DEVELOPING NEW EVALUATION METRICS TO MEASURE AND IMPROVE SUPPLY CHAIN PERFORMANCE AND FLEXIBILITY WITH SUCCESSFUL ERP IMPLEMENTATION AND BPR APPLICATION:

A HYBRID FUZZY AHP / ANP / STATISTICAL ANALYSES APPROACH

A DOCTOR OF PHILOSOPHY (PhD) THESIS

in

Modeling and Design of Engineering Systems (MODES)

Atılım University

by

UĞUR BAÇ

JANUARY 2013

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Approval of the Graduate School of Natural and Applied Sciences, Atılım University.

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Prof.Dr. K. İbrahim Akman

Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Doctor of Philosophy.

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This is to certify that we have read the thesis “Developing New Evaluation Metrics to Measure and Improve Supply Chain Performance and Flexibility with Successful ERP Implementation and BPR Application: A Hybrid Fuzzy AHP / ANP / Statistical Analyses Approach” submitted by “Uğur Baç” and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Doctor of Philosophy.

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Uğur Baç

ABSTRACT

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Supply Chain Management and flexibility has gained a great importance nowadays. Consideration of performance and flexibility of supply chains are popular research topics. To maintain competitive advantage on the market, continuous benchmarking and improvement in performance is mandatory. To adapt continuously changing market conditions, supply chain structure should be flexible. Successful ERP implementation has a considerable effect on supply chain flexibility when it is supported by a BPR application. Some special metrics are needed to evaluate overall supply chain performance and flexibility to achieve and track improvements. In this study, two new evaluation metrics have been developed to evaluate performance and flexibility by a hybrid approach with MCDM models and statistical analyses. Also prerequisites needed for a successful ERP implementation and BPR application have been specified. As a result of this study, a road map has been prepared for benchmarking and improving Supply Chain performance and flexibility by successfully implementing ERP and applying BPR.

Keywords: Supply chain, performance evaluation, flexibility, ERP, BPR, ANP, fuzzy AHP, regression

ÖZ

BAŞARILI ERP VE BPR UYGULAMALARI ILE TEDARİK ZİNCİRLERİNİN PERFORMANSINI VE ESNEKLİĞİNİN ÖLÇÜLÜP GELİŞTİRİLEBİLMESİ İÇİN YENİ DEĞERLENDİRME METRİKLERİNİN GELİŞTİRİLMESİ:

MELEZ BULANIK AHP / AAP / İSTATİSTİKSEL ANALİZLER YAKLAŞIMI

Baç, Uğur

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Tedarik Zinciri Yönetimi ve esneklik günümüzde büyük önem kazanmıştır. Performans ve esneklik üzerine çalışmalar oldukça popüler araştırma konuları arasında ter almaktadır. Rekabet gücünü koruyabilmek için sürekli olarak performans iyileştirmesi ve kıyaslaması yapmak mecburidir. Sürekli değişmekte olan pazar koşullarına uyum sağlayabilmek için tedarik zinciri yapısı esnek olmalıdır. BPR uygulaması ile desteklendiğinde, ERP kullanımı tedarik zinciri üzerinde kayda değer etki göstermektedir. Tedarik zincirinin genel performansını ve esnekliğini ölçebilmek ve gelişmeleri takip edip gerçekleştirebilmek için özel metrikler gereklidir. Bu çalışmada, performans ve esnekliği değerlendirebilmek için ÇÖKV modelleri ve istatistiksel analizlerin kullanıldığı melez yaklaşımlarla iki yeni metrik geliştirilmiştir. Ayrıca, ERP ve BPR başarılarının ön koşulları belirlenmiştir. Çalışma sonucunda, Tedarik Zinciri performansının ve esnekliğinin değerlendirilerek, başarılı ERP ve BPR uygulamaları ile performans ve esnekliği iyileştirecek bir kılavuz hazırlanmıştır.

Anahtar Kelimeler: Tedarik zinciri, performans değerlendirme, esneklik, ERP, BPR, AAP, bulanık AHP, regresyon

To My Parents

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First and foremost, I wish to express my sincere gratitude to my supervisor of this thesis, Asst.Prof.Dr. Turan Erman Erkan for his invaluable guidance, advice, and support. Without his assistance and knowledge this study would not have been successful. Deepest gratitudes are also due to the members of the supervisory committee, Prof.Dr. Armağan Tarım and Asst.Prof.Dr. Hakan Özaktaş, without whose valuable suggestions this thesis would not have been successful. Also I would like to thank to Assoc.Prof.Dr. Ergün Eraslan and Asst.Prof.Dr. Babek Erdebilli who are the members of the examining committee for their contributions. Besides, I am thankful to Prof.Dr. Serkan Eryılmaz, the head of Department of Industrial Engineering of Atılım University, for his convenience during the intense study periods of this study, kindness and patience he gave me. It would not have been possible without the kind support and help of many individuals and organizations. I would like to extend my sincere thanks to all of them. I would also like to convey thanks to the Board of Trustees of Atılım University for providing the financial means and trust by means of three different scientific research projects they have accepted related with this thesis. Last but not least I wish to avail myself of this opportunity, express my most sincere gratitude and love to my beloved parents and my close friends for their understanding, endless patience and encouragement when it was most required.

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LIST OF ABBREVIATIONS

AHP	Analytic Hierarchy Process
ANP	Analytic Network Process
B2B	Business-to-Business
BPM	Business Process Management
BPR	Business Process Reengineering
CI	Consistency Index
CR	Consistency Ratio
CRM	Customer Relationship Management
CSF	Critical Success Factor
DM	Decision Maker
ERP	Enterprise Resource Planning
ES	Enterprise Systems
HRM	Human Resource Management
ICT	Information and Communication Technology

IS	Information Systems
IT	Information Technology
JIT	Just-in-Time
KPI	Key Performance Indicator
MCDM	Multi Criteria Decision Making
MLR	Multiple Linear Regression
MRP	Material Requirements Planning
MRPII	Manufacturing Resources Planning
OM	Operations Management
RI	Random Consistency Index
SC	Supply Chain
SCC	Supply Chain Council
SCM	Supply Chain Management
SCOFS	Supply Chain Overall Flexibility Score
SCOPS	Supply Chain Overall Performance Score
SCOR	Supply Chain Operations Reference
SLR	Simple Linear Regression
TFN	Triangular Fuzzy Number
TQM	Total Quality Management
OLS	Ordinary Least Square

CHAPTER 1

INTRODUCTION

Starting with the motivation of this study, an introduction to the structure of thesis will be given in this section. Following the motivation of the thesis, content of the analysis carried out and importance of their findings will be explained briefly in this chapter.

1.1 Statement of the Problem

Supply Chain Management (SCM) is a very popular field in recent literature. Reason of this popularity is mainly because of seriously increased competition in both domestic and global markets. Increase of competition takes its source from changing customer demands and expectations. Because of the improvements in the technology, customer needs tend to change rapidly. This situation forces business organizations to adapt to new customer needs. The companies, which can adapt to this change quickly and cost effectively, can provide a competitive advantage over their rivals. The companies, which cannot are likely to leave the market in a while.

Keeping the competitive advantage under the complex market circumstances forces enterprises to tend to their Supply Chains (SCs) (Trkman, McCormack, Valadares de Oliveira, and Ladeira, 2010). Business organizations should acquire flexibility in their SCs' all levels to make it easier to adapt changing situations and to act more agile in the continuously changing environment. Companies, which have a flexible

SC structure, can easily satisfy new customer needs on time and with less cost penalties. So acquiring flexibility in the Supply Chain seems the only way to keep the business going especially in the global market. However, because of the complex structure of a SC, defining flexibility is a hard work. So flexibility has to be inspected in details with its each vital element in the Supply Chain's complex hierarchical structure.

Of course acquiring flexibility alone is not enough to guarantee the competence in the market. The most important factor is the overall performance of the SC (Trkman, Štemberger, Jaklič, and Groznik, 2007; Li, Ragu-Nathan, Ragu-Nathan, and Rao, 2006). Flexibility is one of the factors that affect SC performance. Another popular subject on the SC literature is the Enterprise Resource Planning (ERP) systems. ERP systems are supporting the SCM activities and guarantee the works to be handled on time and without mistakes if they have been implemented in the company successfully. However, there is a considerable amount of risk in the implementation success of ERP systems. Since these systems need to be integrated to many levels of the SC structure and they change the way of things handled in the system to great extends, as a prerequisite, companies needs to be ready for this change. Otherwise these pricey ERP software implementation efforts will probably result in failure and this result may affect the SC performance negatively instead of achieving the expected gains in the performance. In contrary, if implementation results in success, ERP system will help companies to act more flexible and, as a result, a considerable increase in the performance of the SC will be acquired. But the success of the implementation relies on some prerequisites that have to be satisfied before and during the implementation phase.

To increase the chance of ERP implementation success, some steps in the companies should be followed to get the structure ready for the implementation. But just following the implementation steps yet alone doesn't guarantee the success. Basically managers of the companies who would like to invest on ERP software should make some structural changes in the company's SC before the implementation phase. This is where Business Process Re-engineering (BPR) comes into play.

BPR requires some radical changes in the SC structure that will result in a change-ready SC structure. Of course, reaching "*open to changes*", "*ready for a successful ERP implementation*", "*ready to get more flexible*", "*ready for higher SC performance*" states are not easy. Similar to the ERP implementation, success of BPR application is not also guaranteed. There are some prerequisites needs to be fulfilled in the BPR application too. If the steps required to fulfill these prerequisites have been followed during the application, SC can be re-engineered successfully which will result in a new, promising SC structure that is open for changes such as ERP implementation and an increment in SC flexibility. All these would result in a considerable increase in the SC performance.

1.2 Scope of the Thesis and Importance of Findings

Because of the highly competitive market environment effective SCM gained a great importance as an Operations Management (OM) strategy. Effectively managing a SC means increasing the system performance to keep the competitive advantage. To track the changes in the performance and benchmark companies' performance, first of all some metrics to measure SC's performance are need. One of the goals of this study is to acquire proper metrics to measure overall SC performance. This metrics have been gathered from the literature and by the analysis carried out by using statistical analyses, in which the real-life data have been used that was gathered by over 200 questionnaires. Then they have been weighted according to some expert evaluations that came from different sectors by using Analytic Network Process (ANP) analysis to propose Supply Chain Overall Performance Score (SCOPS) measurement approach. By using SCOPS metric, SC managers can evaluate their SC's performance and benchmark its performance whenever needed.

As mentioned, an extensive literature survey has been carried out before the development of SCOPS metric. Some gaps have been found during these survey studies such as; lack of service sector SC performance evaluation metrics, real-life applicability problems of proposed metrics, single-firm focused development of metrics, etc. After determining these problems mentioned in the literature, studies in the direction of proposing a new aggregated SC performance evaluation metric in the thesis has been shaped aimed to fill these gaps. So an additional field studies have been carried out in both manufacturing and service companies to test the performance indicators selected from the literature with more than 200 questionnaires that has been applied by cumbersome face-to-face interview method. As a result of the studies carried out, contribution of the SCOPS metric to the literature can be briefly summarized according to its properties such as:

- Coverage of entire SC activities,
- Consideration and integrity with SC flexibility evaluations,
- Consideration of the effects of ERP implementation success
- Consideration of BPR application success,
- Real-life validated metrics,
- Applicability to both manufacturing and service industries,
- Metrics included are easy to calculate in real-life.

After developing SCOPS metric, another goal of the thesis is to improve SC performance. As mentioned in the previous section, having a more flexible SC system is a great advantage on the competitive market and positively affects overall SC performance. But as the definition of the flexibility, also its measurement is a hard process. There are many elements spread all over the SC hierarchy regarding flexibility. Proposing a solution to this problem is the second goal of this study. After completing the literature surveys and questionnaires, vital flexibility metrics have been gathered together and weighted by experts coming from different sectors by using *Hybrid Fuzzy Analytic Hierarchy Process (AHP) / Multiple Linear Regression models* to propose Supply Chain Overall Flexibility Score (SCOFS) to measure flexibility. By using this score, managers of the SC systems can easily answer the vital question of "*How flexible I am?*". By the use of the SCOFS proposed in this study, companies can evaluate their flexibilities and they can find the weak points that lack flexibility in their SC hierarchy.

Similar to the SC performance evaluation metrics, literature addresses some gaps about the SC flexibility evaluation studies. Most important of these gaps is the focus of the majority of flexibility studies is being manufacturing flexibility. Second problem related with most of the current studies is the lack of integration between the flexibility metrics and performance metrics. Also when inspected carefully detailed evaluation of the flexibility hierarchy levels has been omitted in the studies and they have been focused mainly on few of the levels or only one level of the hierarchy; which decreases the chances of the applicability of these metrics in real-life. To develop a detailed flexibility evaluation metric and to be certain of its real-life applicability, in addition to the extensive literature surveys also field studies have been carried out as it has been done in the SCOPS development process. As a result of all these studies, proposed SCOFS metric's contribution to the literature can be briefly explained by defining its properties as:

- Coverage of all vital SC flexibility hierarchy,
- Integration with the SC performance evaluation metric (SCOPS),
- Consideration of the effects of ERP systems,
- Applicability in both manufacturing and service industries,
- Real-life applicability as a result of easy-to-understand factors used in the evaluation of each level.

