage it with the lowest negative impact had to be further analyzed.

X.L. Xie and D. Qi investigated software outsourcing with a services science aspect (Xie, X.L., Qi, D., 2011). Services Science Management and Engineering (SSME) is a term presented by IBM, and was identified as “the application of scientific, management, and engineering discplines to tasks that one person, organization, or system beneficially performs for, and with another person, organization, or system (Spohrer, J., Maglio, P.P.,

2008). In that study, software outsourcing project's phases were integrated with services science to improve the process. Software outsourcing stages including innovation, offer, decision-making, start-up, purchase, analysis, design, performance, execution, checking& accepting, maintain, operation, evaluate, withdraw, improve, delivery, and control assessed in terms of service activities and delivery products stating the participating parties such as contractor, service supplier, professional, vendor, project team, and all team. Finally, it was highlighted that services science was a discipline combining several issues and created value for the customers.

R. Gonzalez, J. Gasco, J. Llopis made an experimental study to investigate IS Outsourcing reasons and risks (Gonzalez, R. et al, 2014). The reasons suggested in that study can be listed as "focusing on strategic issues", "increasing flexibility", "improving the quality", getting rid of routine tasks", "facilitating access to technology", "reducing the risk of obsolescence", "saving staff costs", "having alternatives to IT Staff", "saving technology costs", and "following the fashion". Furthermore, the risks were stated as "provider staff qualification", "lack of compliance with the contract by the provider", "dependence", "loss of technical knowledge", "provider's inability to adapt to the new technologies", "hidden costs", "unclear cost-benefit relationship", "security problems", "irreversibility of the decision", "staff problems", and "possible opposition of the staff ". IS executives of the companies were requested to score the importance value of the above shared outsourcing reasons. According to the survey results, "focus on strategic issues" was the leading reason, followed by "increasing IS flexilibility", improved IS quality", "elimination of troublesome problems", and "increased access to technology" top reasons respectively. However, "following the fashion" seemed to have a relatively low importance comparing with the other reasons. The results showed that strategic causes, technological causes, and economic causes were equivalently significant. Considering the survey results about the risk, "provider staff qualification", the provider does not comply the contract", "an excessive dependence on the provider", "loss of critical skills and competencies", and "inability to adapt to new technologies" were stated as most important risks respectively. On the other hand, "staff issues" and "possible IS staff oppoisition" were noted as a notional low importance. Furthermore, when the risks were

assessed by grouping them arised from the client or the vendor, it was indicated that the risks originated from the vendor was much more significant.

Agile methodology should also be mentioned in more detail, to look at today's IT environments in more detail. The traditional waterfall methodology, which has longer phases of the requirements, analysis, design, implementation, testing and deployment phases are not efficient anymore for lots of the companies. The reason behind it is first of all the long periods, and the stakeholders' expectations could change during that time. Another reason is, when there is a bug in the analysis phase, or some of the requirements are missing and that is noticed in the implementation or test phase; that could mean the project should restart from the requirements phase which would cause huge waste of time and money. Agile methodology is more dynamic, the development is splitted in the smaller iterations which are called sprints, and the features, also can be defined as working small parts, are delivered to the customer in quite short time periods. Waterfall and agile methodology are displayed in Figure 1.2 and 1.3 respectively:

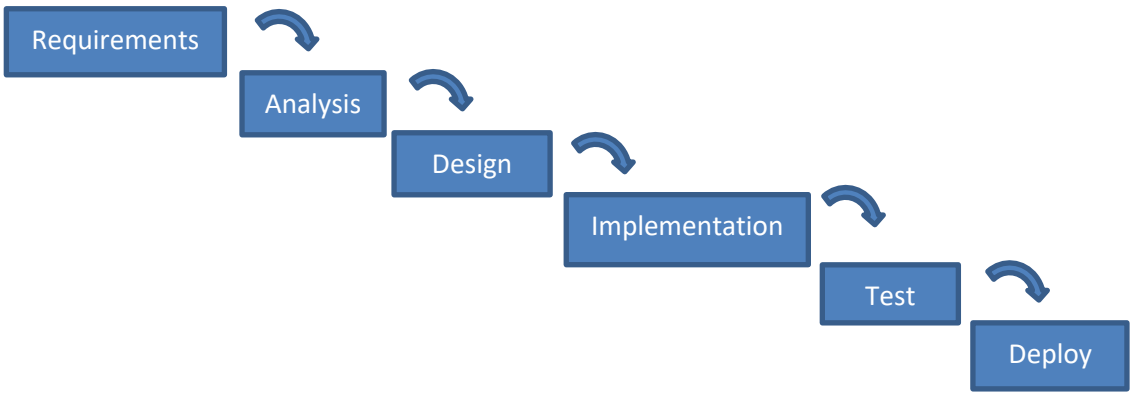
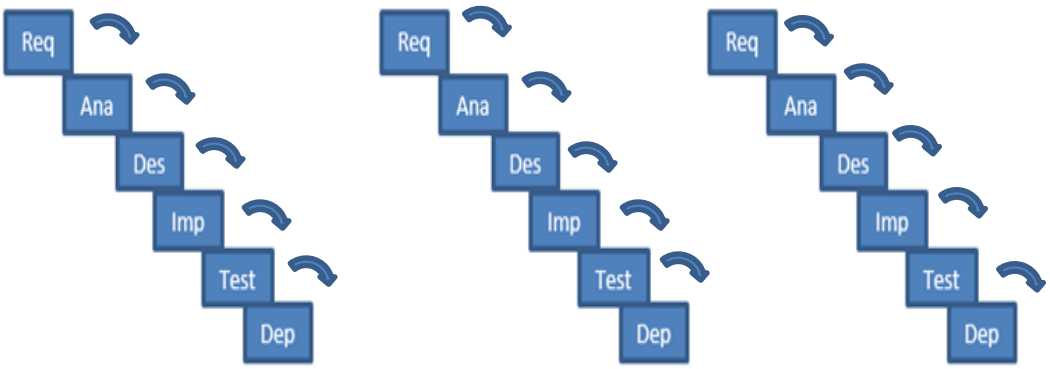


Figure 1.2: Waterfall methodology



Sprint 1 Sprint 2 Sprint 3

Figure 1.3: Agile methodology

Since the satisfaction of both the internal and external stakeholders in IT projects increases by agile methodologies, the vendors also prefer this method frequently. Scrum is another important term, which is a framework for apply the agile metholodogy in the working environment. According the scrum, there is a team including of a product owner, a scrum master, and scrum team members those work with stakeholders. The phases of the scrum is planning, implementation, reviewing, and retrospecting. The sprint duration is approximately between four and six weeks. There is a product backlog consisting of the user requirements, and product owner is responsible for prioritizing those requests. Since the idea of the agile methology is to accomplish delivering the small parts to the customers, epic issues are divided into user stories to obtain quickly developable and testable issues. Sprint planning meeting is actualized in the beginning of the sprint to review the issues with their priorities. Daily scrum is the meeting that is made in the morning and takes fifteen minutes, and each team member talk about what was done the day before, what will be done that day, and what are the impediments. The impediments are noted on the board, and are tried to be solved as quick as possible. The advantage of daily meeting is to give the idea to all the team about their colleagues' occupation, and impediments are coped with much more effectively when there is the whole team to provide their suggestions. There are also estimation sessions, developers give estimation to the user stories by using Fibonacci numbers. Burndown chart is used during the sprint to visualize which issues planned were completed. When the sprint comes to the end, there is a sprint review meeting to overview which tasks were completed and which are

not. The final phase of the sprint is the retrospective meeting, in which every team member expresses what was good, what bas bad, and what could be enhanced during the previous sprint. Moreover, courage, focus, commitment, respect, and openness are the scrum values those every individual comply with.

J. Tick and A. Tick made a research to highlight the different aspects of the software outsourcing project, and they explained an "Innovation Hybrid Strategy of IT-Outsourcing Partnership with Enterprises" (IHSITOP) project was funded by the European Union, in which the university students substituted the vendors (Tick, J., Tick, A., 2015). Initially, it was stated that there were three different categories of IT outsourcing when considered historically. The first one was separate development, in which the vendor was responsible of the whole process and delivering the product to the client in the end and the client is not involved in the process, was not preferred frequently anymore. The second one was the mixed development, and the client took place in the analysis phase in the beginning of the project strictly, and make the User Acceptance Testing (UAT) in the end. UAT is materialized by the client by the attendance of the vendor side optionally, with the aim of controlling if the development was made in the direction that was asked for. The client has the right to object during the tests, and when there is a such circumstance, the scope of the project is checked to make sure if the objection is correct and there is a bug, or it is conflicting to the requirements, of a new request that was in included in the agreed requirements in the beginning of the project.
The last type of the outsourcing explained in J. Tick's and A. Tick's study was cooperative development, which was based on agile development methodologies and the client took place in the overall process. In the mentioned project, the students managed a new model based on use cases, and attracted the attention to UML diagrams which stands for Unified Modelling Language. They suggested use case diagrams, business process diagrams, and activity diagrams to be used for a detailed overview of the system, and a quicker development due to the apprehensibility of the system; and keynoted that how important the original model was to decrease the errors. Also, they stated that workflows, including activities, processes, and cases, should be drawn in the analysis phase before the development began. A 1:1 mapping was proposed to visualize every single activity and their relations with each other, and while preparing these diagrams;

simplicity and preciseness were the attributes those had to be complied. Besides, it was emphasized that diagrams were not only important for better user interfaces, but also for a more efficient use of databases (by class or business object diagrams), and more accurate processes.

J. Stark, M. Arlt, D. H. T. Walker described six dimensions for companies to be able to select the best outsourcing model (Stark, J., 2006). Activity dimension was the first one expressing the activity to be outsourced such as a project, program, portfolios including projects or programs, and operations or business processes. The second dimension was geographic consisted of on-shore outsourcing with a local, regional or national company or an off-shore outsourcing with a global company. The third dimension was the legal entity that could be in the corporation but with another legal entity, or outside of the corporation. The fourth dimension was distribution, displaying the level of outsourcing which could be fully in-house, halfly in-house and halfly outsource, or fully outsourced. The engagement-temporal dimension was about categorizing the approach to the project. The final dimension was mobilization- demobilization, giving the possibilities of a re-entry. The authors highlighted that a lot of strageies can be obtained by associating dissimilar dimensions, and to choose the best strategy a careful decision process had to be performed which was displayed below:

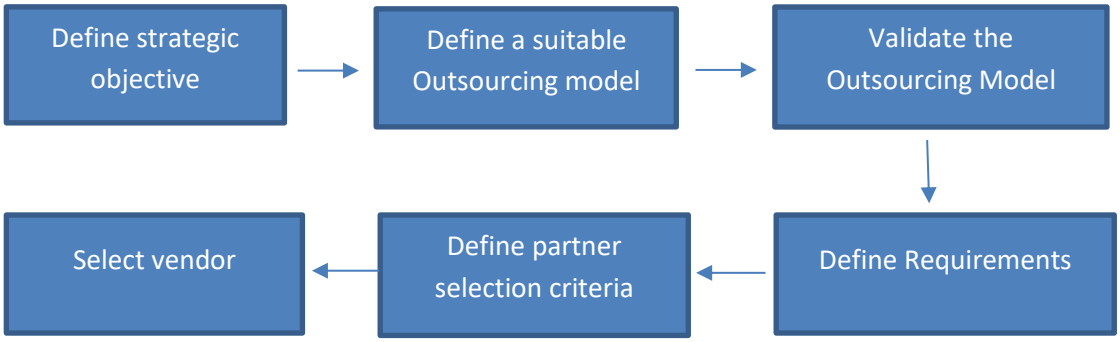


Figure 1.4: Decision Process of IT Outsourcing

It was also noted that formerly decided performance metrics should be tracked during the contract period, and exit scenarios should also be included in the agreement so that in a possible failure; the contract could be cancelled.

Z. Haiwei and W. Xiquan made a research in China by conductiong interviews with five large software outsourcing companies (Haiwei, Z., Xiquan, W., 2009).

2.2. MCDM& IT Outsourcing

The purpose of Multiple Criteria Decision Making is to help the decision-maker to choose the best alternative based on the important criteria evaluation. Individuals make decisions both in their daily lives such as deciding the route so go somewhere or choosing a product to buy from a market, and at the times those can be referred as milestones in their lives like choosing their profession. Generally people make their personal decisions instinctively, based on their past experience and feelings. However, in academy and in industry decision making techniques are applied to choose the best alternative. "Determining the criteria and alternatives", "attaching the numerical measures to the relative importance of the criteria and to the impacts of the alternatives on these criteria", and "processing the numerical values to determine a ranking of each alternative" are three main steps of performing a decision making technique (Triantaphyllou, E., 2000).

MCDM is mostly used in vendor/supplier selection in both public and private organizations. Determining the attributes to interpret and compare the alternatives based on is the substantial part of MCDM process. A comprehensive study on the analysis of vendor selection was made by Gary W. Dickson (Dickson, G.W., 1966). He analyzed 23 factors for purchasing 4 different products including desk, computer, paint, and art work. He calculated mean ratings of each factor and the consequences of his investigation showed that the quality is the most significant factor and the factors coming after that in terms of importance are delivery, performance history, warranties& claim policies, production facilities and capacity, price, technical capability, and financial position respectively. He indicated that the reputation is the only intangible factor needs to be paid attention. Furthermore, he demonstrated that the consideration of the price decreased when the complexity of the product increased. He also pointed out that the type of product or service to be outsourced is quite critical while deciding the attributes to evaluate which makes a general analysis technique for vendor selection hard.