Following the achievement of two main goals of the thesis by creating SCOPS and SCOFS metrics, studies carried out for the improvements of SC performance and flexibility have been almost completed. Firstly by using SCOFS, factors affecting flexibility have been evaluated in the SC hierarchy for different flexibility levels by the *Hybrid Fuzzy AHP / Multiple Linear Regression* analysis. As a result of these analyses flexibility factors that needs the most attention of SC managers have been specified. After determining the factors needed to acquire a flexible Supply Chain structure; importance and effects of flexibility on the SC performance have been evaluated by using SCOPS and SCOFS with the *Hybrid Fuzzy AHP / ANP / Simple Linear Regression model*.

Like the flexibility, ERP system has a great impact on the SC performance. So a *Hybrid ANP / Independent Samples t-Test / Simple Linear Regression model* has been solved to prove the effect of ERP on SC performance (measured by SCOPS). Additionally, to prove the interactions between the ERP system and the SC flexibility (measured by SCOFS) *Hybrid Fuzzy AHP / Independent Samples t-Test / Simple Linear Regression model* have been built. Of course ERP systems have to be implemented successfully to create positive effects on both flexibility and performance. As mentioned on the previous section the necessary steps to be followed during the ERP implementation have been gathered from the literature.

These steps have been evaluated with their relations to the ERP success with Multiple Linear Regression (MLR) model.

Last factor considered in the thesis that affects the SC performance is the BPR. Same as determining the effects of ERP, a *Hybrid ANP / Independent Samples t-Test / Simple Linear Regression model* has been solved to prove the effect of BPR on SC performance (measured by SCOPS). As mentioned before, validity of "prior application of BPR, increases the chance of ERP implementation success" hypotheses has been proved by Independent Samples t-Test. But since some conditions have to be met for a successful BPR application these important steps that affect the success of BPR have been found by the results of related MLR model.

Proposal introduced in the thesis to enhance SC performance, which has been explained up to here, can basically be summarized as in Figure 1, which states the steps need to be followed to achieve an increment in the SC performance. As it can be seen from the Figure 1; BPR lies in the base of all performance achievements, which may be surprising at first thought, but this finding has been validated by the analyses carried out in the thesis. This proposal will be expanded and will be structured as a detailed framework in the following chapters.

Figure 1: Proposal of the thesis

As a result of studies carried out so far, required evaluation metrics have been collected from the literature and from the field studies for measuring SC performance and flexibility and determining the effects of flexibility, ERP, and BPR on SC performance. Each of these metrics and factors has also been validated by the use of proper methodologies. Also, ERP's effect on SC flexibility and BPR's effect on ERP success have been proved by the results of related questionnaire studies and statistical analysis. By using these results, important factors affecting BPR, ERP and flexibility have also been emphasized one by one.

After completing the necessary analyses, another ANP model has been used to weight the BPR, ERP, and flexibility according to their effects on the SC performance. After determining these weights, finally a *Hybrid ANP / Fuzzy AHP / Multiple Linear Regression model* have been built to summarize the effects of flexibility, ERP, and BPR on SC performance. An easy-to-use road map for the evaluation of SC performance increment strategies has been prepared as a result of this last analysis.

SC managers can use this model as a strategic decision tool while making investments for performance increment purposes. As a result of this final model flexibility, ERP, and BPR factors have been weighted according to their effects on SC performance by considering their interrelations. By combining the results of this final model with the findings of the previous models a scoring system has been created to evaluate the total SC performance and total SC flexibility. Base performance and flexibility scores can be calculated by using the metrics developed in the thesis. And improvements in the SC performance can be tracked easily, which are resulted from the BPR application, ERP application and flexibility improvement efforts.

By doing so, a road map for SC managers has been created to assist them on their investment decisions with performance increment in mind. They can decide how to distribute the amount of money and time they are planning to invest between BPR application, ERP implementation and achieving flexibility. Result of this study will also help managers to clarify the way they should follow to reach their objectives with success.

1.3 Outline of the Thesis

Following chapters have been organized starting by a detailed literature survey in Chapter 2 about the Supply Chain Management literature, which also includes SC performance and flexibility topics. Details related with the current findings that focused on the performance and flexibility evaluation metrics has been summarized in this chapter. Also gaps in the literature related with the SC performance and flexibility measurement methodologies have been stated. Following the SC literature surveys, detailed explanations and backgrounds of ERP and BPR literatures including their developments, success and failure factors and the areas of their implementations have been summarized.

Chapter 3 explains the methodology followed in the thesis, together with the related literature surveys, that consist of questionnaire studies conducted, Multi Criteria Decision Making (MCDM) models and statistical methods used. This chapter also includes the list of related metrics to evaluate SC performance and each flexibility level with the studies that addresses them. Also the explanation of the expert pair-wise comparison questionnaires used for the MCDM methods have been given. Detailed explanation of the analyses methods and formulations regarding to each method used has been explained in details in this chapter.

Starting with Chapter 4 applications of related mathematical models and statistical calculations have been explained in details with their results. This chapter contains the explanation and creation of base SCOPS and SCOFS metrics. Also SC flexibility hierarchy and determination of factors that affect each level of SC flexibility have been proved in this chapter.

Chapter 5 contains the related calculations and models that verify individual success factors of BPR application and ERP implementation. Most importantly this section has the related analysis that proves the interrelations between BPR, ERP, SC flexibility, and SC performance.

Chapter 6 proposes a model to weight the main three factors that affects the Supply Chain performance according to their importance with strategic investment in mind to acquire an increase in performance. As a result of analysis carried out in this chapter, development of SCOPS metric has been completed.

Finally in Chapter 7, aggregation of all findings achieved as a result of analysis carried out throughout the thesis has been done. Purpose of this chapter is to combine each evaluation tool under organized formulations. These formulations shaped the SCOPS and SCOFS metrics proposed in the thesis. And by using these two metrics a road map to evaluate supply chain performance under the effects of flexibility, ERP, and BPR has been prepared. Steps that need to be followed have been explained in this chapter to apply the proposed methodology, which also summarizes all the findings of the thesis.

CHAPTER 2

BACKGROUND INFORMATION AND LITERATURE SURVEY

In this chapter, reasons of why Supply Chain receives much attention from practitioners and researchers have been explained with SC's importance. Need for a higher performance and effects of flexibility have been researched. As mentioned in the first chapter, there is a connection between the BPR, ERP, and flexibility. Each one of these SCM strategies has an effect on SC performance. To investigate these effects more deeply a detailed background literature survey has been carried out. After explaining, "*what are they?*" and "*why are they important?*" criteria related to the measurement of these strategies' success and the way these criteria have been used in the thesis have been explained in the following chapters.

2.1 Supply Chain Management

Nowadays, globalization of market forces companies to face more competitive and complex business environment (Carvalho, Barroso, Machado, Azevedo, and Cruz-Machado, 2012; Chen and Lin, 2009). Fighting individually for staying alive is no longer an option for business organizations (Baç and Erkan, 2011). To keep the competitive power in today's market environment, enterprises have to rely on their SCs (Gong, 2008) and they must respond quickly to the changes on the market conditions (Braunscheidel and Suresh, 2009). Competition is no longer between the individual companies in the modern world; it is between the SCs (Trkman et.al., 2010). This explains why SC receives so much attention from practitioners and researchers today (Chuu, 2011).

In the globalization era, competitive advantage can be gained by creating customer value, differentiating the benefits, achieving the firm efficiency, resulting in market share and it is also related with the creation of supplier competencies (Sukati et.al., 2011). In order to raise the competitive advantage of companies, most of the managers also try to unify the whole functions of company within the framework of SCM (Tan, 2001).

SCM covers large scale of areas of operations in the business organizations. These areas extend from operational level to tactical and to strategic levels (Simchi-Levi, Kaminsky, and Simchi-Levi, 2008). Each level represents a hierarchical structure of different functions. Each level in the hierarchy consists of different decision categories (Cho, Lee, Ahn, and Hwang, 2012). Operational level requires everyday ordinary decisions mostly related to the production planning. Tactical level consists more rare decisions related with the policies of the company and some evaluation efforts. Lastly, strategic level decisions are the ones that have been made by the top management regarding the long-term planning and strategies of the company by considering the organizational goals. These differences in each level require different measurement supports, so different categories of evaluation metrics are needed for each level of the SC.

Different researchers define SC differently than others. One of the common definitions of the SCM has been made by Lambert, Cooper, and Pagh (1998) as "*Supply Chain Management is the integration of key business processes from end user through original supplier that provides products, services, and information that add value for customers and other stakeholders*".

Christopher (1992) defines SCM as a network of functions of the organization, which integrates a number of processes to create value in the form of products and services.

Another definition of the SC, which suits best to today's market conditions, is Porter's (1985, 1998) "Value Chain" definition (Su and Yang, 2010), which can be defined as "*a chain of activities that gives the products more added value than the* *sum of the added values of all activities*" (Wang and Wu, 2012). This definition fits perfectly to the objective of SCs.

General framework of Value Chain approach has been given in Figure 2. According to Porter (1985), a business organization is supposed to achieve sustainable competitive improvements to keep its place in the continuously changing market (Finne, 1997). If it is possible to unify the whole strategic organizations in the value chain, the firm can behave as a single integrated entity, so its performance also can be increased by the system of suppliers (Tan, 2001).

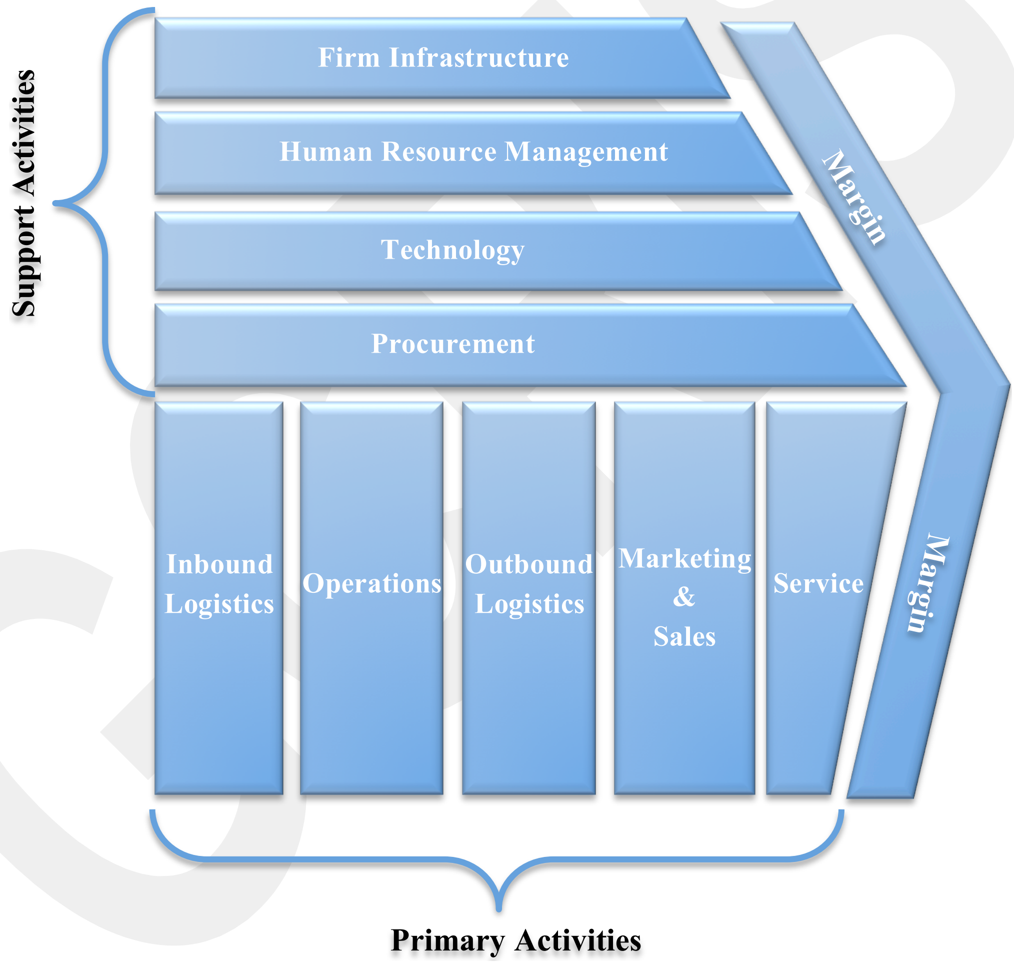


Figure 2: Porter's (1985) Value Chain framework

Dynamically changing business environment needs an effective SCM. Dynamic SCM requires unified decision-making procedures among autonomous supply chain partners with efficient decision information synchronization (Wadhwa, Saxena, and Chan, 2008).

Operations Management (OM) strategies have to be considered by the business organizations to keep their competitive power. SCM is one of the most important approaches that have a direct effect on the OM's performance and flexibility (Gunasekaran and Ngai, 2012a; Li et.al., 2006). For this reason, performance and the efficiency of the SCs have to be enhanced (Chang et.al., 2008).

2.1.1 Supply Chain Performance

SCM is a 21st century paradigm that focuses on the globalization and aims customer satisfaction (Su and Yang, 2009). Companies developed SCM operations strategy to compete in the market (Gunasekaran and Ngai, 2012b; Wu and Chuang, 2010).

SC performance measurement has gained great importance recently (Ganga and Carpinetti, 2011; Taticchi, Tonelli, and Cagnazzo, 2010). To keep or acquire competitive advantage with the rival companies, performance evaluation and improvement of the SC have to be carried out regularly. SC performance has been proved to have effects on competitive advantage (Forslund, 2007) and financial improvements (Presutti and Mawhinney, 2007), in addition to its effects on many other important parts in the companies' overall performance (Gunasekaran and Kobu, 2007). As a result, effectively managed SC offers many advantages such as increased customer services, reduced cycle times, decreased cost, etc. (Banomyong and Supatn, 2011).

To improve the SC performance, first of all, measurement of the performance has to be made for evaluation and benchmarking purposes. To do so, some performance metrics are needed (Gunasekaran, Patel, and McGaughey, 2004). It is not possible to manage a process if its performance cannot be measured (Neely, Adams, and Kennerley, 2002). These performance metrics proposed by many researches in the literature have been discussed in Chapter 3.

There have been some criticisms of the performance metrics' lack of connection, integration, and standardization (Elgazzar, Tipi, Hubbard, and Leach, 2012). Most individually proposed metrics are far away from evaluating the SC as a whole and measurement difficulties rise from their complexity makes them hard to apply in real-life (Ganga and Carpinetti, 2011). Another criticism is about the majority of the metrics proposed in the literature are being related with the manufacturing industry and there is a need of service industry compatible metrics (Cho, Lee, Ahn, and Hwang, 2012). SC performance evaluation metrics should cover the entire system with all of its vital elements to be meaningful (Moon, Yi, and Ngai, 2012; Baç and Erkan, 2011; Shepherd and Günter, 2006; Beamon and Chen, 2001; Gunasekaran, Patel, and Tirtiroglu, 2001). Supply Chain Operations Reference (SCOR) is one of the performance evaluation systems that consider many hierarchical levels in the SC.

SCOR model, by the Supply Chain Council, has been introduced (SCC, 2009) for the performance measurement and benchmarking of SC operations. The SCC developed SCOR model in 1996. This model divides and evaluates SC in three main levels and under five major management processes (Erkan and Baç, 2011).

SCOR model has been a very popular measurement tool to evaluate the Supply Chain performance since it has been introduced (Giannakis, 2011). Benchmarking, best practice analyses, BPR, and process measurement strategies have been integrated in the SCOR model (Elgazzar et.al., 2012). By doing so, a guide for the executives to make evaluations based on some KPIs have been provided (Huang et al., 2005; Lockamy and McCormack, 2004).

Process details considered by the SCOR model according to hierarchy structure it uses can be seen in Figure 3. Implementation phase represented by Level-4 is not included in the SCOR model, because each company has their own unique implementation steps and application procedures.

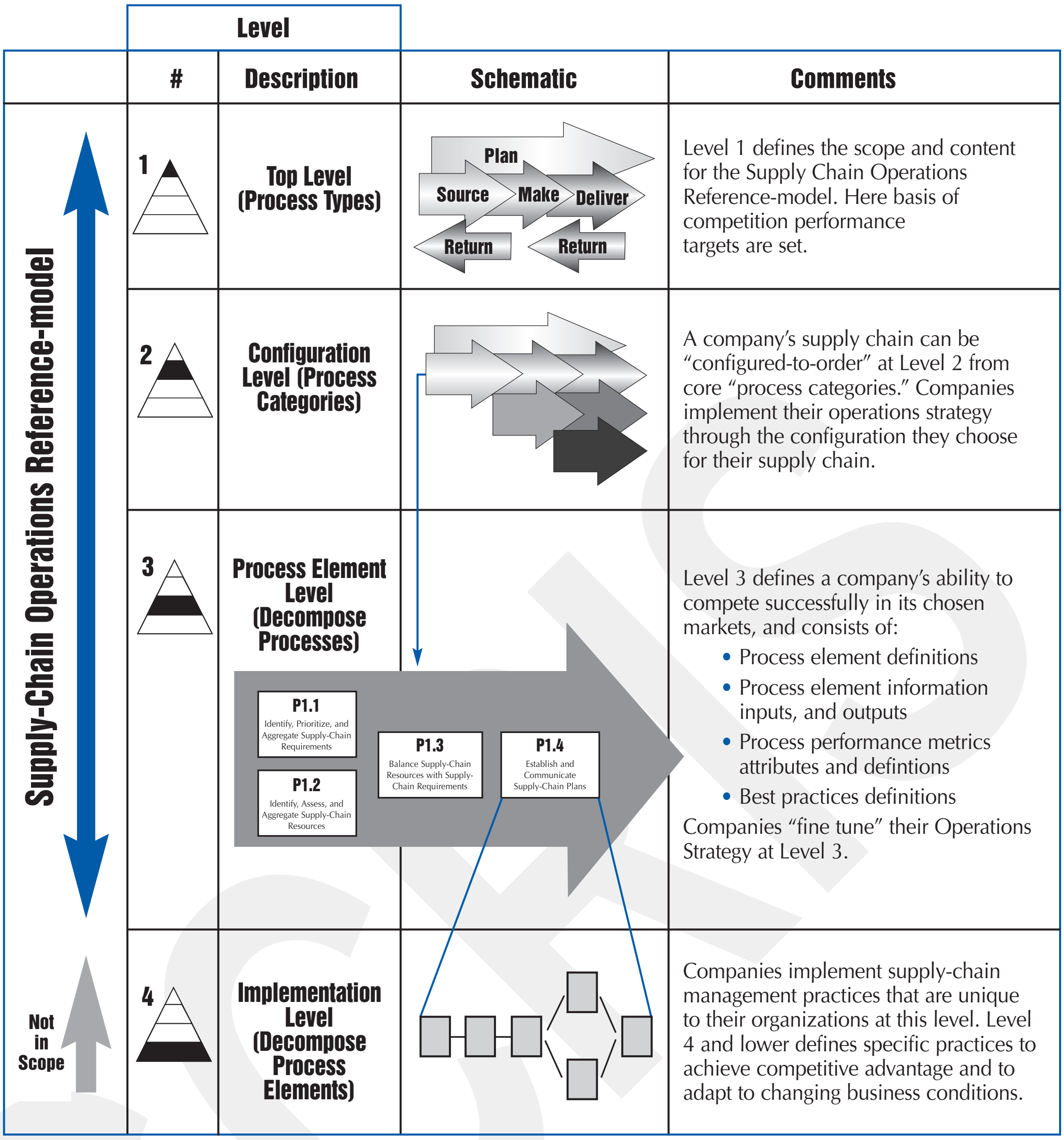


Figure 3: Hierarchical levels of process details in the SCOR model (SCC, 2009)

In the top level of the SCOR model there are five major management processes, which are plan, source, make, deliver, and return. This structure perfectly fits to the SC system's operation. Details of the Level-1 of the SCOR model have been given in Figure 4.

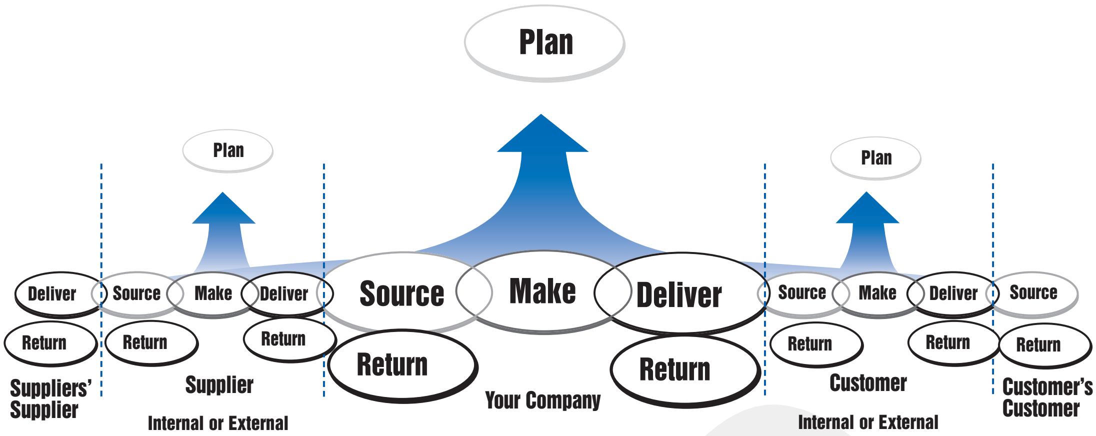


Figure 4: Five major management processes in the SCOR model (SCC, 2009)

In the structures given in Figures 3 and 4; SCOR model includes standard performance metrics for evaluation and comparison purposes that are easy to implement (Elgazzar et.al., 2012). SCOR model captures all the vital hierarchical levels in the Supply Chain (Ganga and Carpinetti, 2011), as it should be as a performance evaluation system.

For its ability to cover various hierarchical levels in the SC system, development of performance and flexibility metrics and the selection of factors to calculate these metrics are based on the SCOR model in the studies carried out in the thesis. By the use of standardized metrics offered by the SCOR model and the researches from the literature, some KPIs have been gathered together to evaluate SC overall performance in the thesis. In the development phase of the proposed metric also important factors such as SC flexibility, ERP, and BPR have been considered in the selection of KPIs. Developed metric would contribute to the literature by its ease of calculation and content that covers SC flexibility, ERP, and BPR by its applicability to both service and manufacturing industries. ANP approach has been used in the weighting of the KPIs that forms the metric for the validity of the proposed metric to take the interrelations into account.

2.1.2 Supply Chain Flexibility

In addition to the metrics needed to evaluate SC performance and benchmarking efforts, flexibility should also be considered to evaluate competitive power of business organizations (Ngai, Chau, and Chan, 2011). SC flexibility begins to attract more attention of the researches (Merschmann and Thonemann, 2011). As the uncertainty and the amount of frequent changes occur in the market increased (Carvalho et.al., 2012; Wu and Chuang, 2010), companies are adding flexibility as a dimension to their operation strategies (Chuu, 2011; Sánchez and Pérez, 2005). According to Gunasekaran and Ngai (2012b), OM has shifted from mass production to mass customization, which requires a great amount of flexibility. Maintaining SC flexibility is important to adapt the continuous changes in the market to keep competitive advantage (Moon, Yi, and Ngai, 2012; Carvalho et.al., 2012; Merschmann and Thonemann, 2011; Chuu, 2011; Gosling, Purvis, and Naim, 2010; Riley and Lockwood, 1997).

Flexibility has important effects in the strategic plan formulation of companies. It sometimes indicates quickly and radically changing of a function or an activity of companies that is being used (Parthasarathy, 2007).

Similar to SCM, flexibility also has different dimensions and it is hard to define it, because of its complexity (Gosling, Purvis, and Naim, 2010; Sánchez and Pérez, 2005). Gerwin (1993) defines flexibility as the adaptive response to environmental changes. In general, flexibility can be defined as the company's capability of orienting itself to the changes with little sacrifices in cost, effort, time, or performance (Morlok and Chang, 2004; Upton, 1994). SC flexibility spans a wide spectrum from the aspect of Value Chain (Vickery, Calantone, Dröge, 1999). After a literature search carried out, Moon, Yi, and Ngai (2012) defined SC flexibility as "*the capability of an organization to respond to internal and external changes in order to gain or maintain a competitive advantage*". This definition suits well to the definition of flexibility as it has been used in the thesis.

Literature addresses many studies that emphasize the need for flexibility evaluation for the measurement of SC performance (Liu and Papageorgiou, 2013; Gunasekaran and Spalanzani, 2012; Gunasekaran and Ngai, 2012a; Moon, Yi, and Ngai, 2012; Saarijärvi, Kuusela, and Spence, 2012; Prajogo and Olhager, 2012; Prajogo and Olhager, 2012; Chuu, 2011; Merschmann and Thonemann, 2011; Vijayasarathy, 2010; Ivanov, Sokolov, and Kaeschel, 2010; Gunasekaran and Ngai, 2009; Cheung and Myers, 2008; Gong, 2008; Simpson, Power, and Samson, 2007; Swafford, Ghosh, and Murthy, 2006; Naim, Potter, Mason, and Bateman, 2006; Gattorna, 2006; Sánchez and Pérez. 2005; Oke, 2005; Chan, 2003; Vickery, Calantone, and Dröge, 1999).