S.H. Ghodsypour*, C. O'Brien proposed a supplier selection method integrating AHP and linear programming by approaching this problem with three main criteria; cost, quality, and service (Ghodsypour, S.H., Brien, C.O., 1996). Their research provided a systematic and objective approach for the supplier selection, and also expressed in addition to the tangible factors, the intangible factors should also be a part of the assessment. Multi Criteria Decision Making process is displayed in Figure 1.5:

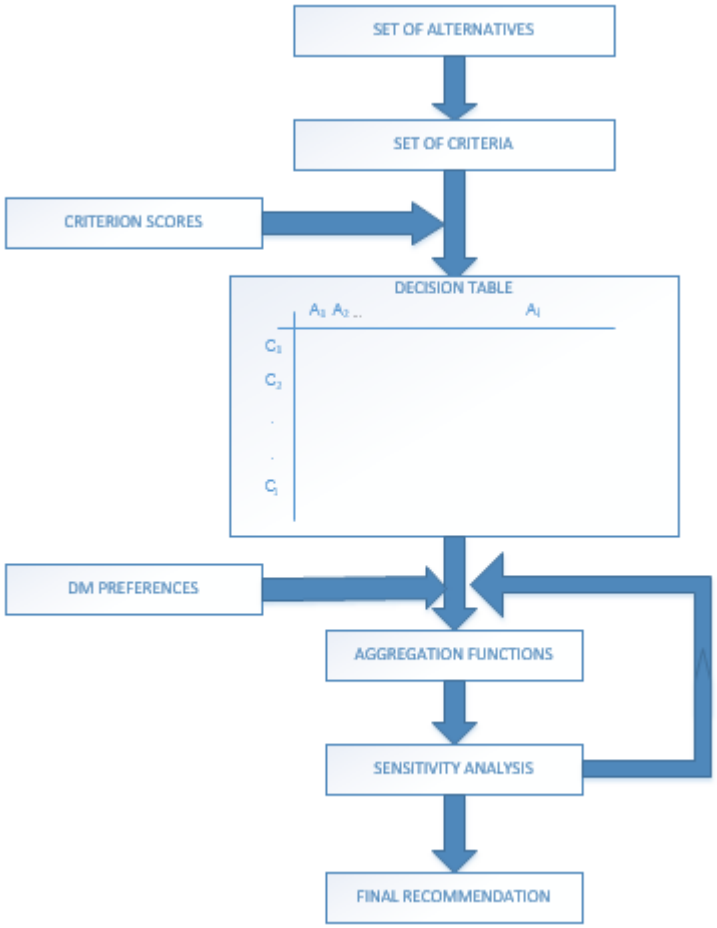


Figure 1.5: MCDM Process (Ghodsypour, et al., 1996).

Three basic patterns of logic are stated as based on simple ordering, human goal-setting behavior, and value maximization. The first pattern, which is based on a simple ordering assumes that there can't be a better alternative in any other aspect, which is also the basis of Pareto optimality. The second logic pattern is based on human goal-setting behavior, and leading to compromising solutions. The last pattern is based on value maximization, in which the concept is "the best decision should be the one offers the best value" (Jankowski, P., 1995). Piotr Jankowski made a comprehensive research in 1995,

evaluating geographical information systems and multiple criteria decision making methods together.

The main MCDM techniques are Multi-Attribute Utility Theory, Analytic Hierarchy Process, Analytic Network Process, Fuzzy Set Theory, Case-based Reasoning, Data Envelopment Analysis, Simple Multi-Attribute Rating Technique, Goal Programming, ELECTRE, PROMETHEE, Simple Additive Weighting, and Technique for Order of Preference by Similarity to Ideal Solution (Velasquez, M., Hester, T.P., 2013).

Wang, Gu and Diao analyzed nine factors including price, location, flexible contract terms, cultural match, reputation, existing relationship, commitment to quality, scope of resources, added capability with a mixed Analytic Hierarchy Process(AHP) and Preference Ranking Organization Methods for Enrichment Evaluations (PROMETHEE) method for supplier selection (Wang, J.J., Gu, R., Diao, X.J., 2008).

MCDM has been used in Information Systems for a long time. In 2000, Yan and Huang developed a decision model using AHP which uses management, strategy, economics, technology, and quality as main criteria (Yang, C., Huang, J.B., 2000). AHP is a well-known MCDM technique that was developed by Saaty in 1980, as an efficient tool to cope with uncertainty by setting priorities to be able to decide the best alternative. It transforms the qualitative and quantitative criteria assessment of decision maker into a final order utilizing a hierarchic structure (Saaty, T.L., 1980). By pairwise comparisons, the confusing decision problem is divided into minor sub-problems. A matrix is created including the criteria both in lines and columns, and numbers from 1 to 9 are used to show the relative importance among determinants. 1 shows equal importance, and 3 shows a slightly superiority of an attribute over another; whereas 5 is strong importance, 7 is very strong and 9 is absolute importance. The even numbers are also used to display the intermediate values. The diagonal in that matrix equals to 1 which includes same criteria in the line and column. After that, priority vector is obtained by normalization and consistency tests are applied to the given values to measure how much logical the evaluation is. In the decision model Yan and Huang proposed, after defining the criteria and sub-criteria weights, three alternatives were chosen in the second phase as facilities management, maintenance of management of information system, and new systems

development where maintenance of management of information system specified as the leading alternative.

N. Venkatraman identified the concept of a value center for Information Technologies Resources, including Cost Center, Profit Center, Service Center, and Investment Center components (Venkatraman, N., 1997). He pointed out that managing IT resources accurately based on those values also enable IT outsourcing to be successful. M.Buck Lew emphasized the difference between hybrid outsourcing and pure outsourcing Information Systems functions (Lew, M.B., 2002). He also pointed out that the functions those will be outsourced should be selected after careful consideration based on the company's business and organizational factors, and technical background.

2.3. EDAS Method

The EDAS method stands for Evaluation Based on Distance Average Solution, and it is a MCDM method that has been developed lately. It was originally suggested by Ghorabaee and his friends, with an experimental study in which EDAS method is compared with the other MCDM techniques to prove it is a valid method (Ghorabaee et al., 2015a). While evaluating the alternatives, the EDAS method considers the average solution.

Firstly introduced by Ghorabaee et al. (2015a), EDAS was proposed as a suitable method for multi-criteria inventory classification (MCIC) problems. EDAS method's results was parallel to the results obtained by previously used methods, in ABC classification of inventory items. Moreover, the authors came up with that the suggested method could also be used for MCDM problems. EDAS method was compared with other MCDM methods including VIKOR, TOPSIS, SAW and COPRAS, and its effectiveness was tested. Spearman's correlation coefficient was used while examining the crosscheck results. The results showed that EDAS method is stable with different criteria weights. Besides, it is consistent with other methods since the similar results were achieved with existing MCDM methods.

EDAS method was extended by Ghorabaee et al. (2016) extended with fuzzy logic and linguistic terms. Their corresponding trapezoidal fuzzy numbers were used to expand the EDAS method in fuzzy environment. To prove the efficiency of the suggested model, a supplier selection problem of a detergent producer was eventuated. Then, the weight of the sub-criteria was altered for the sensitivity analysis. The indicated result was how consistent and efficient the fuzzy EDAS method was in solving MCDM problems.

EDAS method was integrated with the neutrosophic cluster method by Peng and Liu (2017). It was combined with the single-valued neutrosophic numbers, in a study which investigates the selection of a software development project for an internet company. Additionally, objective weights were integrated with subjective weights. Consequently, a similarity formula and a new axiomatic definition of single-valued neutrosophic similarity measure was constructed. Also, it was the first time that a recent single-valued neutrosophic soft approach in MCDM based on EDAS was investigated.

Kahraman et al. (2017) improved an intuitive fuzzy EDAS method by integrating the EDAS method with an interval-valued intuitionistic fuzzy numbers. This method has been used in the evaluation of solid waste disposal sites. To solve the problem of solid waste disposal site selection, three different forms of EDAS method was used; crisp EDAS, ordinary fuzzy EDAS and interval-valued intuitionistic fuzzy EDAS methods. Besides, a sensitivity analysis was performed to demonstrate the robustness of the decisions those were acquired via the proposed intuitionistic fuzzy EDAS. As a conclusion, it was stated that because the uncertainty contained by trapezoidal fuzzy sets and interval-valued intuitionistic fuzzy sets are originally different, the generated rankings might vary from ordinary fuzzy EDAS (OF EDAS) to intuitionistic fuzzy EDAS. It was proposed to use different ranking equations in OF EDAS and IVIF EDAS.

Interval type -2 fuzzy sets and EDAS method were combined by Ghorabaee et al. (2017). The suggested method was used to evaluate the subcontractors in the construction sector. To confirm the results of the method, a comparison with some existing methods and a sensitivity analysis were applied. As the previously explained researches, this study also

proved that the results of the extended EDAS method were consistent with the other methods and also had a decent stability in different sets of criteria weights.

Another research was made by Stanujkic et al. (2017), who associated gray numbers with EDAS method; which was the emergence of EDAS method based on the use of interval grey numbers. The model was utilized in the selection of contractors for a construction project. The suggested approach's usability was approved by checking the results on a previous MCDM example (Zavadskas et al., 2009).

The extended EDAS method was uitilized by Juodagalvienė et al. (2017), based on the use of interval grey numbers for selecting a single-family house's plan shape. SWARA method was implemented to assign relative importance of the criteria and EDAS method was used for ranking the alternatives. In the end, the usability and efficiency of the proposed approach were controlled on a previously solved MCDM example. After the comparison, the propoed method was proved as being usable.

Ecer (2018), combined Fuzzy AHP and EDAS to put forward an integrated FMCDM model and confirmed this model by a case study for the selection of 3PLs providers. Ctieria weights were calculated by using Fuzzy AHP, and EDAS was applied for prioritizing 3PLs providers. A sensitivity analysis was also made to assess the proposed model results more carefully. The results showed that the proposed model was an effective decision making tool for exhaustive evaluation of 3PLs provider based on the opinion of experts under fuzzy environments.

A new approach was proposed by Karabasevic et al. (2018) based on the EDAS method with the aim of personnel selection. The SWARA method was utilized in order to specify the weights, while the EDAS method was applied for ranking the alternatives. The efficiency of the suggested EDAS approach was considered in the conducted empirical application of the proposed model for the selection of IT Business Systems Support (BSS) Experts. Based on the conducted empirical application of the proposed model, it was verified to be an effective, adjustable and an easy to use method in personnel selection.

CODAS, EDAS, WASPAS AND MOORA are the methods those were developed recently, and Mathew and Sahu (2018) applied these MCDM methods, i.e., in material handling equipment selection problem. Both a conveyor selection problem and an automated guided vehicle selection problem with conflicting criteria were solved with this methods. Besides, Spearman rank correlation coefficient was calculated between the ranks obtained by these methods. Additionally, the ranks obtained by various methods were compared with the ranks of other MCDM methods and it was discovered that the relatively new methods CODAS, EDAS and WASPAS had good stability within each other. Finally, CODAS, EDAS and WASPAS methods were proved as being effective in solving material handling equipment selection problem.

Stević et al. (2018) improved a fuzzy EDAS application method to select the most appropriate manufacturer of PVC carpentry for the apartment refurbishing. After obtaining the results, a sensitivity analysis was performed to interpret the stability of the model. In conclusion, based on the conducted sensitivity analysis, the results were stable and that the model gave the best solution for manufacturer of PVC carpentry for the apartment refurbishing.

3. PAYMENT SYSTEMS DOMAIN

In this chapter the payment systems will be explained with giving details about transaction types, transaction channels, security standards, loyalty programs, and so on. However, it is important to note that since the research topic of this thesis is to select an online service provider; transactions made from physical POS or ATMs are out of scope, and only Card Not Present (CNP) transactions will be described there. A CNP transaction is performed through internet, phone, or email in which the cardholder doesn't use the card physically. The card types used in CNP transactions are debit cards, credit card, and prepaid cards.

3.1. Payment Systems Explanation

Although about 85- 90% of the transactions are still cash today, the payment world is becoming more digitalized every day. Visa and MasterCard are still the biggest payment institutions, aiming to decrease the cash transactions and making people prefer card transactions more both in virtual and physical environments. The time's value, the companies' improved delivery services, the easiness of refunds and the technological innovations push individuals make online purchases more and more. That makes a strong Virtual Payment Gateway infrastructure a major issue for the banks and merchants.