According to Gunasekaran and Spalanzani (2012), SC flexibility should also be evaluated for the measurement of the performances of both the manufacturing and service industries. In addition to the manufacturing flexibility evaluation tools, which can be easily found in the literature, there is a need for service flexibility metrics too (Cho, Lee, Ahn, and Hwang, 2012). However majority of the studies in the literature researches machine or production flexibilities, which focus on the manufacturing industries, but keeping the overall flexibility in the core of studies is more important (Gosling, Purvis, and Naim, 2010; Sánchez and Pérez. 2005).

Business organizations are investing in flexibility in the modern world for the advantages it brings in terms of competition (Golini and Kalchschmidt, 2011). For these reasons, flexibility should be considered in the evaluation of SC performance (Trkman et.al., 2010). However, studies that focus on the overall SC flexibility and its effects on the SC performance, as its integrated part, remain limited in the literature (Malhotraa and Mackelprang, 2012; Moon, Yi, and Ngai, 2012; Merschmann and Thonemann, 2011; Chuu, 2011; Sánchez and Pérez, 2005).

SC flexibility should also be evaluated according to different levels in the system's hierarchy (Malhotraa and Mackelprang, 2012; Moon, Yi, and Ngai, 2012; Ngai, Chau, and Chan, 2011; Chuu, 2011; Sánchez and Pérez. 2005; Swafford, Ghosh, and Murthy, 2006; Vickert et.al., 1999). By the evaluation of flexibility in different SC hierarchical levels, more accurate measurement of overall system flexibility can be carried out.

In addition to collection of information about the SC performance KPIs, flexibility levels and indicators, some methods are needed to combine these metrics together to form an evaluation metric. Use of fuzzy theory, MCDM, and group decision making methods are preferred in various SC flexibility analysis (Elgazzar et.al., 2012; Ganga and Carpinetti, 2011; Elgazzar, Tipi, Hubbard, and Leach, 2011; Chuu, 2011 and 2009; Varma, Wadhwa, and Deshmukh, 2008; Sharma and Bhagwat 2007; Lin, Chiu, and Chu, 2006; Wang and Chuu, 2004; Chan, Qi, Chan, Lau, and Ip, 2003; Chan and Qi, 2003). Among these methods, fuzzy approach has been suggested for the evaluation of SC flexibility because of its ability to cope with the uncertainty, which flexibility has in its nature.

To contribute to the literature by combining the SC performance and flexibility in an evaluation metric; studies carried out in the thesis has a significant importance form the aspect of the findings. Flexibility evaluation metric developed in the thesis includes different levels of SC flexibility hierarchy, instead of focusing only on the manufacturing flexibility, as suggested by the literature. Also, studies carried out to determine the factors affecting each level in the hierarchy have been carried out in both manufacturing and service industries by considering the real-life applications in more than 200 companies. All importance-ranking studies have been carried out by the use of fuzzy logic to overcome the difficulties flexibility brings along from the aspect of evaluation. As a result of the studies, an overall Supply Chain flexibility evaluation metric has been proposed which can be applied in any company regardless of its size and type. Literature survey's details about the flexibility hierarchy levels and the metrics related with each level that have been used to evaluate them in the overall SC flexibility score metric have been discussed in Chapter 3.

As it can be realized from the findings of literature survey carried out, SC performance improvement studies have gained a great importance under the complex and highly competitive market conditions. Because of the uncertainty and the high rate of changing conditions in the market, in addition to the SCM, SC flexibility, IT investments (such as ERP), and re-engineering efforts are popular research areas and investment strategies to cope with the market conditions (Gunasekaran and Ngai, 2012b).

As mentioned before the theory prominent in the thesis is to achieve flexibility in the SC to increase performance and keep/obtain competitive advantage in the current market conditions. As the literature suggests achieving flexibility is a requirement to adapt changes. The primary supportive factor of SC flexibility is determined as the ERP systems in the thesis. But also ERP implementation requires a supportive strategy for the implementation success, which is BPR. Importance of these two OM strategies will be identified with the related literature surveys in the following sections.

2.2 Enterprise Resource Planning (ERP)

In 1990, the term ERP was firstly used and described by Gartner Inc. research firm. When it began to use, it became one of the identification tools of software applications (Laudon and Laudon, 2004). ERP is related with the software infrastructure that integrates the whole company both internally and externally (Parthasarathy, 2007). Thus, ERP can be seen as a software package, which is used to unify the overall business organizations (Chase, Aquilano, and Jacobs, 2001). It may be the most rapidly expanding information and software implementation system because nowadays most of the companies have applied or been applying an ERP system (Zhang et.al., 2005).

ERP systems have been created and improved as a response to changing business requirements and new technologies (Parthasarathy and Anbazhagan 2007). ERP is described as the necessary method that companies can use it for their competitive business process upgrades (Ibrahim, Sharp, and Syntetos, 2008). ERP's purpose is to unify the fundamental business processes that are important in all functions of the firm by facilitating the flow of information. These business processes make the organizational functions to work as organized, unified and given importance to successful productions and efficient service (Laudon and Laudon, 2004).

Most of the companies think that ERP systems have many advantages in information technology. ERP systems are desired and for a successful ERP implementation an effective plan, an efficient coordination process and also the control of internal resources are necessary (Nah, Lau, and Kuang, 2001).

Davenport (1998) indicates that ERP is a total of commercial software systems that provide a perfect flow of information through the company's SC and customer information systems. According to Nah et.al. (2001) ERP is the total of business software systems that make it possible for a company to control the internal resources such as finance, human resources and distribution by ensuring a unified information system. Kumar and Van Hillsgersberg (2000) state that ERP is a total of information systems that coordinate the flow of information in the functions of an organization. O'Leary (2000) defines ERP as total of computer-based systems that make it easy to integrate and plan the productivity and customer responses.

ERP aims to create an efficient flow of information even between the departments that are not located in the same region. It facilitates the communication between the company's suppliers and distribution centers. In parallel with the ERP definition of O'Leary (2000), ERP can coordinate the company's activities synchronically. However, ERP systems are seen too complicated, time spending and also expensive. It is always needed to have an additional budget to apply the ERP systems can be resulted as decrease of costs, developed workflows and re-engineering processes (Taylor, 1999).

ERP is related with the term flow of information, and aims to increase its speed through a company. It also tries to lessening the cycle time, decreasing costs and developing the SCM practices (Davenport, 1998). With the ERP implementation, a company should be managed more effectively by choosing the best practice for business processes, ensuring online access to information, standardizing processes and creating one-source information that cause less confusion (O'Leary, 2000). By these purposes, it is desired an increasing in the coordination within the business, efficiency in communication skills and facilitation of organizational planning (Olson, 2004).

2.2.1 The Structure of Enterprise Resource Planning Systems

The structure of an ERP system ensures a unity between the departments of a company and facilitates the transparent flow of information (Davenport, 1998). According to Kremzar and Wallace (2001), while implementing ERP, there should be a radical change of cultural, organizational and business processes in a company. This can be seen as an indispensable regulation for the success of ERP implementation. However, this radical change of information systems seems difficult to apply for the managers.

ERP systems help the unity of departments, in the meaning of exchange and flow of information; and support the integration of business functions as various as finance, human resources, sales, customer information, marketing and also the SC (Dezdar and Ainin, 2011). Most of the enterprise systems have a deep relationship with Customer Relationship Management (CRM), Supply Chain Management (SCM), Enterprise Resource Planning (ERP), Product Lifecycle Management (PLM), and e-procurement software (Shang and Seddon, 2002). Nearly all of the academic researchers agree that there is a relationship between the enterprise performance and the SC competences. And they also confirm the relationship between the enterprise performance and the benefits of ERP (Chang et.al. 2008). It is examined that ERP has a significant effect on improving future supply chain efficiency, and an explicit risk of ERP limiting progress in SCM (Kashyap, 2011). However, the integration of working system of ERP to the SCM is still an area that is not studied so much (Chang et.al. 2008).

SCM system aims sharing of information, cooperation and decision making among the firms that exist in their supply chains (Chung, Tang, and Ahmad, 2011). The main purpose of a SCM system is to ensure the efficiency of the SC. In order to achieve this goal, it tries to control and manage the SC from concept to market. It has two-tailed relationship potential; while it controls the firm's relations with its customers, it also manages the firm's relations with its suppliers. From this aspect, SCM is an effective tool, which increases the functionalities of ERP systems. Because an increasing number of the SCM systems are now using ERP implementation systems. (O'Brien, 2004).

The major characteristics of the ERP systems are as follows (Davenport, 1998; (Rashid, Hossain, and Patrick, 2002; Macris, 2004):

- It affects the organization directly,
- It redesigns most of the business modules like accounting or manufacturing,
- It is supported with the Database Management System that is a kind of relational database system,
- It is an integrated system so that the flow of information without error and the transparency in operational processes can be provided,
- It is a complicated system and it can cause high costs and also risk,
- ERP systems are flexible,

- It needs time spending configuration plans in order to finish the company's duties,
- It supports the online accession of information,
- It uses Internet as a tool,
- It supports flexibility in language and accounting in international companies,
- It gives support to some industries such as health care, banking or chemicals,
- It can customize the company without using any programming.

2.2.2 *Evolution of Enterprise Resource Planning Systems*

The evolution of ERP systems can be explained at the same period of time with the invention of computer systems. A brief demonstration of the evolution of these systems according to years can be seen in Figure 5.

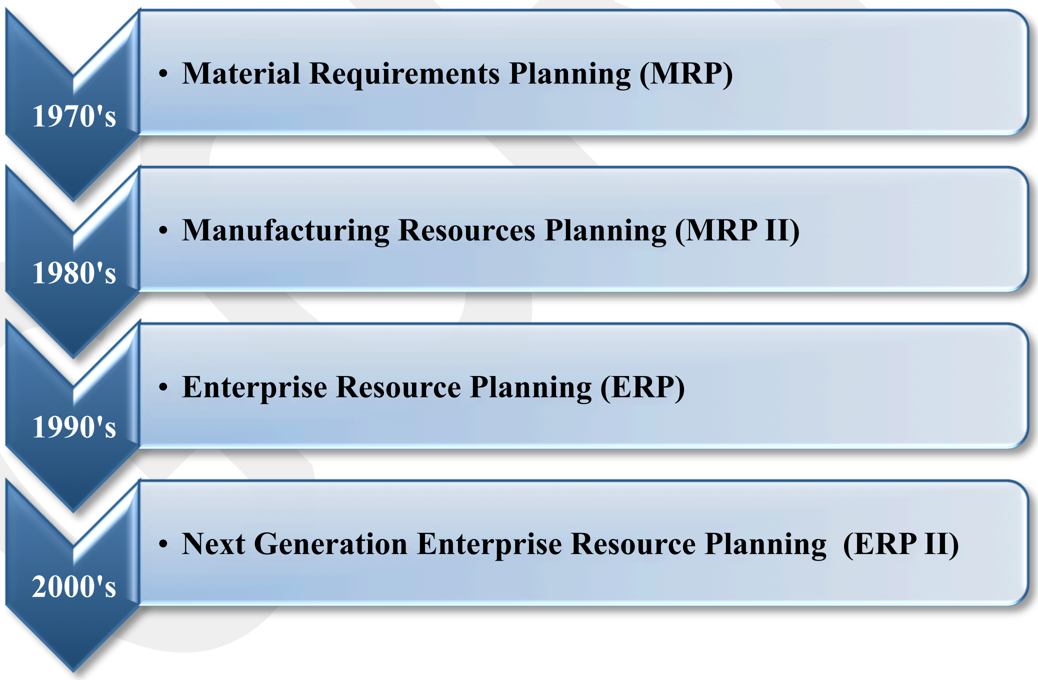


Figure 5: Evolution of ERP systems

In 1960s, in the automation procedure of control systems, the aim was to satisfy the customer's demand. These inventory packages were usually related with different programming languages like that “FORTRAN, ALGOL or COBOL” (Rashid, Hossain, and Patrick, 2002).

In the 1970s, some different systems began to be used, such as Material Requirements Planning (MRP) or Distribution Resource Planning (DRP). These systems also emphasized the automation of all parts of the production scheduling and one-source inventory planning (Kalakota and Robinson, 2001). MPR can be described as an inventory control system and a computational procedure that is used to transform the master-production-working plan for the finished products into a detailed working plan for raw materials and components, which are necessary for the finished products. The detailed working plan includes all the information about the quantities of items, date of order or date of delivery. All these data must be identified for the master-working plan. Both of these working plans should be in use for a successful MPR implementation (Heizer and Render, 2001).

Another phase of these systems is ERP that is began to be used in the end of the 1980s. It can be described as a modification of material requirement planning (MRP) systems that transform master production working plans into detailed working plans of raw materials and components, as it was mentioned above (Grant and Tu, 2005).

In the 1980s, a new software program whose name is Manufacturing Resources Planning (MRPII) began to be applied by companies. This new system tries to synchronize the materials and the production requirements in the manufacturing processes (Rashid, Hossain, and Patrick, 2002). It is advanced kind of MRP, it additionally includes purchasing functions, costing, sales order, etc. It is an expanded model of business requirements planning (BRP) that is not only related with a totally united system but also interested in the manufacturing aspects of the company. (Aghazadeh, 2003).

In the beginning of 1990s, MRPII began to increase its area of influence to finance, human resources, engineering, project management, etc. (Kalakota and Robinson, 2001). ERP evolved from MRP and MPRII and there are some differences between them. For example, ERP is about the system requirements and also technical requirements, it is related with the technological aspects of processes such as graphical user interface, integrated database, fourth generation language, client/server architecture, and computer-based software engineering tools (Russell and Taylor, 1998). MRPII has a traditional structure; it only focuses on planning of internal resources. However, ERP is not only interested in scheduling the internal resources, but also the supplier resources (Chen, 2001).

During the 1990s, the creators and developers of ERP have increased the functions that ERP is related with. As a result of this, the extended version of ERP began to be used which name is ERP II. It contains planning, advanced scheduling, SCM and also Customer Relationship Management (CRM) (Rashid, Hossain, and Patrick, 2002). ERP II indicates the importance of flow of information as a business strategy that can cause going beyond the boundaries of a company (Macris, 2004).

2.2.3 Objectives of Enterprise Resource Planning Systems

Globalization can cause challenges in organizations. ERP is a supportive tool for achieving these challenges. It uses human capital management, financials, operations and analysis as a method. It aims to develop productivity, understand and answer the changes in market and apply new business strategies. So that, the competitive advantage of a company can be increased compared to the other companies (Mishra, 2008). The main object of ERP are to aid businesses in achieving succeed in the global marketplace by uniting and synchronizing the isolated functions into business processes (Davenport 1998).

The previous troubles with the information systems lead companies to use new information technologies. ERP systems can be seen as a problem solver model that is why it began to be used. It includes technological infrastructures that are created to support the possibility of use of other processes (Holland and Light, 1999). Although ERP systems seem complicated and troublesome to apply, by using a structured, coordinated and disciplined model, this problem may be overcome easily (Ptak and Schragenheim, 2000). ERP systems make it possible to manage the deployment of resources within a single organization. By using ERP, companies can automate and develop their basic activities such as manufacturing, human resources or SCM. So that they can make it easier to control the management system, accelerate the decision making process and decrease operational costs of the business (Holland and Light, 1999). ERP is deeply related with the integration, standardization, synchronization, extension and assurance of future flexibility for corporate processes (Bingi, Sharma, and Godla, 1999).

Flexibility is important not only for improvement and sustainability, but also for successful management processes (Parthasarathy, 2007). By using ERP systems, it can be easier to provide the flexibility of production, and to handle with the difficulties of customer orientation. There is an explicit difference between some industries that are using the production planning systems and that are not using. The industries that utilize ERP systems can achieve a competitive advantage in the market (Curran and Ladd, 2000).

Most of the managers generally think that the ERP implementation processes are causing a pause on the productivity of the firm. And if any other change is needed, some difficulties can occur such as long delay time and high costs of making changes. However, some investigations show that, rather than a continuous improvement, rapid change of the business processes and SC structures are preferred by both managers and customers. Thus the flexibility in adapting to changing supply chain can be more effective by using the ERP systems which accommodates the changing processes (Akkermans et.al., 2003).

2.2.4 Advantages and Disadvantages of Enterprise Resource Planning Systems

Davenport (1998) indicates that ERP implementation provides many benefits to the organization, such as decreasing of cycle time, advancing flow of information, promotion of the e-business, faster transactions, better financial management and supporting to constitute new organizational strategies. According to Cliffe (1999), applying an ERP system is seen expensive and risky. However, since the benefits of this system are understood, most of the companies think that they can overcome its troubles and apply the system successfully (Markus and Yanis, 2000).

There are many positive effects of ERP systems. Creating important value for the company by applying various flexible supply chain options is one of the advantages of ERP systems (Hayes, Hunton, and Reck, 2001). More strategically, while using ERP system, dealing the whole business environment with a Business Process Re-engineering (BPR) project can support the improvement of the enterprise's performance (Chiplunkar, Deshmukh, and Chattopadhyay, 2003).

As it was explained in the BPR section of the thesis, BPR is a change of business processes by rethinking and reshaping, whose aim is to reach an effective degree in the measures of performance like customer service, quality and cost (Hammer, 1990). The ERP implementation is a systematic procedure that integrates both the business process and ERP system. The firms that utilize the BPR must make the ERP systems convenient to their changed business processes (Xue et.al., 2005).

Rockefeller and Rockefeller (1998) state that BPR is a significant part of the ERP implementation. According to authors, business experiences and procedures can be seen as a guide or a mapping process for the further investigations. Being a guide can compose the basis of the whole ERP system. The re-design of the procedures can be managed by the vendors of ERP software, by the consultants or by the organization's own working team (Keller and Teufel, 1998). An ERP system also helps to assure better service to customers and to strengthen supplier partnerships (Willis, Willis-Brown, and McMillan, 2001). If the mapping process can be carried out perfectly, the BPR implementation will also be successful (Plenert, 1994).

Some companies can have difficulties in gaining the measurable advantages of ERP systems (James and Wolf, 2000). However, it is possible that there can be some unprecedented benefits of ERP implementations on business computing and business process improvements (Watson and Schneider, 1999). According to James and Wolf (2000), it is obvious that many of the advantages of ERP systems cannot be predicted in the beginning of the implementation steps. This process should be seen as an investment for future activities and for future growth that is based on the IT of the companies.

In the paper of Su and Yang (2010), "A structural equation model for analyzing the impact of ERP on SCM", the benefits of ERP systems tried to be explained. According to the results of this analysis, when the benefits of ERP systems in a firm are investigated, flexibility can be seen in some of the title of ERP benefits. The former example is that, as an operational benefit, flexibility indicates the developed engine repair scheduling and delivery to constitute the business flexibility. The latter is that, as a customer and relationship integration, flexibility can be described as a tool of adaptation to suddenly occurred operational circumstances. The organizational culture is also an important factor that affects the flexibility. If the organizational culture permits the re-engineering of the processes, this firm can get better improvements. In the business re-engineering processes, flexibility is a supportive tool of quicker adaptation and effective changes of organizations (Oliver, 1999).

It is possible to list the benefits of ERP systems, so the first advantage is to facilitate the flow of information and ensure accurate and consistent information (Davenport, 1998). Elimination of unnecessary data and operations is another advantage of ERP (Rashid, Hossain, and Patrick, 2002). By using ERP systems, firms can gain competitive advantage over competitors (Kremzar and Wallace 2001). O'Leary (2000) also indicates that it is a competitive necessity to apply ERP system. It provides an integrated enterprise that all functions and departments can do their works coordinated (Dillon, 1999). Another benefit of ERP is improvement in the SC due to the use of e-communication and e-commerce (Yusuf, Gunasekaran, and Abthorpe, 2004). ERP systems can be seen as a catalyzator of radical and deep business changes that cause significant performance development (Watson and Schneider, 1999). So gaining efficiency can be possible by reshaping the business processes with ERP (Graham, 2009).

Besides the advantages of ERP, it has also some disadvantages. For example, there may not be cohesion between the packages and needs of the company (Markus and Tanis, 2000). Another disadvantage of ERP is that it takes long period of time to redesign the information technology. And also it needs high budgets to implement ERP. Companies may not use a budget that is so high, and they have to wait maybe years to gain the benefits (Holland, Light, and Kawalek, 1999). ERP's may not have a positive effect on business practices and organisational culture if it is implemented defectively (Soh, Kien, and Tay-Yap, 2000).

Generally, ERP systems are complicated, and their implementation procedure is expensive, time consuming, and challenging, but they have worthwile benefits (Taylor, 1999). If it may be possible to apply successfully, the advantages it yields will be more reliable and strong (Sebastianelli and Rishel, 2003). As a result, a company, which uses ERP implementation, can gain important benefits as it was mentioned above (Kremzar and Wallace, 2001).

2.2.5 Fundamental Success and Failure Factors in Enterprise Resource Planning Implementation

The critical success factors (CSFs) were first introduced by John Rockart, in 1980s (Boynton and Zmud, 1984). CSFs have an importance in realizing the stated purposes of organizations. They are also significant for the success of the ERP implementation. CSFs try to make it easy to identify and prioritize the factors, which affects the success (Dezdar and Sulaiman, 2009). There are various approches and numerous authors that investigate these factors (Dezdar, 2011). In literature, there are diverse studies that are written to emphasize these factors. The prerequisites for the success of ERP implementation can be investigated widely (Umble, Haft, and Umble, 2003).

For example, one of the key ERP implementation prerequisites is to understand the strategy and the strategic purposes of business. So the consistency between the projet strategy of ERP and the strategy of enterprise is one of the implementation items (Yang et.al., 2007). The goals and expectations should be clearly described. The company's strategy must be appropriate with the whole business strategy (Parr and Shanks, 2000). Successful ERP implementation requires an explicit definition of purposes, improvement of work and resource plans, and the scope of the project (Laughlin, 1999).

In order to achieve a successful implementation the key business processes must be re-engineered. This means that an effective ERP implementation must be related with the BRP procedures (Minahan, 1998). The purpose of ERP should be to develop the business, not to implement software. So the implementation process should be manage by business itself and meet the business' own requirements (Chew, Leonard-Barton, and Bohn, 1991). The ERP implementation team is also an important factor that affects the success of ERP. Because, the team will be responsible from creating a detailed project plan, determining due dates and deciding which resources will be needed (Umble, Haft, and Umble, 2003).

One other critical success factors is the education of implementation team and the workers. Responsibility and job definitions must also be determined and the education procedure must be applied (Hutchins, 1998). All the ERP implementation success factors that has been considered in the studies carried out in the thesis has been explained in details with the related literature studies that address them in the following chapter.

As a summary, for conducting a successful ERP implementation, adopting an explicit business purpose and milestones, taking care with team composition (Krammergaar and Rose, 2002), understanding of the basis of changes, considering the project risk, conducting a powerful leadership and monitoring the budget are the main success factors (Mandal and Gunasekaran, 2003).

To implement the ERP system successfully is not sufficient itself, if the system is not flexible enough to adapt the changing needs of company (Davenport, 1998). The high costs in deployment and the difficulties in sustainability of ERP systems are the main complaints of both corporations and managers (Schniederjans and Kim, 2003).

Implementation of ERP is a large and complex operation that can result some unsuccessful implementations on business performance (Parr and Shanks, 2000). Davenport (1998) states that most of the ERP implementation systems fail during the application period. This can be good evidence about the difficulties of ERP implementations.

One of the most important reasons of ERP implementation failures is the workers resistance of applying the system (Kapp et.al., 2001). Education and training are the key factors that affect the success or failure of the implementation. They may sometimes be undervalued and be given less time, as a result cross-functional business processes can not be understood exactly (Zhang et.al., 2005). Technically complicated solutions need much expertise, and the lack of experience can also be the cause of failures (Davenport, 1998). As it was mentioned before, BRP is also an important factor that affects the success or failure of ERP implementation process. The resistance to apply BRP in a company can cause the failure of ERP systems (Schniederjans and Kim, 2003).

The causes of ERP implementations failure can be given as follows (Umble, Haft, and Umble, 2003):

- Deficiency of strategic purposes.
- Deficiency of top management's support
- Deficiency of project management implementation.
- False choice about the implementation team.
- Not being ready to make differences.
- Deficiency of education and training.
- Mistrust in data.
- The difficulties of applying new performance measurements.

An organization should aim to apply a successful ERP system, which facilitates to improve and implement a variety of flexible supply chain alternatives. So that organization can gain significant cost and value advantages (Lai, 2006), such as decreasing of operating costs, generating accurately forecasts of demand, reducing production cycle times, and increasing customer satisfaction (Yang et.al., 2007).

2.3 Business Process Reengineering

Main purpose of the thesis is to propose a road map for evaluating and increasing Supply Chain performance by achieving flexibility to gain competitive advantage by adapting the frequently changing market environment. So increasing the flexibility is vital nowadays to compete with the rival companies, but to achieve flexibility successful ERP implementation is needed. As mentioned before, success of ERP implementation depends upon many factors, among which, Business Process Re-engineering (BPR) is the most crucial one that prepares the SC structure for the changes that ERP brings along. As a result of these dependencies, factors needed for acquiring performance improvements extends back to the BPR, which underlies the main factor that prepares the system for the change and improvement; which makes it the most important strategic performance improvement factor.

BPR is being thought as the main element, which prepares the firms for ERP culture. In the thesis, BPR strategies and their affects will be investigated from the aspect of their applicability on SCs together with their effects on the performance. As a result of the thesis, a road map will be built to design a flexible SC to increase the efficiency and effectiveness of the system. This system will be supported with the ERP, which will be implemented to the SC successfully with the help of BPR applications.