A standard authorization process of an online transaction is shared in Figure 2.1:

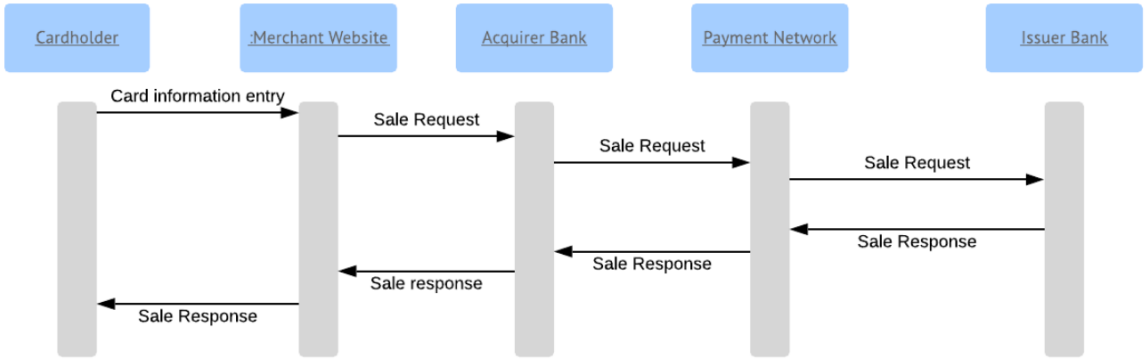


Figure 2.1: Authorization flow

It starts with the cardholder's card information entry in the checkout page. Merchant website creates a sale request message including card data (Card Number, Expiry Date, and Cardholder Verification Value (CVV)), transaction amount, and currency; and then sends it to the Acquirer Bank. Acquirer Bank is the bank which has the merchant's bank account. After receiving the sale request, acquirer bank checks the CARD BIN (Bank Identification Number) and decide the card scheme (brand). Depending on the brand, Acquirer Bank sends the sale request to the card network. Today Visa, MasterCard, Amex, JCB, MIR, Diners, Discovery are the well-known card brands. After receiving the sale request, the network forwards the sale request to the Issuer Bank by checking card BIN. Issuer is the cardholder's bank, and decides the transaction result by checking if the card number, expiry date, and CVV is valid or the card limit is enough for that transaction. Also, that card may be a stolen card; or that transaction might have fraud risk, which means the transaction is not made by the real cardholder but someone else. After all this evaluations, Issuer Bank determines the transaction result, and sends the response message to the Payment Network. Payment network forwards the transaction result to the acquirer bank, and acquirer bank proceeds by sending the response message to the merchant. After receiving the transaction result, the merchant displays successful or fail order page to the cardholder. And this process takes only a few seconds.

3.1.1. Transaction Types

Sale:

Also called as authorization, it is a financial transaction type that is performed by the cardholder's card number, expiry date, and cvv information. The message is initiated by the cardholder and transmitted to the Issuer Bank by the other parties including Payment Service Provider, Acquirer Bank, Card network. Then the issuer checks the below concerns:

- Is it a lost/stolen card?
- Is the Card Number valid?
- Is the Expiry Date correct?
- Is the CVV value correct?
- Is the card limit enough for that transaction?

After evaluating the transaction based on the shared matters, the Issuer Bank creates a response message with approval or rejection status. Also, sale is a primary transaction since it does not have any record in the past.

Pre-authorization:

A non financial transaction making a limit reservation. The aim is to check if the card limit is enough for that transaction, and if it is that the merchant reserves that limit to turn it into a financial transaction in the future. This transaction type is generally preferred by travel agencies and leasing companies. Pre-authorization is also called as a primary transaction.

Post- authorization:

It is a financial transaction materialized with the previously made pre-authorization record, which makes it a secondary transaction. The merchant sends a post-authorization transaction request including the order record, and the Issuer Bank checks is the pre-authorization transaction is still valid, if it is then approves the post-auth transaction. This transaction is launched by the merchant.

Refund:

It is the return of the previous successful financial transaction, also decided by the Issuer Bank. It is eventuated after the money is transferred to the merchant's bank account. After the Issuer's approval, the transaction amount is deposited to the issuer's bank account in a specified time interval based on the merchant's agreement with the Acquirer Bank. Refund transaction is initiated by the merchant based on cardholder's request. For the return of a speficic amount of the transaction, partial refund transaction is performed.

Void

It is the reverse of a previous successful financial transaction, and the transaction result is decided by the Issuer Bank. It is also initiated by the merchant after the cardholder's application. Furthermore, the difference between a refund and void transaction is; void is eventuated before the money transfer.

Settlement

Also called as end of day, it is a transaction aiming to control the successful transactions performed in that day. It is performed everyday regularly between the merchant and acquirer bank at a certain time, usually around midnight, and the merchant sends the total amount of all sale, pre-authorization, post-authorization, refund, and void transactions. The bank checks those total amounts with the records on its side. If all the amounts are equal on both sides, then the settlement response is returned as successful. After the successful settlement transaction, the money is transferred to the acquirer bank's account from the issuer's bank account. If there is a contradicting amount; then settlement response is returned as unsuccessful by the acquirer bank. Then the merchants send the batch upload message.

Batch Upload

It is a list of all the transactions performed at the specific day. The objective of this message is to find out the differences on the transaction records and update the mismatchs. One side is decided as base, and the changes are made according to that side.

Installment Sale

It is an authorization transaction with the installment campaign. All the installment amounts and the dates of all the transactions are sent to the Issuer Bank by the Acquirer Bank. The Issuer makes the first payment at the transaction time, and saves the other installments to the cardholder's account as awaiting payment for following months. The installment options are generally provided by the card BIN (Bank Identification Number).

Bonus Sale

Also called as point sale, it is another transaction with a campaign. The points available is decided based on card number. A sale transaction can be a full point sale or partial points sale in which the remaining amount is paid from the cardholder's credit account.

Inquiry

Inquiry transactions are materialized to learn either the result of a previous transaction or the supported installment or bonus options for the card that will perform the transaction.

Recurring Payment

It is a sales transaction with more than one installments and approved or rejected by the Issuer Bank. However, it does not reserve the whole amount from the cardholder's account. Instead, it is performed as a new sale transaction each month or year. Membership payments is an example to the recurring payment transactions.

3.1.2. Transaction Channels

The Card not Present transaction channels are explained below, and today's payment world mostly favoured channels are API for e-commerce transactions, and Gate channel for 3DSecure transactions.

Mail Order Telephone Order (MOTO)

MOTO transactions are made by the merchant's entry of card information including card number, expiry date, and CVV after learning it via telephone or email. Transactions performed through MOTO channel are regarded as Card on File transactions since the merchant has the access to the card information, and they are not used frequently.

Application Programming Interface (API)

API transactions are eventuated when the cardholder enters the card information on the merchant website. Also called as E-commerce, those transactions are host-to-host which means sending the transaction request and receiving the transaction response from backend. The successful or failure result page of the merchant website is displayed to the cardholder without redirecting the cardholder to another page. Moreover, a user or merchant can also be created from API channel.

Gate Channel

In gate channel, the transaction is performed by HTTP post which means that there is a redirection, and the card information is received from cardholder in another web page that does not belong to the merchant. This can be a Hosted Payment Page of a payment service provider company, or an alternative payment method's web page. This channel is used when a 3D secure transaction will be performed which requires the cardholder's redirection to another page to enter the static or dynamic verification code for the Issuer Bank's authentication. Additionally, the merchant might prefer not to make an integration with the specific payment method; and redirects the cardholder to the PSP with an HTTP post giving the transaction information including the amount, currency, time, and payment method excluding the card information. The cardholder enters the card information in the web page it is redirected to, and the transaction result is returned to the merchant and the merchant shows successful or unsuccessful transaction result page.

File channel

File transactions are performed by the file upload of the merchants. The transaction type, transaction amount, currency, and card information are included in those files. It should be noted that this is a very rarely performed transaction type.

3.1.3. 3D Secure Process

3D (Domain) Secure process, which was introduced by Visa with the name "Verified by Visa" in 2002 to prevent fraud in online transactions. Three domains are Acquirer Domain, Interoperability Domain, and Issuer Domain including Merchant Plug-in (MPI), Directory Server (DS), and Access Control Service (ACS) additionally to the Merchant Website, Acquirer Bank and Issuer Bank. 3D Secure's aim is to authenticate the cardholder, and it is performed by a static password, or a dynamic password that is generated during the payment process. 3D Secure flow starts with the cardholder's card information entry at the checkout page in case merchant website supports 3D secure. Merchant website sends the transaction to Payment Service Provider (PSP), and PSP sends it to MPI. MPI is the component which creates and sends the Verifying Enrollment Request (Vereq) message to DS. Based on Card BIN received in the vereq message, DS directs the transaction to Issuer ACS. ACS checks if the card is enrolled in 3D Secure or not; and if included then sends also ACS Url in Verifying Enrollment Response (Veres)

message to DS. Veres is directed to MPI by DS, and MPI creates Payer Authentication Request (Pareq) message and redirects the cardholder to ACS page for the authentication. Cardholder authentication takes place in ACS page, and ACS returns the Payer Authentication Response (Pares) message to MPI. Then, MPI sends the 3D Authentication result to merchant. After the completion of the authentication process, merchant proceeds with the authorization.

Three important values generated in the 3DSecure process are shared below:

- *CAVV (Cardholder Authentication Verification Value)* is a term introduced by Visa, the corresponding value presented by Mastercard is Accountholder Authentication Value (AAV), and that is a transaction identifier which is a base64 encoded 28 character length value generated by the Issuer. CAVV/AAV value obtained at the authentication process must be sent in the authorization message to prove that before the sale transaction, there was an authentication process. If the merchant sends this value in the authorization message, then it has the application right for a chargeback.
- *ECI (Ecommerce Indicator)* demonstrates the security level of authentication transaction. It should be mentioned that ECI values assigned by Visa and Mastercard differs. It is also generated by the issuer, and should be sent in the authorization message.
- *XID (Transaction Id)* is another transaction identifier which is unique and decided by the merchant.

When the cardholder enters that password in the authentication page, Issuer Bank confirms the transaction is made by the real cardholder; and becomes liable of the transaction. Liability means being responsible of the chargeback, in case of fraud.

Since the technology and our lives have changed dramatically since 2002, 3DSecure version 1.0 is insufficient in a lot of aspects. The disadvantages of 3DSecure version 1.0 are listed below:

- The confusing workflow (decreases the conversion)
- Incompatibility with mobile devices
- Shortage of seamless integration

- A small number of authentication methods available
- Restricted frictionless flow ability

EMVco, which is an institution owned by Visa, American Express, Mastercard, Discover, JCB, and Union Pay, declared 3DS Secure version 2.0 in 2016 as with the improvements listed below:

- Application based purchases on mobile or other smart devices
- Enhances customer experience by risked based decisioning
- New authentication types like biometrics
- Non-payment messages such as adding card information to e-wallet

The first point 3D Secure 2.0 differs from 3D Secure 1.0 is the components. MPI is renamed as 3DS Server, and merchant payment gateway is mentioned as 3DS Requestor in 3DS 2.0. The messages are also different, and instead of vereq, veres, pareq, and pares there are AReq, ARes, CReq, CRes, RReq, and RRes. Frictionless flow, also called as risk based authentication, does not involve cardholder interaction and it is decided by evaluating the transaction data supplied by the merchant. The IP, billing or shipping address, the amount, the product/service to be purchased, the time can be exemplified for the data to be analyzed.

Table 2.1: Authentication Results of 3D Secure

User Interface Information	VERes Status	PARes Status	CAVV/AAV	ECI Visa	ECI Mastercard	Description
Merchant not Securecode-enabled	-	-	-	-	-	Merchant not Securecode- enabled
DS Error	Error	-	-	7	-	The merchant was unable to provide the appropriate credentials to the Directory Server
Not Eligible	U	-	-	7	-	Unable to Authenticate
Not Participating	N	-	-	6	-	Cardholder Not Participaing
3-D Secure Error	Y	Error	-	-	-	PARes validation failed. Merchant should not submit authorization request
3-D Secure Failed	Y	N	-	-	-	Authentication Failed. Merchant should not submit authorization request
3-D Secure ACS Error	Y	U	-	7	-	The issuer ACS is not able to complete the authentication request
3-D Secure Attempt	Y	A	No	-	01	-
Full 3-D Secure Attempt	Y	A	Yes	6	01	Merchant attempted to authenticate the cardholder, but either the cardholder or issuer is not participating
3-D Secure Successful	Y	Y	No	-	02	Authentication Successful without AAV
Full 3-D Secure Successful	Y	Y	Yes	5	02	Authentication Successful

3.2. Payment Domain Standards

3.2.1. PCI DSS and PA DSS

PCI DSS (Payment Card Industry Data Security Standards) and PA DSS (Payment Application Data Security Standards) are the two basic standards in payment industry. PCI was emerged by a council which is the aggregation of Visa, Mastercard, American Express, JCB.The objective of PCI is to ensure card transactions are secure, and toprevent fraud transactions. All the parties of payment process containing merchants, banks, and payment service providers have to be compliant with PCI; otherwise they can't process transactions. If a company is responsible for its own payment application, it needs to be compliant with PCI DSS. However, once that application is used by the third parties; then PA DSS compliance is also required.

PCI DSS standards are shared below:

- Firewall Management
- Vendor Default Controls
- Data Protection
- Data Transmission Encryption
- Anti-virus Controls
- System&Application Security
- Data Access Controls
- Personal Access Controls
- Physical Access Controls
- Data&Network Access Controls
- Security Testing
- Information Security Policy

PCI DSS compliance process starts with an assessment in which a gap analysis is performed by investigating how the card transactions are processed, how the data is stored, what kind of information of cardholder is stored, what are the risks of third parties' obtainment of card information. Then the process proceeds with Remediate process, in which enhancements are performed. The vulnerabilities are debugged by development, or workaround, and it is ensured that the cardholder data is not used

unless required. The final stage is Report, and that is given based on audit standards in precise periods. Also, the level of the company is decided based on the number of processed transactions in a year.

According to PCI DSS, account data is divided into two groups as cardholder data and sensitive authentication data (PCI Security Standards Council, 2013). Cardholder data includes Primary Account Number (PAN), Cardholder Name, Expiration Date, and Service Code whereas Sensitive Authentication Data includes Full track data (magnetic stripe data or equivalent on a chip), CAV2/CVC2/CVV2/CID, PINs/PIN Blocks.