2.3.1 Business Process Management (BPM)

To understand BPR clearly, Business Process Management (BPM) should be comprehended first. BPM can be defined as a general approach that leads to organizational improvement. According to Lee and Dale (1998), BPM is an improvement of processes that is analytical, structured and cross-functional. Zairi (1997) states another definition of BPM. As a structured and analytical approach, BPM makes a combination of the use of improvement tools such as re-engineering and benchmarking. Moreover, manufacturing, marketing, communications and other important elements of a business' operation are the fundamental activities that are continuously improved and analyzed by BPM.

Peppard and Rowland (1995) state that the effectiveness and the success of BPM is related with the power of the significant organizational drivers that encourage the impetus for change. The globalization, technological developments, regulations, the stakeholders' action and the change of business boundaries can affect the process' fundamental drivers (Armistead et.al., 1997).

2.3.2 Business Process Re-engineering's Importance

Information managers who have a vision to plan, guide, and lead the implementation of required changes in information technologies and throughout the SC needs to consider re-engineering. Because of the improvement processes in both of management sciences (as BPR) and information systems (as ERP systems), the information systems of the enterprises become to be based on process-oriented rather than data-oriented (Dong, 2001). The way that firms conduct their business is the process of change and it is called re-engineering. Re-engineering projects are defined by scope and magnitude of these changes. For example, a process redesign can be seen when a re-engineering project affects only a single business process and is being implemented to streamline for efficiency. Business re-engineering is considered, if a project affects one of the core business processes and is being implemented to match the best practice of another company.

If re-engineering is done properly, it can produce dramatic gains in productivity and organizational capability (Reinhard, 2005). At the end of 1980's and at the beginning of 1990's, when re-engineering has begun to be used, BPR has seen as an effective tool of support that can be the cause of developments of the organization’s performance (Huizing et.al., 1997). Most business firms have recognized the need for re-engineering. Such companies as IBM, Xerox, Kodak and Ford Motor have succeeded in re-engineering efforts and this has motivated scores of other companies to begin their own re-engineering initiatives.

According to Preissler (2000) re-engineering is not comprehensible or cannot be easily defined. Sometimes it can be said that re-engineering is a confusing syndrome. It frequently becomes the disguise for a downsizing activity. Some organizations prefer to re-engineer functions; this is mostly mentioned reason for failure in re-engineering projects.

As a strategy, re-engineering is selected and constructed in terms of the criteria of profitability and the maintenance of workplace power relations (Rinehart, 2001). Re-engineering and other management strategies intended to control the labor process. They are not evidence of revolutions or transformations in a labor process because workers are continuing to acquiesce the old system and resist these new managerial attempts to control (Lavin, 2006). Manganelli (1993) indicates that the chosen content of a project contains only a part of the process, thus the possibility for success is diminished, and maybe eliminated. When processes cross-organizational boundaries, via decreasing the count of mistakes and reducing the inefficiencies that arise in the business is one of the main reasons that re-engineering improves performance. Many organizations cannot select the correct processes to re-engineer; because, they do not take account of projects’ importance to the firm. Manganelli

(1993) also emphasizes that effective re-engineering projects are focused on strategic value-added processes and concludes that the path to success in any project with a content as deep and broad as a re-engineering project requires a detailed methodology.

Re-engineering replaces comparatively cheap low asset based information technology for something that are not cheap, such as physical products and people (Preissler, 2000). Re-engineering makes it possible for the information systems organization to push computer power out to users, breaking down the barriers that once segregated the information systems function from the rest of the organization. Re-engineering based on firm management support and an open creative atmosphere. Both information systems and Supply Chain managers are working for the same results. It is hoped to do more with less while increasing competitiveness and to cut costs while offering extraordinary customer service (Delligatta, 1992). Re-engineering gives an opportunity for both to respond to these challenges.

Bill Gates states, "*an important re-engineering principle is that companies should focus on their core competencies and outsource everything else*" (quoted in Beneden, 2000). Corporations should decide the activities which are core and which are not core. After that, the non-core activities are outsourced. The cause of outsourcing is reducing the costs (Grimshaw et.al., 2002).

The aim of re-engineering is to leave the rules of organizing and managing a business that are not sufficient in the development process. It rejects some of the old rules and then tries to find creative new ways to make the work more effective. These new rules may be created with the desire to reach a high degree of improvement in performance (Khan, 2000). Michael Hammer, firstly uses the term of Business Process Re-engineering (BPR), in his article in 1990, '*Re-engineering Work: Don't Automate, Obliterate*' and defined it as a way to breakthrough the slow continuous improvement barriers, promising fast, massive improvements. According to Hammer and Champy (1993) BPR is "*a redesign and rethinking procedure of business processes whose purpose is to have successful improvements in most of the business performance measures, such as quality, cost, service, and speed*". In order to align its activities with its strategic business objectives, BPR disregards the organizational charts, quits the procedures that are applied and using, and questions the old assumptions to reshape the basic way the firm manages (Johansson et.al., 1993). The alignment between functional actions and critical purposes is one of the key factors that affect the success of businesses. If businesses exhibit such alignment, it will be more successful and effective than those that do not (Miller and Hayslip, 1989; Williams and Novak, 1990; Hill, 1994).

2.3.3 Business Process Re-engineering as a Business Strategy

Manganelli and Klein (1994) try to make a definition, which emphasizes on optimizing workflow and productivity of an organization. According to this definition, BPR is the fast, sudden and extreme reshape of strategic, fundamental business processes, and also the systems, procedures, and organizational structures that encourage them to optimize the workflows and productivity of an organization. BPR's purpose is the coordination of strategic resources to make the customer value important. Re-engineering tries to create process structure and eliminate procedures that do not have any importance from the customer's point of view. Thus, BPR can be seen as a revolutionary program, which focuses on organizational change to make business processes more effective, efficient, and flexible (Grover et.al. 1995; Stoddard and Jarvenpaa, 1995). According to Reif (2001) BPR's main question is "*What is the best way to accomplish this task?*". In order to answer that, BPR requires the examination of processes from a perspective using today's best-known business practices and technologies. If BPR is successful, it means that it involves multiple parties: Individuals who currently perform the work, customers or users who interact with those who process the work, technologists, and managers. These are the parts of a working BPR team; these individuals leverage technology and best practices to reduce work and time spent on tasks, in case streamlining business processes.

BPR is discontinuous and revolutionary so it is not like classical improvement programs which are continuing and incremental (Short and Venkatrarnan, 1992; Hammer and Champy, 1993). In classical incremental improvement programs, the changes through the operation systems are evaluated by using decision criteria. However, there is an increasing proof that these classical evaluation criteria are not coherent with a long-term fundamental outlook (Wheelwright, 1984; Schroeder,

1984) and, also with the purposes of BPR. The need and the developments of research are the elements of a new modeling procedure that evaluate the effects of BPR redesigns according to the firm's strategic goals (Crowe et.al., 1997). BPR would rather strategic changes in a firm's management system because increasing changes may not be sufficient for the firm to become effective and competitive (Barua et al., 1996). According to Konopka (2007) BPR is a tool of improving business processes to reform businesses to sustain competitiveness in today's marketplace. The main characteristic of BPR is the idea of changing the entire process not just improving parts of it. Replacing the old processes with the new ones would be more optimized process; because, it is not sufficient to ensure new approaches in performance to empower employees with a better tool. Business re-engineering can be described as reconsideration and reshape of an whole business system such as jobs, organizational structures, organization systems and values and beliefs to achieve dramatic developments in performances (Preissler, 2000). In the 1960's re-engineering has emerged as the much-touted remedy, deriving many basic concepts from the systems analysis and operations analysis disciplines (Wilde, 1992). It has seen that re-engineering of business processes could be successful by borrowing from the information technology and Industrial Engineering disciplines and by defining the common non-value-added activities across functional hierarchies (Knorr, 1991). Davenport and Short (1990) state that the industrial engineers of the future will focus on the redesign of business process enabled by information technology. This can be an explanation of why re-engineering projects are often technology based.

The main goal of BPR is "*rethinking the practices of business*" to meet the needs of customers (Paper et.al., 2001). It is related with making fundamental change in how companies conduct business, about rethinking everything from down to top, about starting with the proverbial clean sheet of paper (Hammer, 2001). BPR is focused on reducing cost and cycle time (Lawler et.al., 2001). Because it goes across functional processes, it is mostly associated with information technology to improve those processes (Olson, 2005).

All organizational development processes involve a staged implementation strategy. Bennis and Mische (1995) presented the phased approach to BPR depicted in Figure 6. This five-phased process that apply the new rules and fundamental changes previously described, is suitable with the development processes for the Key Performance Indicators (KPI) and ERP information processing capability to support and monitor the BPR impact (Pietka, 2003).

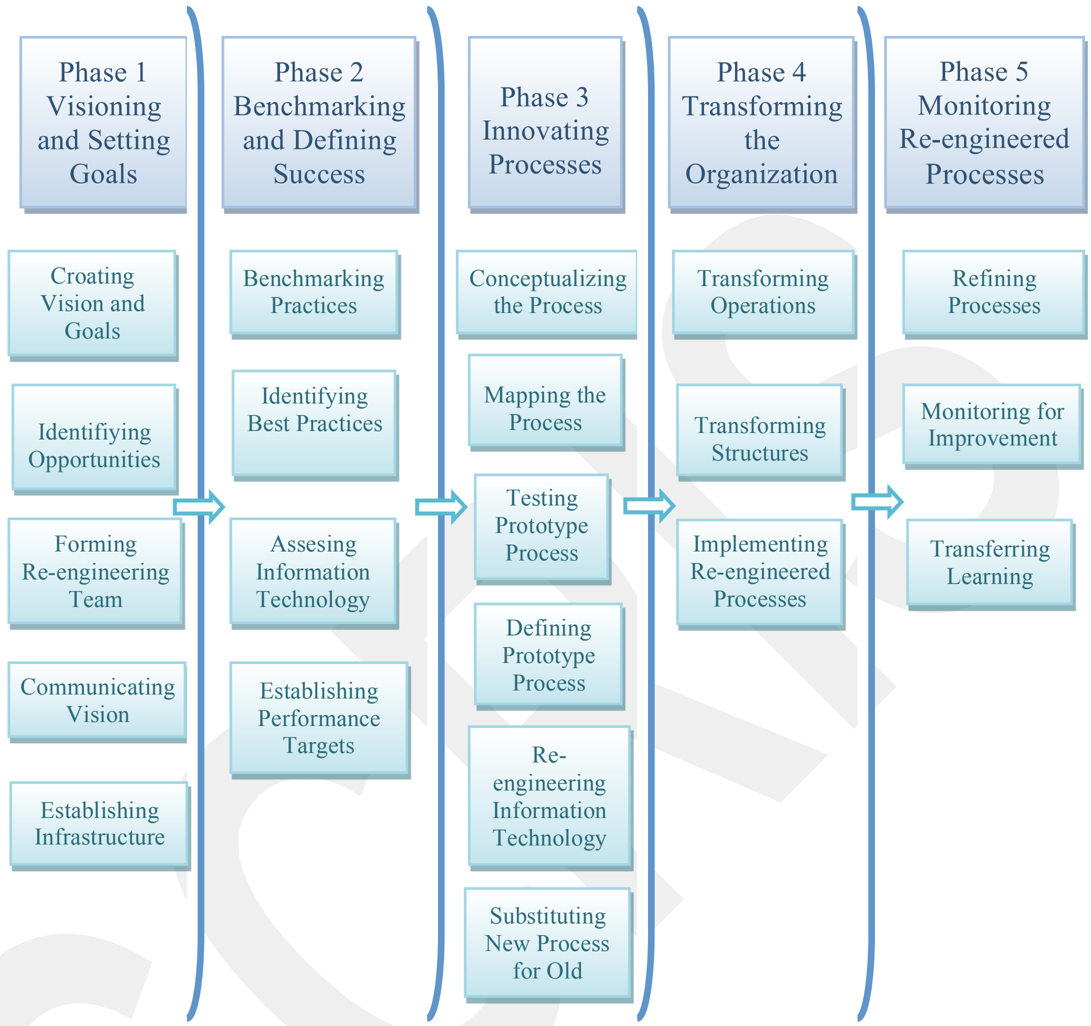


Figure 6: Phased approach to BPR (Bennis and Mische, 1995)

The fields of BPM and BPR try to better learn a business's important mechanisms to develop, or sometimes change the business performance by describing the new business opportunities for outsourcing, for improving business effectiveness and for areas within the business that technology is used to contribute the business processes (Lindsay et.al., 2003).

Organizations are mostly obliged to make basic, rapid and critical change in order to gain or even retain customers (Birkner and Birkner, 1998) because the global competition environment is forcing organizations to become leaner and more convenient (Paper, Rodger, and Pendharkar, 2001). It is needed to give rapid answers that shows no sign of slowing (Hammer, 2001) There is a desire to drive so many innovative organizational change strategies for example employee involvement, total quality management (TQM), and BPR (Lawler, Mohrman, and Benson, 2001). Most of these strategies try to make the organization more effective (Lawler et.al. 2001) so that they focus on improving processes and improvement projects, which are the instruments of the improving processes (Gryna, 1988; Pyzdek, 2001). As organizational performance improvement strategies, TQM and business BPR can be used one or both by organizations to succeed (Jarrar and Aspinwall, 1999). It is possible to say that there is a movement to instill organizational stability. And organizations are experimenting with performance improvement strategies' combinations such as combining the most successful examples of TQM and BPR to attempt to pace remaining and quantum developments in a continuous improvement procedure (Jarrar and Aspinwall, 1999).

Despite the effect of information technology on business is massive, Champy (2000) stated that the magnitude of the change would be limited by the ability of the company and its people to control the change process.

2.3.4 Information Technology Enabled Business Process Re-engineering

The developments in manufacturing technology that tries to decrease production cost and in Information Technology (IT) that makes it possible the massive amounts of data to be transmitted at an unprecedented ratio have changed most of the classical ways of doing business (Ng, 2002). According to Ozcelik (2005), it is useful to leverage the possible benefits of using IT in operational units, so that firms prefer re-engineering their business processes. This is called as 'IT-enabled BPR'. According to Tapscott and Caston (1993) the computer usage in business can cause some important shifts for an organization. Each of them affects a different kind of business opportunities. In order to function as an integrated business and become an extended enterprise, using IT makes it possible to create a high-performance team structure and to develop further relationships with the other organizations,. By using BPR, a business can increase its value. But it should first change the way that how IT is applied (Konopka, 2007).

Business processes are reshaped by IT that makes it possible to simplify the information traffic between globally distributed processes, and guarantees the usefulness of abrupt and permanent information across the business (Tapscott and Caston, 1993). According to Davenport and Short (1990), there is a close relationship between IT and BPR; both of them are continuing to refine each other. Moreover, IT is not only composed of automating outdated functions. It has a significant importance because of exploiting its possibilities to design new effective and successful business processes (Hammer, 1990; Venkatraman, 1993).

In the 1990s, the popularity of IT-enabled BPR was related with the idea that firms need to apply IT in their business units as part of an organizational development and change process (Milgrom and Roberts, 1990). This is the cause of unsuccessfulness of investments in IT and re-engineering in isolation (Barua et.al., 1996). Moreover, the benefits of IT may be more than predicted because of the negative interactions with current organizational practices (Brynjolfsson et.al., 1997). As a result, it is assumed that during the 1990s, firms invested approximately $1.6 trillion in IT-related intangible assets and on the contrary, re-engineering is spending nearly $167 billion in IT equipment (Brynjolfsson and Yang 1997).

According to Brynjolfsson and Hitt (2000), an important part of the worth of an IT investment is its capability to enable the possible changes in business processes and work procedures of firms, that cause increasing of productivity by reducing costs or developing intangible sides of current products, such as timeliness, quality or variety. In reality, re-engineered business processes of the firms can become more productive and effective than the others (Brynjolfsson, 1994).

As it is mentioned, most of BPR practitioners think that the success of BPR is related with the way of application of Information Technology (Tapscott and Caston, 1993; Kettinger et.al., 1995). Hammer and Champy (1993) stated that re-engineering process require a change on the way company thinks about IT. They also tried to explain the implementation of state of the art IT as a fundamental enabler toward BPR. In re-engineering process, the application of IT can be seen as a tool that has affected all functions and departments of firms. For example it increasingly displace classical labor and capital inputs because of the superior price and performance advance in IT equipment comparatively to these inputs (Dewan and Min, 1997).

There are many advantages of IT-enabled BPR. Organizations, which use it, can gain the satisfaction of customers, growth of sustenance, financial advantages and so on. CIGNA Corporation can be an example of a firm that is succeeded in completing so many IT-enabled BPR projects, and achieved to save approximately $100 million by developing customer service and increasing the degree of quality while reducing operating costs (Caron et.al., 1994). Manganelli and Klein (1994) state that the convenient methodologies of re-engineering should indicate the empowerment of human resources and also the application of IT as the most important enablers of radical changes. The terms that are used in an organization management procedure have also so many impacts over IT process. Modernization and simplification of capturing and distributing processes, coordination between departments, success of analyzing and decision making, and also parallelism in enabling process change are the examples of these terms and processes (Davenport, 1993).

It can be said that the emerging trend of adopting commercial IT application packages, such as enterprise systems (ES), presents a challenge to traditional strategic IT research; because, it is inspired from previous analytical assumptions with regards to technological and process heterogeneity (Chen, 2004). In information systems (IS), one of the key trends is to move to enterprise systems (ES). ES can be described as a process-based application system, whose purpose is to coordinate the transactional information systems and business processes in a distributed business environment. The ES' value comes from the system-enabled managerial, operational, and strategic support that it offers (Shang and Seddon, 2002). ES is a kind of integrated transactional system that encompasses several interconnected modules while covering major functional areas of an enterprise. Business operations are influenced by its implementations in two significant ways. The former way is to feature a central database and open system architecture; ES contains an application information technology (IT) infrastructure that integrates information flows across functional information systems (IS) (Weill and Broadbent, 2000). The infrastructure flexibility of IT increases by the modularized and client-server architecture, in terms of scalability, connectivity, compatibility, and integrity (Byrd and Turner, 2001). The scope and flexibility of long-term information support and IT infrastructure capability are affected by the use of ES. The latter way is to be a process oriented system. ES is a fundamental catalyst for BPR. The business value is related with some ES capabilities such as IT infrastructure capability, BPR capability, knowledge management capability, and IS management capability (Lee and Lee, 2000; Markus and Tanis, 2000; Sprott, 2000; Davenport, 2000; Dibbern, Brehm, and Heinzl, 2002). The supporters of BPR have convincingly emphasized the important role of IT infrastructure in cross-functional communication, coordination, and integration (Venkatraman, 1994; Rockart, Earl, and Ross, 1996; Broadbent, Weill, and Clair, 1999). ES makes it possible to reshape the business processes, as an infrastructure-related tool. It uses the ways to design and facilitate the flow of information across organizational entities and ensures their consistency and availability (Davenport, 2000). ES-based IT infrastructure encompasses a high level of IT and business process integration; an essential function did need to achieve business process optimization and strategic resource advantage (Venkatraman, 1991). BPR is a continuous process across the life cycle of ES implementation. It is continuous because it does not only happen in the early stage of system planning and implementation. It permanently tries to maximize the strategic utilization of ES (Davenport, 1998). If firms hope to capture the benefits of ES, they should examine their business processes constantly to align them with the changing business environment. However, Devaraj and Kohli (2002) have been given some detailed examples of unsuccessful IT-enabled BPR projects. There is also a need for further investigations to understand whether IT-enabled BPR does really provide benefits for organizations.

Davenport (1998, 2000) emphasizes on the BPR's important effect over the success of ES deployment and utilization. According to the case data analysis of Ng (2002) (including Quantum, Digital China, Nestle, International Multifood, Metalica, Tektronix, Geneva Pharmaceutical, University of Nebraska, Dow Coming, and Dead Sea Works), Business Process Re-engineering is the major driving force for ES implementation. As a result of these data analysis, the implementation of ES involves many essential issues of business process design. The best practices of industries should require extensive process change, and as a transaction-based application, ES imposes its implementations. The institutionalization process of ES-entailed best practice is a little complicated. It causes wide organizational change and the involvement of functional professionals (Dibbern, Brehm, and Heinzl, 2002; Hall, 2002). The firm's capacity in job design leads to the success of institutionalizing the best practice and for this it is necessary to have management skills in coordination and integration of the firm. It is expected to deploy ES efficiently from the firms that can develop process thinking and implement appropriate change strategies. And also, empirical researches show that in ES deployment, BPR is a significant variable. So that, the value of ES is related with the success of BPR (Ng, 2002).

An extensive information system that unites all aspects of a business should be a part of the company. In this situation, a business re-engineering plan seems to be successful (Bingi, Sharma, and Godla, 1999). Service and Maddux (1999) have the same thought and additionally they say that the quantum leaps in productivity, the company's competition ability and sustainable competitive advantage can be the results of developed information systems. This is not a new approach; because Porter (1985, 1998) emphasized the information systems' strategic value in changing the way companies do business (Porter and Millar, 1985).

In order to carry out the ES project and to smooth the process of ES deployment and process re-engineering, there is a need of employed cross-functional teams, process ownership, articulated vision of business process, and renewed organizational incentive systems and job design. In the literature, the examples of this situation can be seen as it is mentioned above (Westerman and Cotteleer, 1999; McFarlan, Chen, and Peimers, 2002; Pliskin and Zarotski, 2000; Radosevich, 1997).

BPR capability has been measured by Chen (2004) by using 7 items, which were derived from prior researches. According to Chen (2004), BPR's measurement items highlight re-engineering mechanisms which are recognized as major driving forces in the success of BPR, such as shared business responsibility and risks, integration of ES and business process, and organizational incentive systems. This measurement frame is designed for capturing the social complexity of ES-enabled BPR. It covers the contextual factors that are possible to cause a deviation from the assumed ES outcome. Studies of Chen (2004) finally showed that the grade of BPR capacity is integrated with ES outcomes, which BPR has also a positive and statistical effect on.

2.3.5 Fundamental Success and Failure Factors in Business Process Re-engineering

Hammer (1993) states that re-engineering is getting more out of people instead of much getting rid of people. Sometimes it can be difficult to measure the benefits of systems projects, so it is needed arbitrary judgments to quantify benefits such as increased productivity, increased quality, and reduced costs. Re-engineering systems have some similar characteristics with other systems. Its benefits can not be measured easily, because they may be intangible. But, for the justification of the large investment and gauging the success, making objective measurements are necessary. So, the use of indirect measurements is increased.

Ozcelik (2005) indicates that the success of BPR and the evaluation metrics can change both from firm to firm and inside the same firms department. Furthermore, the hopes about the success of BPR may be varying from one organization to another. For example the sense of success in an organization may not be the same in another one. In detail, if the market share of a new company increases, this can be seen as a good performance. However, if the profit margins are decreased by higher market share, this may not be sufficient for an established and old firm. Another example is that, the measures of BPR success can differ even across the departments within an organization. As an explanation, the improvements in the Return on Investment or Return on Assets can aid to measure the productivity of a company. This is useful for the finance department of a firm.

Scientific management has some continual practices, such as the pacing and directing of work, the separation of conception and execution, the standardization, rationalization, simplification, and reutilization of tasks, activities, and processes, the obsession with monitoring, measuring, and scrutinizing the work and the worker, disciplining and rewarding workers for their performance and behavior, the endurance of hierarchical relations among management, supervisors, and workers, and the perpetual preoccupation to speed up the pace of work. These may be seen as fundamental for managers who undertake the Business Process Re-engineering (Head, 2003). If there is not a proper planning prior to BPR implementation, the process can result in failure. To create an effective plan, important factors must be determined and applied to planning effort of the implementation process. According to Hazeltine (1993) the causes of most failures are the lack of project leadership at the top or the difficulty associated with looking at the world in a different way. Huizing, Koster, and Bouman (1997) indicate four independent factors that can affect the achievement of BPR performance improvements. They state that the organizational fit between the ambition of the BPR project and these four independent factors, which are breadth, depth, planning and coordination must be balanced. In order to make a successful project, organizational fit is one of the key elements of the process.

Raymond, Bergeron, and Rivard (1998) while investigating the BPR process, looked at four independent factors as well. For example, they studied the harmony of BPR principles; the differences of the human resources, methodological trouble of the project and organizational support. They also interested in whether benefits are impressed by the size of the company. Raymond et.al., (1998) stated that the advantages of implementing a BPR could occur not only in large and small medium size firms, but also in large-scale enterprises.

Bashein et.al. (1994), state that it is possible to describe some significant subjects in the business reports to identify the obstacles that re-engineering projects can face. With these described key obstacles, they identified additional positive and negative preconditions to Business Process Re-engineering success. In the literature, the most common condition for success is widely involvement of users about the design of systems (Lees, 1987; Park, 1990). Clement and Van den Besselaar (1993) say that the systems designers should involve users in the systems design process, because designers realize that this involvement will yield better systems requirements and increase acceptance. Also, Bashein et.al., (1994), think that the possibilities of success in re-engineering projects are considerably higher when all administrators in the organization are utterly committed to the effort. They also find that technology based projects may not be so successful if they are not driven by a senior manager. In addition to technology and the highly visible line manager, one of the important factors for success is the connection to an important strategic thrust. According to Dixon et.al., (1994), managers are unanimous in their agreement that top management sponsorship, involvement and commitment that is needed for BPR success.

Success may be easier when empowered workers, with cooperative work styles, are members of the re-engineering cross-functional team. The advantage of having such a cross functional teams is concluded by the researches conducted by Dixon et.al., (1994), Bashein et.al., (1994), and Ng (2002). According to Dixon and his friends (1994) considerable amount of training of the participants is required before the project and also during the project. Bashein et.al., (1994) also find that in re-engineering concepts specialized training and design principles is required.