PA DSS requirements are listed below:

- Do not retain sensitive data (CAV2, CID, CVC2, CVV2, PIN)
- Protect stored cardholder data
- Provide secure authentication features
- Log payment authentication features
- Develop secure payment applications
- Protect wireless transmissions
- Test applications to address vulnerabilities
- Facilitate secure network implementation
- Do not store cardholder data on a server connected to the Internet.
- Facilitate secure remote access to payment application
- Encrypt sensitive traffic over public networks
- Encrypt all non- console administrative access
- Maintain a PA DSS Implementation Guide for customers, resellers, and integrators
- Assign PA-DSS responsibilities for personnel, and maintain training programs for personnel, customers, resellers, and integrators

Because of PCI and PA DSS standards, the account data is able to be stored encrypted in Database. There are encryption algorithms, to obtain the encrypted data. The most popular encryption algorithms are Triple DES, RSA, Blowfish, Twofish, MD5, and AES.

When there is an encryption, the obtained data is reversible, which makes storing the data secure, and displaying it in report screens or export files is also possible. The visible and encrypted forms of a data as integer and character is displayed below:

Input data: Test
Output data: 19:xy9fVEA8D2n/RVyA2qvI3A==

Input data: 45555543567897
Output data: 19:xUyiFLouylt0+ReloLYNhA==

Additionally to the encryption, there is also hash data algorithm. On the contrary to encrypted data, hash data is irreversible. The well known hash algorithms are MD5, SHA2, SHA3, and SHA256.

Hash values are stored in the Database in a separate column, and when there is a search; this value is used. For instance, in a transaction, order, or user search, the specific information is entered in the screen and the inquiry is performed. Then the hash of the entered value is calculated; and searched in the hash column in database. When there is a match, that record is displayed in the screen. Hash algorithm working flow is showed in Figure 2.2:

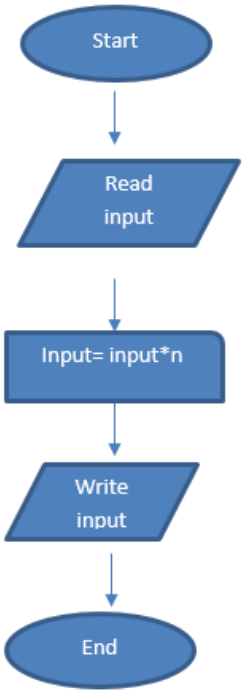


Figure 2.2: Hash Value Calculation

When there is a connection between two parties and the transaction data is processed in that line, sending encrypted data is also a key to the security standards. The key pairs are used to enable the data to be decrypted by the other party. Private- public key pair is the most widespread way of encryption. Verifying the certificate is displayed in Figure 2.3:

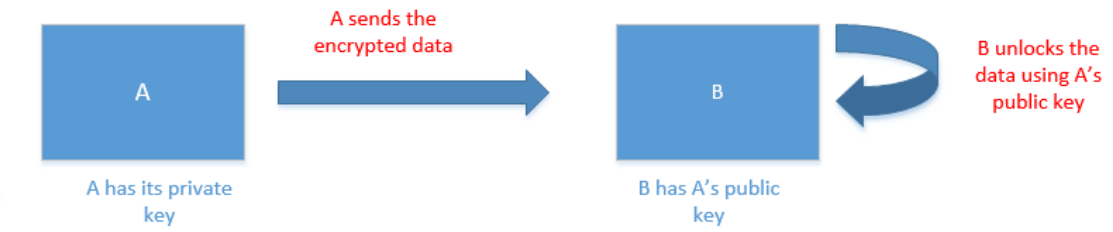


Figure 2.3: Certificate Validation Process

3.2.2. ISO8583 Standard

ISO8583 is a global standard introduced by International Organization of Standardization for payment transactions made with credit and debit cards from virtual POS, physical POS, or ATMs (Automated Teller Machines). The data belongs to the request and response messages are exchanged based on this protocol. It can be considered as a transaction is splitted into small pieces and sent the other party, and that party obtains the complete message by combining the small pieces in the correct order. The base of Mastercard and Visa authorization messages are ISO8583, and other card schemes also use this. Messages consist of message type, one or more bitmaps, and data elements.

- *Message type* includes four digits, the first one displays the ISO8583 version either 1987, 1993, or 2003. The second digit is the message class, such as sales or reverse. The third digit shows the message function if it is a request or response message. The last digit shows the message origin as acquirer or issuer. A message type indicator equal to 0110 demonstrates that the message version is 1987, and it is an authorization response message sent by the acquirer.

- *Bitmap* can be one or more in a message, and it is a 16 hexadecimal character value indicating that how many data elements are sent in that message. A messae can include both primary bitmap and secondary bitmap, as displayed below:
  priBitmapReq: 00703c0580 e18014
  secBitmapReq: 00 00
  0000111000000111100000001011000000011100001100000000000010100
  (toplam 64)
  which demonstrates that Fields 1, 2, 3, 4, 11, 12, 13, 14, 22, 24, 25, 41, 42, 43, 48, 49, 60, and 62 are sent in the message.
- *Data elements* include the transaction data such as card number, expiry date, transaction amount and currency, transaction date and time, the merchant id, etc.

Data types are listed below:

  - Alpha: fix length char and digits
  - Numeric: fixed length numbers
  - Llvar: numbers and the length is variable
  - Lllvar: alphanumeric, the length is variable

In both llvar and lllvar data types for which the length is variable, the field starts with a two or three digit indicating the length of the value. Also, if the data is shorter then it should be, then the field should be filled by space or zero; otherwise the field slips and all the field of the message can be mixed.

Table 2.2: ISO 8583 Message Fields

Field Number	Data	Data Type	Length Format	Length
MTI	Message Type	numeric	fixed	4
1	Bitmap	alphanumeric	fixed	8
2	Primary Account Number	numeric	llvar	19
3	Processing Code	numeric	fixed	6
4	Transaction Amount	numeric	fixed	12
6	Cardholder Billing Amount	numeric	fixed	12
7	Transaction Data and Time (MMDDhhmmss)	numeric	fixed	10
11	STAN (System Trace Audit Number)	numeric	fixed	6
12	Time (hhmmss)	numeric	fixed	6
13	date (MMDD)	numeric	fixed	4
14	Expiry Date	numeric	fixed	2
22	POS(Point of Service) Entry Mode	numeric	fixed	3
25	POS Condition Mode	numeric	fixed	2
37	RRN (Retrievel Reference Number)	alphanumeric	fixed	12
38	Authorization number	alphanumeric	fixed	6
39	Response code	alphanumeric	fixed	2
41	Terminal ID	alphanumeric	fixed	8
42	Merchant ID	numeric	fixed	15
48	Additional Data	alphanumeric	lllvar	999
49	Currency Code	numeric	fixed	4

A sample ISO8583 message is shared below:

priBitmapReq: 703c0580 e18014
secBitmapReq: 00 00
adding field 1 : 0220
adding field 2 : 161111 11111111 1111
adding field 3 : 987000.
adding field 4 : 000000010000.
adding field 11 : 000600.
adding field 12 : 093712.
adding field 13 : 0219.
adding field 14 : 0000.
adding field 22 : 0012.
adding field 24 : 0000.
adding field 25 : 59.
adding field 41 : S003TU05.
adding field 42 : 655018729 .
adding field 43 binary data
00 13 72 00 00 00 00 00 00 00 00 00 00 00 00 00
01 03 00 00 00 00 00 20 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00
adding field 48 binary data
03 25 38 4e
adding field 49 : 0949.
adding field 60 binary data
01 36 20 20 20 20 20 49 20 20 20 20 31 49 32 30
49 53 30 45 34 4e 30 30 30 30 20 20 20 20 20 20
20 20 20 20 20 20 20 20 20 20 00 00 00 00 00 ff
ff 35 35 4e 35 36 20 37 32 38 79 6a 70 61 75 62
20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20
20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20
20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20

20 20 20 20 20 20 20 20 20 37 34 30 31 30 2e 30

32 37 2e 31 31 31 2e 30 31 38

adding field 62 binary data

00 80 30 30 30 30 30 30 34 34 00 39 34 35 07 43

36 31 34 33 31 30 34 32 30 33 37 20 20 20 20 20

20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20

20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20

20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20

20 20

Table 2.3: ISO8583 Response Codes and Explanations

Response Code	Message
00	Approved
01	Refer to the card issuer
02	Refer to the card issuer (special condition)
03	Invalid merchant or service provider
04	Pickup card
05	Do not honour
06	General error
07	Pickup card(special condition)
08	Honour with ID
09	Request in Progress
10	Partial approval
11	Approved (VIP)
12	Invalid transaction
13	Invalid amount
14	Invalid account number
15	No such issuer
16	Insufficient funds
28	Original is denied
29	Original not found
30	Format error
36	Restricted card, pickup

38	Allowable PIN tries exceeded, pickup
41	Lost card, pickup
43	Stolen card, pickup
52	No checking account
53	No saving account
54	Expired card
55	Incorrect PIN
57	Transaction not permitted to cardholder
58	Transaction not permitted to terminal
61	Exceeds withdrawal amount limit
62	Restricted card
63	Security violation
65	Activity count limit exceeded
75	Allowable number of PIN tries exceeded
76	Key synchronisation error
77	Repeat/reversal data are inconsistent with original message
78	Unsafe PIN
85	Approval of request-for PIN management message
91	Issuer or switch unkown for routing
92	Financial institution unkown for routing
95	Reconcile error
96	System malfunction
98	Duplicate reversal

Table 2.4: Historical Overview for Payment Systems

Year	Action
1850- 1915	American Express formed Money orders introduced by American Express Credit Letter Company- First credit payment letter Western Union- Payment with telegram
1950-1960	Diners Club Card released The first modern credit card issued- Franklin National Bank Bankamericard launch First plastic AMEX card Japan Credit Bureau(JCB) launched
1960-1970	Interbank Card Association(ICA) foundation First Automated Teller Machine (ATM)
1970-1980	IBM unveils Magnetic stripe (chip) Bankamericard renamed by Visa Electronic payment authorization system emerged (VisaNet) Interbank and Master Charged renamed by Mastercard JCB Credit Card launched
1980-2000	Prepaid Cards Emerged Discover Card, Maestro Card launch EMV (Europay Mastercard Visa) standards First Version
2000-2010	China Union Pay (CUP) foundation 3D Secure emerged Verified by Visa, Mastercard Secure Code, J/Secure, AMEX Safekey Contactless payments NFC (Near Field Communication) PayWave, Mastercard Contactless
2010-2020	Tokenization e-Wallets emerged: Visa Checkout, PayPal, Google Wallet, Samsung Pay, Amazon Pay, Masterpass, BKM Express MIR Russian National Payment Card System QR Code payments emerged: Alipay, mVisa, Masterpass, WeChat Pay Alternative payment methods unveiled: UPOP, Alipay, Ideal, Sofort, Qiwi, Giropay, Entercash EMV 3-D Secure (3D Secure 2.0) emerged

3.3. Alternative Payment Methods

In the previous years, payment options of the merchants' support was about the card schemas like Visa, MasterCard, Amex, JCB, etc. However, in today's payment world, banks are able to provide their merchants a lot more possibilities, and alternative payment methods is one of them. The basic difference of these transactions is that the acquirer bank does not take place in the authorization process.

After a bank has a financial agreement with the payment method, the virtual POS system of the bank has an integration process with the payment method's web page. After the integration is completed, the merchants display the new payment method's logo in their checkout page. Unlike a credit card transaction flow, when the cardholder checks that payment method; cardholder is redirected to the payment method's page. Cardholder can either have a user in which card information is stored in the e-wallet, or enter the card information there, or make a money transfer to complete the payment. The transaction result is either learnt at the moment transaction is performed, or later with an asynchronous message. In an asynchronous message workflow, the transaction proceeds without having the result and has the pending status. Later, in previously decided time intervals, an inquiry transaction is sent to the backend and asks for the transaction result until the timeout. Timeout is also a previously decided duration for a transaction based on payment method. Of the transaction is not responded until the timeout duration passes, then its status is automatically updated as unsuccessful. If the transaction if finalized as successful, then the virtual POS system sends the bank an advice message. Advice message includes information about transaction amount, currency, transaction time, the merchant id, the payment method, the country, etc. The well-known payment methods are UPOP, Paypal, Sofort, Ideal, Elo, etc. The payment methods are listed in the below figure:

Additionally to Masterpass, VisaCheckout those are today's most popular e-wallet systems, BKM Express is Turkey's local e-wallet system.

Table 2.5: Alternative Payment Methods

Payment Method	Original Country	Payment Type
UPOP	China	bank transfer, debit card, credit card
Sofort	Austria, Germany	bank transfer
Paypal	United States	e-wallet
Ideal	Netherlands	bank transfer
Elo	Brazil	credit card, debit card, prepaid card
Boleto	Brazil	bank transfer
Giropay	Germany	bank transfer
WeChatPay	China	e-wallet
Eps	Austria	bank transfer
Alipay	China	e-wallet
Qiwi	Russia	e-wallet
Entercash	Malta	bank transfer
Bancontact	Belgium	credit card, debit card
SEPA	European Union	bank transfer
BKM Express	Turkey	e-wallet
Trustly	Sweeden	bank transfer
Yandex Money	Russia	e-wallet
Google Pay	United States	e-wallet
Amazon Pay	United States	e-wallet
Apple Pay	United States	mobile payment

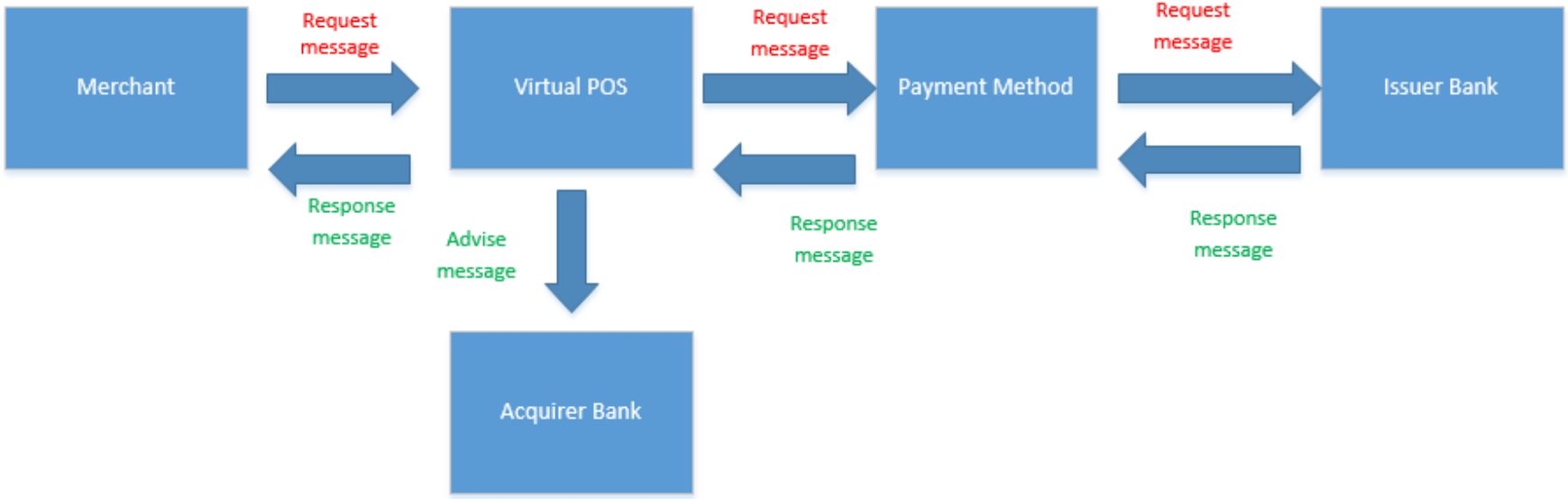


Figure 2.4: Alternative Payment Method Transaction Flow

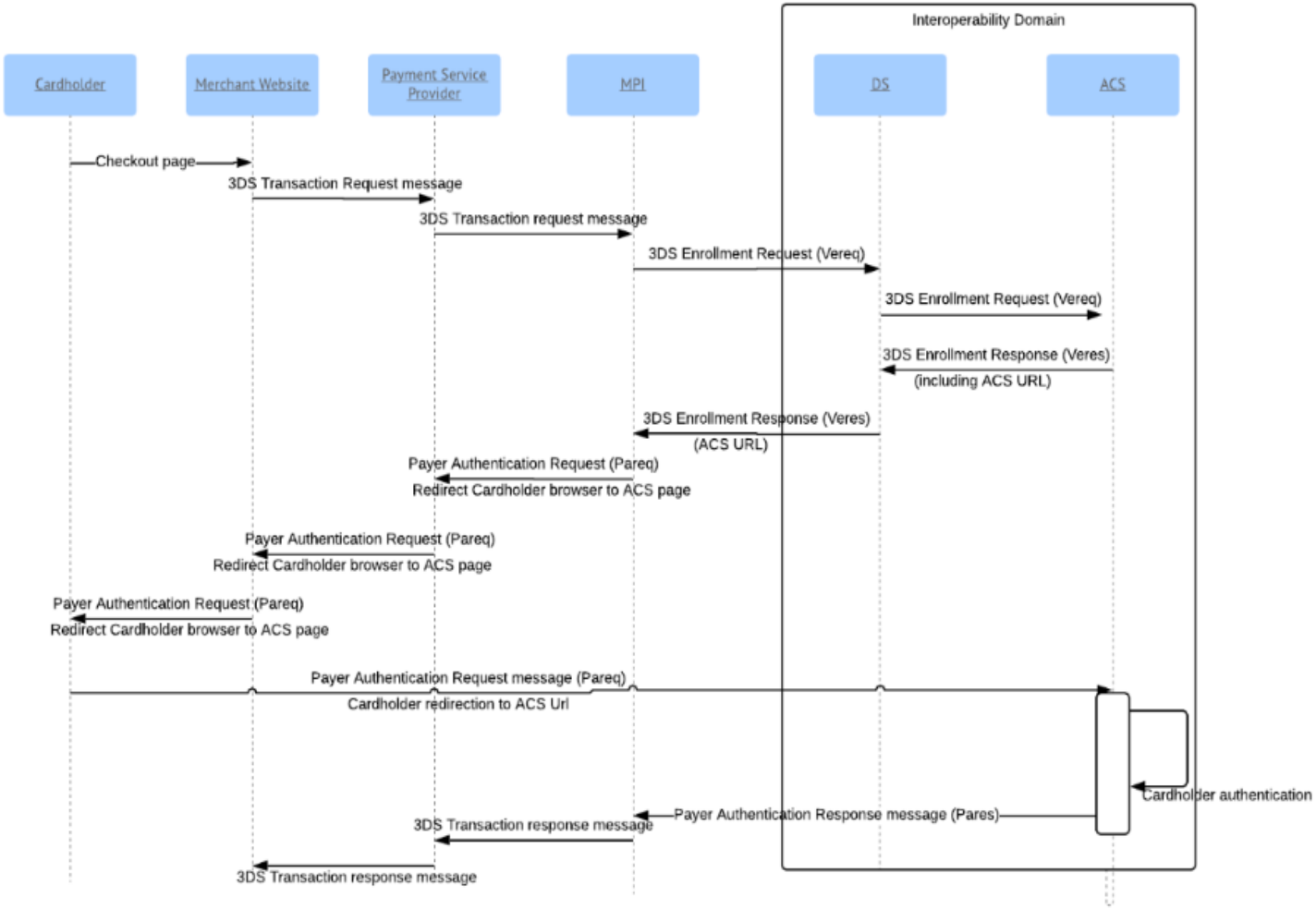


Figure 2.5: 3Dsecure 1.0 flow

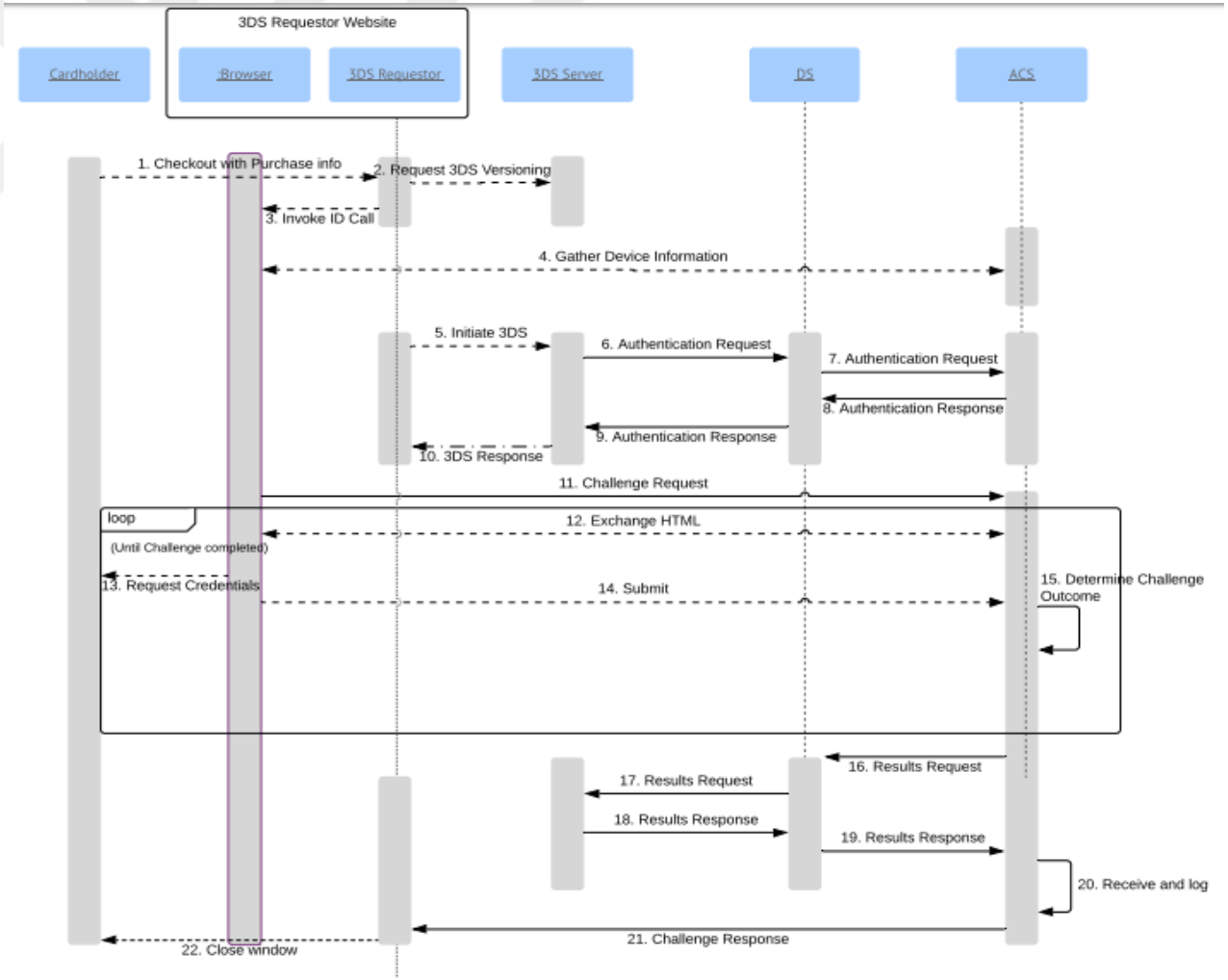


Figure 2.6: 3Dsecure 2.0 flow

4. METHODOLOGY

Type-2 fuzzy sets are one of the major extensions of the type-1 fuzzy sets. Type-2 fuzzy sets are demonstrated by primary and secondary membership values. In this section, the basic definitions of interval type-2 fuzzy sets are briefly reviewed.

Definition 1: A type-2 fuzzy set $\tilde{\tilde{A}}$ in the universe of discourse *X* can be represented by a type-2 membership function $\mu_{\tilde{\tilde{A}}}$ expressed as follows (Mendel et al., 2006):

$$\tilde{\tilde{A}} = \{((x,u), \mu_{\tilde{\tilde{A}}}(x,u)) | \forall x \in X, \forall u \in J_x \subseteq [0,1], 0 \leq \mu_{\tilde{\tilde{A}}}(x,u) \leq 1\} \quad \textbf{(1)}$$

Where J_x defines an interval in [0, 1]. The type-2 fuzzy set $\tilde{\tilde{A}}$ can also expressed as follows (Mendel et al., 2006):

$$\tilde{\tilde{A}} = \int_{x \in X} \int_{u \in J_x} \mu_{\tilde{\tilde{A}}}(x,u)/(x,u) \qquad \textbf{(2)}$$

Where $J_x \subseteq [0, 1]$ and $\int \int$ denotes union over all admissible x and u.

Definition 2: Let $\tilde{\tilde{A}}$ be a type-2 fuzzy set in the universe of discourse *X* defined by the type-2 membership function $\mu_{\tilde{\tilde{A}}}$. If all $\mu_{\tilde{\tilde{A}}}(x,u) = 1$, then $\tilde{\tilde{A}}$ is called an interval type-2 fuzzy set (Mendel et al., 2006). An interval type-2 fuzzy set $\tilde{\tilde{A}}$ can be considered as a specific condition of a type-2 fuzzy set, expressed as follows (Mendel et al., 2006):

$$\tilde{\tilde{A}} = \int_{x \in X} \int_{u \in Jx} 1/(x,u) \quad \textbf{(3)}$$

Where $J_x \subseteq [0, 1]$.

Definition 3: If the upper membership function and the lower membership function are both trapezoidal fuzzy sets then it is called trapezoidal interval type-2 fuzzy sets. Let $\tilde{\tilde{A}}$

be a trapezoidal interval type-2 fuzzy set. $\tilde{\tilde{A}}$ can be expressed as follows (Chen and Lee, 2010):

$$\tilde{\tilde{A}} = (\tilde{A}^T \mid T \in \{U, L\}) = a_i^T;\ H_{1A}^T;\ H_{2A}^T \mid T \in \{U, L\}, i = 1,2,3,4) \qquad \textbf{(4)}$$

Where $\tilde{A}^U$ and $\tilde{A}^L$ defines the upper and lower membership functions of $\tilde{\tilde{A}}$, respectively. $H_j^U \in [0, 1]$ and $H_j^L \in [0, 1]$ (j = 1, 2) defines the membership values of the corresponding elements a_{j+1}^U *and* a_{j+1}^L, respectively. Figure 1 demonstrates an example of a trapezoidal interval type-2 fuzzy sets.

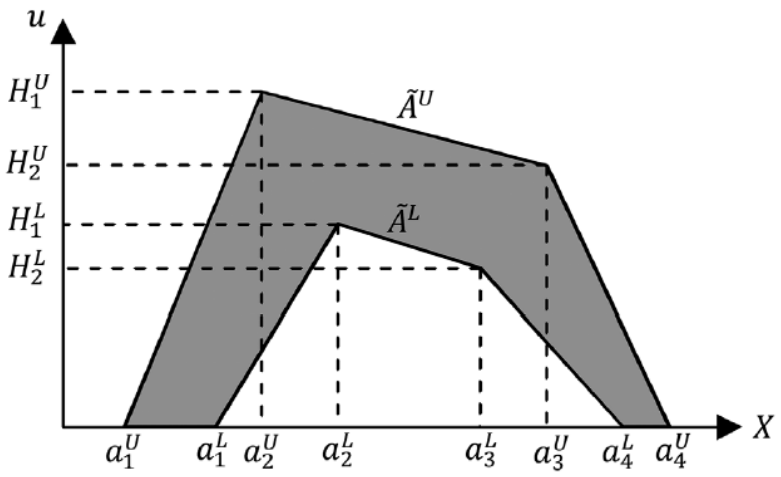


Figure 3.1*:* The upper and the lower trapezoidal membership functions of interval type-2 fuzzy sets (Chen & Lee, 2010).

Definition 4: Let $\tilde{\tilde{A}}$ and $\tilde{\tilde{B}}$ be two trapezoidal interval type-2 fuzzy sets and *d* is a crisp number, then the arithmetic calculations of $\tilde{\tilde{A}}$ and $\tilde{\tilde{B}}$ are defined as follows (Ghorabaee et al., 2015b; Ghorabaee et al., 2016b). Where,

$$\tilde{\tilde{A}} = \left(\tilde{A}^T \,\middle|\, T \in \{U, L\}\right) = a_i^T;\ H_{1A}^T;\ H_{2A}^T \mid T \in \{U, L\}, i = 1,2,3,4)$$

$$\tilde{\tilde{B}} = \left(\tilde{B}^T \,\middle|\, T \in \{U, L\}\right) = b_i^T;\ H_{1B}^T;\ H_{2B}^T \mid T \in \{U, L\}, i = 1,2,3,4$$

- Addition:

$$\tilde{\tilde{A}} \oplus \tilde{\tilde{B}} = (a_i^T + b_i^T; \min(H_{1A}^T, H_{1B}^T), \min(H_{2A}^T, H_{2B}^T)) \mid T \in \{U, L\}, i = 1,2,3,4) \quad \textbf{(5)}$$

$$\tilde{\tilde{A}} + d = (a_i^T + d;\ H_{1A}^T, H_{2A}^T) \mid T \in \{U, L\}, i = 1,2,3,4) \quad \textbf{(6)}$$

- Subtraction:

$$\tilde{\tilde{A}} \ominus \tilde{\tilde{B}} = (a_i^T - b_{5-i}^T; \min(H_{1A}^T, H_{1B}^T), \min(H_{2A}^T, H_{2B}^T)) \mid T \in \{U, L\}, i = 1,2,3,4) \quad \textbf{(7)}$$

- Multiplication:

$$\tilde{\tilde{A}} \otimes \tilde{\tilde{B}} = (X_i^T; \min(H_{1A}^T, H_{1B}^T), \min(H_{2A}^T, H_{2B}^T) \mid T \in \{U, L\}, i = 1,2,3,4) \quad \textbf{(8)}$$

$$X_i^T = \begin{cases} \min(a_i^T b_i^T, a_i^T b_{5-i}^T, a_{5-i}^T b_i^T, a_{5-i}^T b_{5-i}^T)\ if\ i = 1,2 \\ \max(a_i^T b_i^T, a_i^T b_{5-i}^T, a_{5-i}^T b_i^T, a_{5-i}^T b_{5-i}^T)\ if\ i = 3,4 \end{cases} \quad \textbf{(9)}$$

$$d.\tilde{\tilde{A}} = \begin{cases} \mathrm{d}.a_i^T; H_{1A}^T, H_{2A}^T \mid T \in \{U, L\}, i = 1,2,3,4)\ if\ d \geq 0 \\ \mathrm{d}.a_{5-i}^T; H_{1A}^T, H_{2A}^T \mid T \in \{U, L\}, i = 1,2,3,4) if\ d \leq 0 \end{cases} \quad \textbf{(10)}$$

Definition 5: The crisp score of a trapezoidal interval type-2 fuzzy set is expressed as follows (Ghorabaee et al., 2015b):

$$\Im\left(\tilde{\tilde{A}}\right) = \frac{1}{2}\left(\sum_{T\in\{U,L\}} \frac{a_i^T + (1+H_{1A}^T)a_2^T + (1+H_{2A}^T)a_3^T + a_4^T}{4+H_{1A}^T+H_{2A}^T} \right) \quad \textbf{(11)}$$

Definition 6: In order to find the maximum between a trapezoidal interval type-2 fuzzy set fuzzy number and zero the following function is defined (Ghorabaee et al., 2015b).

$$\mathcal{Z}(\tilde{\tilde{A}}) = \begin{cases} \tilde{\tilde{A}}\ \ if\ \Im\left(\tilde{\tilde{A}}\right) > 0 \\ \tilde{\tilde{0}}\ \ if\ \Im\left(\tilde{\tilde{A}}\right) \leq 0 \end{cases} \quad \textbf{(12)}$$

where $\tilde{\tilde{0}}$ = ((0,0,0,0;1,1), (0,0,0,0;1,1)).

Ghorabaee et al. (2015) firstly introduced the EDAS method and Ghorabaee et al. (2017) extended the EDAS method by using interval type-2 fuzzy sets. The definitions which are presented above are used for extending the EDAS method by using interval type-2 fuzzy sets.

Suppose that we have a set of *n* alternatives ($\mathcal{A} = \{\mathcal{A}_1, \mathcal{A}_2, \dots \mathcal{A}_n\}$) a set of m criteria ($\mathcal{C} = \{\mathcal{C}_1, \mathcal{C}_2, \dots \mathcal{C}_m\}$) and k decision makers ($\mathcal{D} = \{\mathcal{D}_1, \mathcal{D}_2, \dots \mathcal{D}_k\}$). The steps of EDAS interval type-2 fuzzy sets method are presented as follows (Ghorabaee et al., 2017):

Step 1: The average decision matrix (*X*), is defined as follows:

$$X = \left[\tilde{\tilde{x}}_{ij}\right]_{nxm} \qquad \textbf{(13)}$$

Where,

$$\tilde{\tilde{x}}_{ij} = \frac{1}{k} \bigoplus_{p=1}^{k} \tilde{\tilde{x}}_{ij}^{p} \qquad \textbf{(14)}$$

and $\tilde{\tilde{x}}_{ij}^{p}$ denotes the performance value of alternative $\mathcal{A}_i$ $(1 \le i \le n)$ with respect to criterion $\mathcal{C}_j$ $(1 \le j \le m)$ assigned by the p^{th} decision maker $(1 \le p \le k)$.

Step 2: The matrix of criteria weights, is defined as follows:

$$W = \left[\tilde{\tilde{w}}_j\right]_{1xm} \qquad \textbf{(15)}$$

Where,

$$\tilde{\tilde{w}}_j = \frac{1}{k} \bigoplus_{p=1}^{k} \tilde{\tilde{w}}_j^p \qquad \textbf{(16)}$$

and $\tilde{\tilde{w}}_j^p$ denotes the weight of criterion $\mathcal{C}_j$ $(1 \le j \le m)$ assigned by the p^{th} decision maker $(1 \le p \le k)$.

Step 3: Determine the matrix of average solutions, shown as follows:

$$AV = \left[\tilde{\tilde{\mathcal{M}}}_j\right]_{1xm} \qquad \textbf{(17)}$$

Where,

$$\tilde{\tilde{\mathcal{M}}}_j = \frac{1}{n} \bigoplus_{i=1}^{n} \tilde{\tilde{x}}_{ij} \qquad \textbf{(18)}$$

$\tilde{\tilde{\mathcal{M}}}_j$ represents the average solutions with respect to each criterion. Therefore, the dimension of the matrix is equal to the dimension of criteria weights matrix.

Step 4: If B is the set of beneficial criteria and N is the set of non-beneficial criteria. Then the matrices of positive distance from average (PDA) and negative distance from average (NDA) are calculated with regard to the type of criteria as follows:

$$PDA = \left[\tilde{\tilde{\mathcal{P}}}_{ij}\right]_{nxm} \qquad \textbf{(19)}$$

$$NDA = \left[\tilde{\tilde{\mathcal{N}}}_{ij}\right]_{nxm} \qquad \textbf{(20)}$$

$$\tilde{\tilde{\mathcal{P}}}_{ij} = \begin{cases} \frac{\mathcal{Z}(\tilde{\tilde{x}}_{ij} \ominus \tilde{\tilde{\mathcal{M}}}_j)}{\mathcal{C}\left(\tilde{\tilde{\mathcal{M}}}_j\right)} \; if \; j \in B \\ \frac{\mathcal{Z}(\tilde{\tilde{\mathcal{M}}}_j \ominus \tilde{\tilde{x}}_{ij})}{\mathcal{C}\left(\tilde{\tilde{\mathcal{M}}}_j\right)} if \; j \in N \end{cases} \qquad \textbf{(21)}$$

$$\tilde{\tilde{n}}_{ij} = \begin{cases} \frac{\mathcal{Z}(\tilde{\tilde{M}}_j \ominus \tilde{\tilde{x}}_{ij})}{\Subset(\tilde{\tilde{M}}_j)} \; if \; j \in B \\ \frac{\mathcal{Z}(\tilde{\tilde{x}}_{ij} \ominus \tilde{\tilde{M}}_j)}{\Subset(\tilde{\tilde{M}}_j)} if \; j \in N \end{cases} \quad \textbf{(22)}$$

where $\tilde{\tilde{p}}_{ij}$ and $\tilde{\tilde{n}}_{ij}$ denote the positive and negative distance of performance value of i^{th} alternative from the average solution in terms of j^{th} criterion, respectively.

Step 5: The weighted sum of positive and negative distances for all alternatives are calculated as follows:

$$\tilde{\tilde{sp}}_i = \bigoplus_{j=1}^{m} (\tilde{\tilde{w}}_j \otimes \tilde{\tilde{p}}_{ij}) \quad \textbf{(23)}$$

$$\tilde{\tilde{sn}}_i = \bigoplus_{j=1}^{m} (\tilde{\tilde{w}}_j \otimes \tilde{\tilde{n}}_{ij}) \quad \textbf{(24)}$$

Step 6: The normalized values of $\tilde{\tilde{sp}}_i$ and $\tilde{\tilde{sn}}_i$ for all alternatives are calculated as follows:

$$\tilde{\tilde{np}}_i = \frac{\tilde{\tilde{sp}}_i}{max_i(\Subset(\tilde{\tilde{sp}}_i))} \quad \textbf{(25)}$$

$$\tilde{\tilde{nn}}_i = 1 - \frac{\tilde{\tilde{sn}}_i}{max_i(\Subset(\tilde{\tilde{sn}}_i))} \quad \textbf{(26)}$$

Step 7: The appraisal score $\tilde{\tilde{h}}_i$ for all alternatives is calculated as follows:

$$\tilde{\tilde{h}}_i = \frac{1}{2}(\tilde{\tilde{np}}_i \oplus \tilde{\tilde{nn}}_i) \quad \textbf{(27)}$$

Step 8: The method proposed by Ghorabaee et al. (2014) is used in this step for computing the ranking value (*RV*) of trapezoidal interval type-2 fuzzy sets. The alternatives according to the decreasing ranking values of appraisal (*RV*) scores are

ranked and the alternative with the highest appraisal score is accepted as the best option among other alternatives.

5. REAL LIFE APPLICATION

In this chapter, decision making problem of a bank for outsourcing will be solved with the previously presented methodology. That bank is looking for a Payment Service Provider (PSP), mainly to focus on its core business. There are three alternatives, and these alternatives will be evaluated based on seven different criteria.

5.1. Alternatives

Utilizing the previously explained model, three different software companies are the alternatives those will be evaluated. These are private companies, and because of that their names can't be specified. We named the companies as A_1, A_2 and A_3 which are listed in Table 4.1. We received the proposals from those companies, and scored the financial factors based on them. The proposals also can't be shared also due to the privacy regulations. The quality and service factors are scored based on the reputation and past experiences of the companies. Out of the companies, A_1 is a company that is new in the market. A_2 is the market leader which provides outsourcing service to 18 banks both in Turkey and Europe. The market share A_2 has is more than 75%. A_3 is the company 3rd in this sector which can be referred as medium scale.

Table 4.1: Alternatives' General Overview

Alternative	Scale	Age	Market Share
A1	Small	Less than 1 year	Less than 5%
A2	Large	20 years	More than 75%
A3	Medium	5 years	15%

While applying the model in this thesis A_1, A_2, and A_3 companies are interpreted based on the criteria and sub-criteria those are explained below by three committee member experts of the deciding committee of the company that will decide which Service Provider to work with.

5.2. Criteria and sub-criteria for PSP selection

The criteria and sub-criteria from a bank's perspective to select a PSP will be specified and explained in this section. Deciding the criteria has always been a major issue in the vendor selection process. Weber, Current, and Benton evaluated 74 articles and pointed out that "net price", "quality, and "delivery" criteria are stated as the most considerable factors (1991). Dickson also made a research on the factors to be scored during the vendor selection process, and found out the elements to be decided depends on the product/service to be purchased (Dickson, G.W., 1966). Saurabh Kumar Garg, Steve Versteeg and Rajkumar Buyya stated the high level criteria were stated as accountability, agility, cost, performance, assurance, security/privacy, and usability for Cloud Service Outsourcing (Garg, S.K., 2013). In this study, initial cost, software development cost, quality, availability, reliability, security, and service are the main criteria. The main and sub-criteria are listed in Table 4.2.

When making a purchasing, buying a product/service that is cost effective is the first consideration made which shows the price is obviously a vital factor. In this study the first two main criteria are initial cost and development cost, which can be considered as a categorization as acquisition and on-going costs for financial factors.

Initial Cost (C_1):

Initial cost is the fixed cost that is paid initially for the use of the standard product or service. The vendor/service provider company usually has a standard product/service, and after the settlement enables the use of it to the client company.

Development Cost (C_2):

Software development cost contains all the development related costs, after the initial purchase. Change request cost and maintenance cost are the sub-criteria for it.

Change Request Cost (C_{21}):

Change requests are the additional demands based on the client or end user needs for customizations those are not met with the standard product. Being compliant with the regulations of the sector is another reason for the new development. In Payment Domain, BKM (Interbank Card Center) or BDDK (Banking Regulation and Supervision Agency) are the institutions which determine the regulations in Turkey; whereas Visa, MasterCard, and EMVCo (Europay Mastercard Visa Cooperation) are the foundations identifying the regulations globally. Another motivation for the additional development for a bank or merchant is to fall in step with the innovations originates from the technological improvement since being able to compete with the other companies is not possible by ignoring the technological growth.

Maintenance Cost (C_{22}):

Maintenance includes fixing the bugs arise in the production environment. Bugs are solved and new packages are deployed to the production environment. Based on the criticality of the problem, the delivery of the new package is planned. When there are two or more bugs simultaneously, they are prioritized and solved in an order that will cause less damage to the client. The one causing the financial loss often has the higher priority, whereas a problem provokes incompatibility with a regulation can also be important. The product owner of the vendor company is liable of prioritization. The Service Provider does not invoice the fixing of the bugs, but there is a yearly constant maintenance cost instead.

Quality (C_3):

Quality is another considerable factor to be evaluated while deciding the Service Provider. Service response time, sustainability, suitability, accuracy, transparency, interoperability, availability, reliability, stability, adaptability, elasticity, and usability factors are expressed as sub factors of quality for Cloud Computing Outsourcing Service (Weber, 1991). In this study, bug free and performance are selected as quality sub-criteria.

Bug free (C_{31}):

In Payment Domain, taking into account that the high number of transactions processed through the gateway, even a small error or a short interruption of the system causing the

transactions to be unsuccessful may result banks and merchants to lose enormous endorsements. Because of that, having a bug free product and deploying packages for additional development without bug is quite important factor.

Performance (C_{32}):

Performance is an element which should be reckoned during the evaluation process of a product/service. Syaripah Ruzaini Syed Aris, Haryani Haron, and Nor Azlin Murat stated performance as a key metric of the quality in their research on the determinants of vendor selection process in IT (Haron, H., 2011). According to R. Dhivya, R. Devi, Dr.R.Shanmugalakshmi functionality, service response time, and accuracy are the main indicators of a system's performance (Dhivya, R., et. al., 2016).

Availability (C_4):

Availability is defined as a customer's access to a product/service. Although a Physical POS can tolerate an inaccessibility arises out of working hours of the stores, Virtual POS should remain available for 7/24. In case of an unavailability, the merchant either proceeds with the backup acquirer bank or lose giro and both consequences harm the acquirer bank of the merchant.

Reliability (C_5):

Reliability is an indicator of how a product/service operates without collapsing along a speficied time and condition. For this reason, it can also be described as the mean time the Service Provider faces the failure (Dickson, 1966). Furthermore, the company reputation affects the reliability factor based on the past experiences.

Service (C_6):

The last main criteria to be analyzed in this article is the service. Transparency, on-time delivery, and monitoring is the sub-crtieria for the service.

Transparency (C_{61}):

Transparency is about Service Provider to have the system clear and apparent to its client. For example, a system can be defined as transparent if the client should be able to export the reports for transactions/activities, access the support tickets, and sight what is going on in real-time.

On-time delivery (C_{62}):

Time is valuable to companies as much as it is to individuals in their daily lives. When there is a promise that can't be kept, it can disrupt the client company's plan, and more importantly injure the trust between the companies. Failing about the on-time deliveries can even result in the termination of the contract between the companies which makes this criteria a very significant one.

Monitoring (C_{63}):

Monitoring is related to the continuous control of the system's working, and making sure that the functionality is smooth and the performance is good. The advantage of the monitoring is the ability to notice a problem before it arises, or the quick intervention in case of an urgency.

Security (C_7):

Security is another key concern for the banks, since both the personal and sensitive data can be exposed in case of a security bug, which can be result as a disaster.

Data Security (C_{71}):

The important data stored in the Database is encrypted in Database, however in case the encryption algorithm is found out, the data can be decrypt by the attackers. The warehouse security is also significant in data security.

Connection Security (C_{72}):

Transaction channels are between the merchant and PSP, and between PSP and the bank. These channels' security and resistancy to the attacks are major for the sensitive information to not be uncovered; otherwise there might be enormous financial losses.

Table 4.2: Criteria and Sub-Criteria

Main Criteria	**Sub-Criteria**	**Positive/Negative**
Initial Cost (C_1)	-	Negative
Development Cost (C_2)	Change Request Cost (C_{21}) Maintenance Cost (C_{22})	Negative
Quality (C_3)	Bug Free (C_{31}) Performance (C_{32})	Positive
Availability (C_4)	-	Positive
Reliability (C_5)	-	Positive
Service (C_6)	Transparency (C_{61}) On-time Delivery (C_{62}) Monitoring (C_{63})	Positive
Security (C_7)	Data Security (C_{71}) Connection Security (C_{72})	Positive

5.3. Model Application

In the suggested model, the scores of the alternatives will be transformed into Internal Type-2 Fuzzy Sets. The linguistic scores and the corresponding Interval Type-2 Fuzzy Set values are shared in Table 4.3:

Table 4.3: Linguistic Varible's Corresponding IT2FS Values

Linguistic Variable	**Interval Type-2 Fuzzy Sets**
Very Low (VL)	(0.00 0.00 0.00 0.10 ; 1.00 1.00) (0.00 0.00 0.00 0.05 ; 0.90 0.90)
Low (L)	(0.00 0.10 0.15 0.30 ; 1.00 1.00) (0.05 0.10 0.15 0.20 ; 0.90 0.90)
Medium Low (ML)	(0.10 0.30 0.35 0.50 ; 1.00 1.00) (0.20 0.30 0.35 0.40 ; 0.90 0.90)
Medium (M)	(0.30 0.50 0.55 0.70 ; 1.00 1.00) (0.40 0.50 0.55 0.60 ; 0.90 0.90)
Medium High (MH)	(0.50 0.70 0.75 0.90 ; 1.00 1.00) (0.60 0.70 0.75 0.80 ; 0.90 0.90)
High (H)	(0.70 0.85 0.90 1.00 ; 1.00 1.00) (0.80 0.85 0.90 0.95 ; 0.90 0.90)
Very High (VH)	(0.90 1.00 1.00 1.00 ; 1.00 1.00) (0.95 1.00 1.00 1.00 ; 0.90 0.90)

Based on the decision makers' evaluations, each criteria's importance values is showed in the below table. The main criteria importance values are equal to the average values of sub-criteria. Decision makers for the selection of the best alternative are high level managers of the banks. The scores given by three decision makers are listed in Table 4.4.

Table 4.4: Weights of criteria by Decision Makers

Criteria	**DM_1**	**DM_2**	**DM_3**
Initial Cost (C_1)	MH	M	M
Development Cost (C_2)	M	M	M
Quality (C_3)	H	VH	VH
Availability (C_4)	H	H	H
Reliability (C_5)	H	H	H
Service (C_6)	H	VH	H
Security (C_7)	VH	VH	VH

Also, it should be noted that, out of the above shared criteria; initial cost and development cost are the negative criteria that should be minimized whereas the other criteria

including quality, availability, reliability, service, and security are positive criteria those should be maximized.

By using criteria weights listed in Table 4.4, the complete criteria weight matrix of decision-makers was determined by using Eq. (3.17) and Eq. (3.18). The criteria matrix is displayed in Table 4.5.

Table 4.5: Matrix of Criteria Weights

Criteria	**Criteria Weights (Upper Bounds)**						**Criteria Weights (Lower Bounds)**					
Initial Cost (C_1)	0.37	0.57	0.62	0.77	1.00	1.00	0.47	0.57	0.62	0.67	0.90	0.90
Development Cost (C_2)	0.30	0.50	0.55	0.70	1.00	1.00	0.40	0.50	0.55	0.60	0.90	0.90
Quality (C_3)	0.83	0.95	0.97	1.00	1.00	1.00	0.90	0.95	0.97	0.98	0.90	0.90
Availability (C_4)	0.70	0.85	0.90	1.00	1.00	1.00	0.80	0.85	0.90	0.95	0.90	0.90
Reliability (C_5)	0.70	0.85	0.90	1.00	1.00	1.00	0.80	0.85	0.90	0.95	0.90	0.90
Service (C_6)	0.77	0.90	0.93	1.00	1.00	1.00	0.85	0.90	0.93	0.97	0.90	0.90
Security (C_7)	0.90	1.00	1.00	1.00	1.00	1.00	0.95	1.00	1.00	1.00	0.90	0.90

From Table 4.5, it can be referred that security, quality, and service criteria are the most critical ones respectively, relative to them the cost criteria is not that important. In the next step, the performances of alternatives A_1, A_2, A_3 based on criteria were evaluated by the decision makers.

The linguistic scores of alternatives based on criteria given by three decision makers are listed in Table 4.6a, 4.6b, and 4.6c.

Table 4.6a: Performance Values of Alternatives for Decision Maker 1

Criteria	**A_1**	**A_2**	**A_3**
Initial Cost (***C_1***)	ML	VH	H
Development Cost(***C_2***)	M	H	H
Quality (***C_3***)	M	VH	H
Availaibility (***C_4***)	MH	H	MH
Reliability (***C_5***)	MH	H	MH
Service (***C_6***)	M	VH	MH
Security (***C_7***)	MH	VH	H

Table 4.6b: Performance Values of Alternatives for Decision Maker 2

Criteria	**A_1**	**A_2**	**A_3**
Initial Cost (***C_1***)	L	H	H
Development Cost(***C_2***)	M	H	H
Quality (***C_3***)	ML	VH	H
Availaibility (***C_4***)	MH	H	MH
Reliability (***C_5***)	H	H	MH
Service (***C_6***)	M	VH	H
Security (***C_7***)	MH	VH	H

Table 4.6c: Performance Values of Alternatives for Decision Maker 3

Criteria	**A_1**	**A_2**	**A_3**
Initial Cost (***C_1***)	ML	VH	H
Development Cost(***C_2***)	M	H	H
Quality (***C_3***)	ML	H	H
Availaibility (***C_4***)	ML	H	MH
Reliability (***C_5***)	M	H	MH
Service (***C_6***)	M	VH	H
Security (***C_7***)	MH	VH	VH

By using the performance values given by decision makers in Table 4.6a, 4.6b, and 4.6c in Eq. (3.19) and Eq. (3.20), the average solutions matrix is computed for each alternative. The average solution values are presented in Table 4.7a, 4.7b, and 4.7c.

Table 4.7a: Average Decision Matrix of Decision Makers for A_1

Criteria												
C_1	0.07	0.23	0.28	0.43	1	1	0.15	0.23	0.3	0.3	0.9	0.9
C_2	0.3	0.5	0.55	0.7	1	1	0.4	0.5	0.6	0.6	0.9	0.9
C_3	0.17	0.37	0.42	0.57	1	1	0.27	0.37	0.4	0.5	0.9	0.9
C_4	0.37	0.57	0.62	0.77	1	1	0.47	0.57	0.6	0.7	0.9	0.9
C_5	0.5	0.68	0.73	0.87	1	1	0.6	0.68	0.7	0.8	0.9	0.9
C_6	0.3	0.5	0.55	0.7	1	1	0.4	0.5	0.6	0.6	0.9	0.9
C_7	0.5	0.7	0.75	0.9	1	1	0.6	0.7	0.8	0.8	0.9	0.9

Table 4.7b: Average Decision Matrix of Decision Makers for A_2

Criteria												
C_1	0.83	0.95	0.97	1	1	1	0.9	0.95	0.97	0.98	0.9	0.9
C_2	0.7	0.85	0.9	1	1	1	0.8	0.85	0.9	0.95	0.9	0.9
C_3	0.83	0.95	0.97	1	1	1	0.9	0.95	0.97	0.98	0.9	0.9
C_4	0.7	0.85	0.9	1	1	1	0.8	0.85	0.9	0.95	0.9	0.9
C_5	0.7	0.85	0.9	1	1	1	0.8	0.85	0.9	0.95	0.9	0.9
C_6	0.9	1	1	1	1	1	0.95	1	1	1	0.9	0.9
C_7	0.9	1	1	1	1	1	0.95	1	1	1	0.9	0.9

Table 4.7c: Average Decision Matrix of Decision Makers for A_3

Criteria												
C_1	0.7	0.85	0.9	1	1	1	0.8	0.85	0.9	0.95	0.9	0.9
C_2	0.7	0.85	0.9	1	1	1	0.8	0.85	0.9	0.95	0.9	0.9
C_3	0.7	0.85	0.9	1	1	1	0.8	0.85	0.9	0.95	0.9	0.9
C_4	0.5	0.7	0.75	0.9	1	1	0.6	0.7	0.75	0.8	0.9	0.9
C_5	0.5	0.7	0.75	0.9	1	1	0.6	0.7	0.75	0.8	0.9	0.9
C_6	0.63	0.8	0.85	0.97	1	1	0.73	0.8	0.85	0.9	0.9	0.9
C_7	0.77	0.9	0.93	1	1	1	0.85	0.9	0.93	0.97	0.9	0.9

The crisp scores for initial cost, development cost, quality, availability, reliability, service, and security criteria are represented in Table 4.8.

Considering the crisp scores displayed in Table 4.8, security (C_7) is the most important criteria for the decision makers, and initial cost (C_8) is the least important one.

Positive and negative distances are calculated by using the average decision matrix and average solutions matrix which are represented in Table 4.7 and 4.8 respectively. Positive distance of performance values from the average solution is calculated by using Eq. (3.21) and (3.23), and negavite distance of performance values from the average solution is calculated by using Eq. (3.22) and (3.24). Positive distance values are represented in Table 4.9, and negative distance values are represented in Table 4.10.

Table 4.8: Matrix of Average Solutions

Criteria	**Fuzzy Value**	**Crisp Score**
C_1	(0.20 0.25 0.27 0.30 0.38 0.38, 0.23 0.25 0.27 0.28 0.34 0.34)	0.26
C_2	(0.21 0.28 0.29 0.34 0.38 0.38, 0.25 0.28 0.29 0.31 0.34 0.34)	0.28
C_3	(0.21 0.27 0.29 0.32 0.38 0.38, 0.25 0.27 0.29 0.30 0.34 0.34)	0.27
C_4	(0.20 0.26 0.28 0.33 0.38 0.38, 0.23 0.26 0.28 0.30 0.34 0.34)	0.27
C_5	(0.21 0.28 0.30 0.35 0.38 0.38, 0.25 0.28 0.30 0.32 0.34 0.34)	0.29
C_6	(0.23 0.29 0.30 0.33 0.38 0.38, 0.26 0.29 0.30 0.31 0.34 0.34)	0.29
C_7	(0.27 0.33 0.34 0.36 0.38 0.38, 0.30 0.33 0.34 0.35 0.34 0.34)	0.33

Table 4.9: Alternatives' Positive Difference Values to the Solution

Criteria	**A_1- Positive difference values from the solution**											
C_1	0.52	0.08	-0.06	-0.50	1	1	0.31	0.08	-0.06	-0.19	0.9	1
C_2	-0.39	-0.95	-1.09	-1.53	1	1	-0.65	-0.95	-1.09	-1.22	0.9	1
C_3	-0.13	0.44	0.57	1.02	1	1	0.14	0.44	0.57	0.71	0.9	1
C_4	0.64	1.21	1.35	1.79	1	1	0.91	1.21	1.35	1.48	0.9	1
C_5	1.16	1.66	1.80	2.18	1	1	1.43	1.66	1.80	1.93	0.9	1
C_6	0.39	0.95	1.09	1.53	1	1	0.65	0.95	1.09	1.22	0.9	1
C_7	1.16	1.72	1.86	2.30	1	1	1.43	1.72	1.86	2.00	0.9	1
Criteria	**A_2- Positive difference values from the solution**											
C_1	-2.45	-2.69	-2.70	-2.69	1	1	-2.59	-2.69	-2.70	-2.71	0.9	1
C_2	-1.93	-2.30	-2.44	-2.69	1	1	-2.20	-2.30	-2.44	-2.58	0.9	1
C_3	2.45	2.69	2.70	2.69	1	1	2.59	2.69	2.70	2.71	0.9	1
C_4	1.93	2.30	2.44	2.69	1	1	2.20	2.30	2.44	2.58	0.9	1
C_5	1.93	2.30	2.44	2.69	1	1	2.20	2.30	2.44	2.58	0.9	1
C_6	2.71	2.88	2.83	2.69	1	1	2.78	2.88	2.83	2.77	0.9	1
C_7	2.71	2.88	2.83	2.69	1	1	2.78	2.88	2.83	2.77	0.9	1
Criteria	**A_3- Positive difference values from the solution**											
C_1	-1.93	-2.30	-2.44	-2.69	1	1	-2.20	-2.30	-2.44	-2.58	0.9	0.9
C_2	-1.93	-2.30	-2.44	-2.69	1	1	-2.20	-2.30	-2.44	-2.58	0.9	0.9
C_3	1.93	2.30	2.44	2.69	1	1	2.20	2.30	2.44	2.58	0.9	0.9
C_4	1.16	1.72	1.86	2.30	1	1	1.43	1.72	1.86	2.00	0.9	0.9
C_5	1.16	1.72	1.86	2.30	1	1	1.43	1.72	1.86	2.00	0.9	0.9
C_6	1.68	2.11	2.25	2.56	1	1	1.94	2.11	2.25	2.38	0.9	0.9
C_7	2.19	2.50	2.57	2.69	1	1	2.39	2.50	2.57	2.64	0.9	0.9

Table 4.10: Alternatives' Negative Difference Values to the Solution

Criteria	**A_1- Negative difference values from the solution**											
C_1	-0.52	-0.08	0.06	0.50	1	1	-0.31	-0.08	0.06	0.19	0.9	1
C_2	0.39	0.95	1.09	1.53	1	1	0.65	0.95	1.09	1.22	0.9	1
C_3	0.13	-0.44	-0.57	-1.02	1	1	-0.14	-0.44	-0.57	-0.71	0.9	1
C_4	-0.64	-1.21	-1.35	-1.79	1	1	-0.91	-1.21	-1.35	-1.48	0.9	1
C_5	-1.16	-1.66	-1.80	-2.18	1	1	-1.43	-1.66	-1.80	-1.93	0.9	1
C_6	-0.39	-0.95	-1.09	-1.53	1	1	-0.65	-0.95	-1.09	-1.22	0.9	1
C_7	-1.16	-1.72	-1.86	-2.30	1	1	-1.43	-1.72	-1.86	-2.00	0.9	1
Criteria	**A_2- Negative difference values from the solution**											
C_1	2.45	2.69	2.70	2.69	1	1	2.59	2.69	2.70	2.71	0.9	0.9
C_2	1.93	2.30	2.44	2.69	1	1	2.20	2.30	2.44	2.58	0.9	0.9
C_3	-2.45	-2.69	-2.70	-2.69	1	1	-2.59	-2.69	-2.70	-2.71	0.9	0.9
C_4	-1.93	-2.30	-2.44	-2.69	1	1	-2.20	-2.30	-2.44	-2.58	0.9	0.9
C_5	-1.93	-2.30	-2.44	-2.69	1	1	-2.20	-2.30	-2.44	-2.58	0.9	0.9
C_6	-2.71	-2.88	-2.83	-2.69	1	1	-2.78	-2.88	-2.83	-2.77	0.9	0.9
C_7	-2.71	-2.88	-2.83	-2.69	1	1	-2.78	-2.88	-2.83	-2.77	0.9	0.9
Criteria	**A_3- Negative difference values from the solution**											
C_1	1.93	2.30	2.44	2.69	1	1	2.20	2.30	2.44	2.58	0.9	0.9
C_2	1.93	2.30	2.44	2.69	1	1	2.20	2.30	2.44	2.58	0.9	0.9
C_3	-1.93	-2.30	-2.44	-2.69	1	1	-2.20	-2.30	-2.44	-2.58	0.9	0.9
C_4	-1.16	-1.72	-1.86	-2.30	1	1	-1.43	-1.72	-1.86	-2.00	0.9	0.9
C_5	-1.16	-1.72	-1.86	-2.30	1	1	-1.43	-1.72	-1.86	-2.00	0.9	0.9
C_6	-1.68	-2.11	-2.25	-2.56	1	1	-1.94	-2.11	-2.25	-2.38	0.9	0.9
C_7	-2.19	-2.50	-2.57	-2.69	1	1	-2.39	-2.50	-2.57	-2.64	0.9	0.9

The weighted sum of positive and negative distances and their normalized values are computed for all alternatives based on Eq. (3.25), Eq. (3.26), Eq. (3.27) and Eq. (3.28) respectively. The calculation results are shown in Table 4.11 and Table 4.12.

Table 4.11: Weighted Sum of Positive distance values of Alternatives

Alternative	**Normalized Value**											
A_1	2.69	5.48	6.22	8.43	1	1	4.05	5.48	6.22	7	0.9	0.9
A_2	9.26	12	12.5	13.5	1	1	10.8	12	12.5	13	0.9	0.9
A_3	6.49	9.52	10.4	12.6	1	1	8.18	9.52	10.4	11.3	0.9	0.9

Table 4.12: Weighted Sum of Negative distance values of Alternatives

Alternative	**Normalized Value**											
A_1	0.14	0.54	0.67	1.17	1.00	1.00	0.30	0.54	0.67	0.82	0.90	0.90
A_2	1.61	2.83	3.17	4.13	1	1	2.23	2.83	3.17	3.52	0.9	0.90
A_3	1.42	2.61	3.01	4.13	1	1	2.05	2.61	3.01	3.44	0.9	0.90

Table 4.13: Positive Normalized values of Alternatives

Alternative	**Fuzzy Value**											
A_1	0.22	0.46	0.52	0.70	1	1	0.34	0.46	0.52	0.58	0.9	0.9
A_2	0.77	0.99	1.04	1.12	1	1	0.90	0.99	1.04	1.08	0.9	0.9
A_3	0.54	0.79	0.86	1.04	1	1	0.68	0.79	0.86	0.94	0.9	0.9

By using weighted sum and normalized values represented in Table 4.11, 4.12, 4.13, and 4.14; the evaluation scores of each alternative can be calculated by using Eq. (3.29).

Table 4.14: Negative Normalized values of Alternatives

Alternative	**Fuzzy Value**											
A_1	0.97	0.88	0.85	0.75	1	1	0.93	0.88	0.85	0.82	0.9	0.9
A_2	0.65	0.39	0.31	0.11	1	1	0.52	0.39	0.31	0.24	0.9	0.9
A_3	0.69	0.44	0.35	0.11	1	1	0.56	0.44	0.35	0.26	0.9	0.9

The overall ranking values are displayed in Table 4.15, which demonstrates the ranking is as follows: $A_2 > A_1 > A_3$.

Out of three PSP companies, A_2 is the best alternative since it provides the highest level for the most important criteria for the decision makers. Payment infrastruce of the companies has a quite extensive impact on the overall company which indicates that the hight costs are tolerated when high quality of service is guaranteed.

Table 4.15: Overall Ranking Values of Alternatives

Alternative	**Fuzzy Value**												**Ranking Value**
A_1	0.60	0.67	0.69	0.72	1	1	0.64	0.67	0.69	0.70	0.9	0.9	0.6734
A_2	0.71	0.69	0.68	0.61	1	1	0.71	0.69	0.68	0.66	0.9	0.9	**0.6802**
A_3	0.62	0.61	0.61	0.58	1	1	0.62	0.61	0.61	0.60	0.9	0.9	0.6072

6. CONCLUSION

Payment systems' importance is increasing everyday in parallel to the technological innovations. People prefer to make e-commerce purchases since they are both safe and fast. 3D Secure authentication makes the banks or merchants liable against fraud, which protects the cardholders at the same time. The transaction volumes are quite high for online purchases, and all the parties participating to the payment flow including merchants, acquirer banks, issuer banks, and card schemes such as Mastercard and Visa are gaining profit from each transaction made by credit or debit cards. Because of that, providing many payment options from both smart devices and computers with an enhanced customer experience in a secure environment is a key concern for the banks and merchants.

In this study, decision making problem for IT Outsourcing is illustrated with the Payment Service Provider selection problem of a bank. Before the problem and model, a comprehensive literature review about IT Outsourcing, and Multi Criteria Decision Making is shared. Moreover, since the problem is about Payment Systems Domain, a deep knowledge of the domain was provided. The objective of explaning domain is both informing the reader about payment systems and making the criteria more understandable. There are three alternative companies, and those alternatives are evaluated based on initial cost, development cost, quality, reliability, availability, service and security criteria. Interval type-2 Fuzzy EDAS method is implemented to solve the problem. Three decision maker who are high level managers of IT companies assessed both the criteria weights, and scored the alternatives. Security, quality, and service criteria are the highest weights respectively; whereas initial cost and development cost criteria has the lowest weights.

A_1 alternative is a recently founded company, A_2 is a large company which has the furthest market share, where A_3 is a medium scale company that has a market share around 15%. A_1 offers the relatively low prices while other criteria is about medium level.

A_2 has high prices, but provides very high quality and security. A_3 also has high prices although not as much as A_2 does, and offers high quality and service.

Despite the the fact that A_2 is selected as the best option. However it should be mentioned that the overall ranking scores are quite close to each other. The reason A_2 stands out is that its product has very high quality and security. This result indicates that the new companies in the market should have very good strategy and offering good prices is not adequate unless the expected service is not provided in terms of quality, security, and service.

This study can be improved by applying a few changes in the problem. For instance, sub-criteria can be added to the model to obtain more accurate results. Besides, not outsourcing its virtual payment gateway for an acquirer bank should also be evaluated. Another improvement suggestion is increasing the number of interviewed people for the criteria selection and including people from all the parties: merchant, software company acquirer bank. Sensitivity analysis can also be performed to understand how accurate the problem result is.

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BIOGRAPHICAL SKETCH

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