Bashein et.al., (1994) lists several factors which directly affect BPR success. One of these factors is to have realistic goals and objectives. They think that companies with executives who are eager to understand the problems, risks and opportunities associated with re-engineering can develop realistic targets. If executives can not convince their workers for a change in the company, BPR will fail (Hammer, 1995). Many of the executives fail to ask the probing questions that might lead them to query their basic operating assumptions, to reshape their strategies, and to re-engineer their processes (Hammer and Stanton, 1997). If the re-engineering process can be managed successfully, senior executives must be willing to quit the existing design, to focus on the purpose and function of core processes and to redesign the process using the most appropriate technology available. As with all quality and productivity improvement initiatives, the rest of the employees also must "buy into" the BPR process and be able to form cross-functional teams (Hammer, 1994; 1995). Hammer (1999) states that the re-engineering process can bring all the departments together working toward a common purpose. Although many companies have started the re-engineering process, only a few of them have been successful in changing the way they manage their companies. These companies need to change their systems from process redesign to process management (Hammer and Stanton, 1999). It is significant to have a clear vision for the senior managers of an organization. The way of meeting the strategic purposes for the business processes oof an organization is also a factor that affects success. Re-engineering attempts will be more successful if the project team members are assigned to the project full-time, allowing for their total participation. Also, to be successful, the company must be willing to create an adequate budget. Yasin et.al., (1995), Willis (1998), and Kim and Arnold (1996) say that customer orientation, flexibility, and innovation are also essential for BPR intervention success.

Hall, Rosenthal, and Wade's (1993) study of re-engineering projects defines some factors that are needed to make successful re-engineering projects: Firstly, the firm must set aggressive re-engineering performance targets. Second, assign a senior manager to have responsibility with the project. And finally, manage an extensive pilot implementation before the full implementation. They also say that the failure to build a good measurement system, to track performance before, during, and after implementation can allow a project to drift without proper corrective action. Thus, a measurement system should be developed to measure performance at all departments of the company.

The purpose of the BPR project is another factor of success. Preissler (2000) states that when employees view a re-engineering project as growth-oriented, rather than cost-cutting, they are enthusiastic and the project has a better chance of succeeding. The need of communication is also one of the key factors that he highlights. While the project is underway, communicating the re-engineering team's efforts is also critically important. Communications to the employees should also focus on the positive side of re-engineering.

According to Bashein et.al., (1994) and Manganelli (1993), the success of the project is also affected by the sponsors. As stated by the authors the sponsor is either not a senior level executive or the executive is the wrong sponsor for the project; which cause drawbacks to success. When the content of the re-engineering project is limited to functions, rather than processes, the executive sponsor can not usually do his/her best and this will also cause to influential improvements in effectiveness of organization and advantage of competitiveness (Newell, Swan, and Robertson, 1998). Processes cover broad areas need the most senior management to sanction and guide the project functions cover smaller areas, with a corresponding lower level of management. Middle management is responsible with the daily operations of the firm. They are also an important key for the success of any project that is undertaken at the firm. When middle managers are not included in the design and implementation of the re-engineering project, the managers feel that their power and even their jobs may disappear as a result of the redesign. So that they will actively resist the incorporation of the redesigned process across all functions and sites (Preissler, 2000).

Managements approach is also another issue. Hiring consultants for BPR implementation and isolation current workers and managers from this effort and keeping them at their daily work results in confusion and a continued reliance on the consultants, until the process owner can absorb the new process. This management style and attitude is wrong for re-engineering and most consultants avoid these assignments (Bashein et.al., 1994).

To achieve a successful re-engineering, a significant amount of data collection and analysis should be supported. Enterprise Resource Planning (ERP) is compatible with and supports BPR initiatives (Hammer, 1999). Reif (2001) summarizes the key factors for successful BPR application and indicates that five factors appearing in the related literatures of BPR, in successful BPR system implementations, project management, and outsourcing are always used and in failed implementations they are always absent. These factors are:

- An effective project leader must manage the ERP system implementation to be successful,
- Project content must be controlled,
- Staff must be appropriately participated in the ERP system implementation,
- A successful ERP system implementation must be integrated with the project planning methodology,
- Data conversion and system testing must be the part of a successful ERP system implementation.

Most businesses currently underline analyzing the current processes before and during the implementation period of BPR although Teng et.al., (1998) think that doing such is not statistically important to the goal fulfillment.

It is not certain that every company that uses BPR is going to be successful (Davenport and Short, 1990; Hammer, 1990; Kotter, 1995). Holland and Kumar (1995) determine some important reasons for failures like not selecting the right (meaningful) process, or lack of balanced, sustained executive support. Because of different approaches on the implementation of BPR, technology available in the study period, structure of the enterprise on which the studies carried; there are so many papers that are written in the literature about the results and success of BPR.

Davenport (1998), one of the first researchers of ES and BPR, speculates that the best practice in a single industry might lead to a decreasing of the value of innovation in business process design. The only consistent theme across all the literature is that BPR is not functionally oriented, because it is process oriented. If it can be applied carefully, it is known that BPR can succeed to be effective in a number of areas such as productivity, customer satisfaction, quality of organization, market coverage, reduction of costs and defects reduction (see Teng et.al., 1998; Raymond et.al., 1998; Grover et.al., 1995; Kettinger et.al., 1997; Davenport and Short, 1990; Hammer, 1990). According to Preissler (2000), there should be criteria for measurement of the performance of re-engineered processes, so that it will be easier to contend that an organization's re-engineering projects are successful and contribute to the organization's performance.

The process control system should be re-engineered in order to realize a quantum leap improvement, is required (Earl, Sampler, and Short, 1995). According to Pietka (2003), ERP is a strategy to bring deliberate and fundamental change in the business processes. It aims to achieve breakthrough improvements in performance, also support BPR and so that it organizes the information management capability and makes use of BPR to develop a long-term improvement plan (Hammer, 1999).

Although IT in re-engineering seems very important, designing and implementing an ERP system under a BPR context require a pertinent model. On the contrary, there is an implementation paradigm for integration of ERP and BPR that has four dimensions such as fundamental, process, radical, and dramatic (Ng, 2002). Embedded BPR should allow the setup of workflow according to the organization processes and users requirements, in order to establish core requirements in the conceptualization phase prior to ERP implementation. Generally, to prepare the design and practice of the proposed enterprise information system for global manufacturing, it is possible to follow these seven steps (Ng, 2002):

- Describe the boundaries of the project,
- Determine the vision, values and purposes of the business,
- Reshape business processes and model,
- Evaluate concept and benefits,

- Plan for reaching the solution,
- Implement the reshape, and
- Transition to continuous process improvement and analyze the results.

Through the execution of BPR, enterprises will find that the proposed model is incorporated with the concept of BPR to support ERP that includes the previously mentioned key elements.

BPR has a relationship with the systems development life cycle and ERP systems. ERP systems mainly try to unite the information and information-based processes within and across operational parts in an organization system (Kumar and van Hillegersberg, 2000) and support management decision-making at all levels within the organization (Li, 1999). Hence, BPR activities are complemented and enabled by ERP systems. In the literature BPR is seen as the achievement of performance improvements and there is also a deep relationship between the strategic advantages of ERP's success and the achievement of BPR performance improvements (Kappos 2000). Bartholomew (1999) says that after the advent of ERP, the call for Business Process Re-engineering is increased dramatically. The main product of SAP, Baan, PeopleSoft and their many competitors is software that supports major changes (reinvention) in the firm's current Supply Chain process.

After completing the summary of all the related literature survey that has been carried out to emphasize the importance and the motivation of the thesis, next chapter defines the methodology of the thesis consists of the information related with the qualitative and quantitative studies carried out; mathematical and statistical methods used, and their literature reviews.

CHAPTER 3

METHODOLOGY

After stating the importance of SC performance, flexibility, ERP and BPR by the related literature surveys, methodology to be followed in the thesis has been structured. *Main goal* is to develop some measures to evaluate SC performance and flexibility for benchmarking and improvement efforts in the SCM. *Second goal* is to prove the relations between the SC performance, SC flexibility, ERP and BPR. *Third goal* is to find the related metrics that affects each of these items individually. Some of these metrics (the ones related with performance and flexibility) have also been used to develop the pre-told score measures. After proving all the relations between performance, flexibility, ERP and BPR, and finding the factors that affect each of these items, *final goal* of the thesis is to weight the strategies according to the amount of their effect on SC performance. By the achievement of these goals a road map will be created as the output of the thesis which can be used to evaluate the overall performance and flexibility of the SC and keep track of improvements achieved in the performance by applying BPR, implementing ERP and achieving flexibility.

To achieve these goals six questionnaires have been prepared. Two of them was necessary to make company based evaluations and measurements and four of them was necessary to acquire expert evaluations needed to make the criteria prioritizations required for the analyses of scoring the performance and the flexibility of SCs.

Following the preparation and application of questionnaires Multi Criteria Decision Making (MCDM) analysis have been used to develop score measurement system. As MCDM techniques fuzzy AHP and ANP approaches have been used in the thesis. To prove the related inter and intra relations between the performance, flexibility, ERP and BPR statistical analysis methods such as Simple Linear Regression, Multiple Linear Regression and Independent Samples t-Test have been used. At the most part of the models built in this study includes hybrid approaches that combine the MCDM and statistical analysis. Output of one is used as an input of another.

3.1 Questionnaires

Firstly a literature survey has been completed to designate the factors related with the performance measurement, flexibility categories in the SC hierarchy, ERP implementation success and BPR application success. Following the completion of literature surveys two company evaluation questionnaires and two factor evaluation MCDM questionnaires have been prepared. Both company evaluation questionnaires have been prepared to be applicable on Turkish enterprises in different cities with different sizes and with different operation areas. A 7-point Likert Scale has been utilized in the first two questionnaires. 1 equals to “Strongly Disagree” and 7 equals to “Strongly Agree” options. The mid point of 4 was labeled “Neither Agree nor Disagree”. 7-point scale has been preferred over 5-point scale because of the difficulty of items to be evaluated. Differences between the company sectors make this evaluation even harder. For the reliability of answer 7-point Likert Scale performed well at questionnaire application phase.

On the other hand, MCDM questionnaires have been prepared for the expert decisions for the pair-wise comparisons and interdependency determinations of related factors. These questionnaires have been applied to experts where they came from different sectors such as: academic society, manufacturing sector and service sector. 9-point comparison scale (Saaty, 1980) and linguistic fuzzy scale (Anagnostopoulos et.al., 2007) have been used for these pair-wise comparisons. These scales will be explained in details in the related chapters.

3.1.1 BPR Application and ERP Implementation Successes: Company Evaluation Questionnaire

First questionnaire is designed to measure the SC performance, ERP implementation and BPR application successes on companies. This questionnaire includes performance evaluation metrics; factors need to be satisfied during the ERP implementation and BPR application phases. Performance metrics used to calculate the Supply Chain Overall Performance Score (SCOPS). BPR and ERP successes have been used with SCOPS to prove the effect of these 2 factors on SC performance and to prove the relation between the BPR application and ERP implementation successes. Lastly, factors measured in the questionnaire have been used to clarify the steps that need to be followed to successfully implement an ERP system and to apply BPR to a SC.

Questionnaire starts with general company information questions. These questions have been asked to outline the profile of the Turkish enterprises that has been evaluated. These questions asked to acquire such information:

- Company type,
- Number of employees, and
- Product line.

By using the information above, general understanding of ERP and BPR concepts can be defined for the Turkish companies. Such results will be useful for future researches to make cross-country comparisons.

3.1.1.1 Performance Measurement

First part of the creation of this questionnaire's evaluation questions consists of literature survey to determine the necessary metrics to evaluate SC performance. SC can be seemed as a Value Chain defined by Porter and Millar (1985) and O'Brien (1999). ERP implementation requires BPR application in the Value Chain (Kappos, 2000). Under this assumption, the effects of ERP and BPR can be summarized under some major key performance indicators. There are many metrics on the literature to evaluate SC performance. Most famous and detailed metrics have been defined by the Supply Chain Council (SCC) and known as Supply Chain Operations Reference (SCOR) model. After a detailed literature survey about the performance evaluation of SC systems; some metrics from Gunasekaran and Ngai (2012b); Whitten, Green, and Zelbst (2012); Barnes and Liao (2012); Cho, Lee, Ahn, and Hwang (2012); Prajogo and Olhager (2012); Baç and Erkan (2011); Cao and Zhang (2011); El-Baz (2011); Kayakutlu and Buyukozkan (2011), Trkman, McCormack, Valadares de Oliveira, and Ladeira (2010); Wu and Chuang (2010); Ramaa, Rangaswamy, and Subramanya (2009); Gunasekaran and Kobu (2007); Gunasekaran, Patel, and McGaughey (2004); Kim and Narasimhan (2002); Gunasekaran, Patel, and Tirtiroglu, (2001); Oliver (1999); Beamon (1999); Radding (1999); Stein (1998); Raymond, Bergeron, and Rivard (1998); Teng, Jeong, and Grover (1998); Kettinger, Teng, and Guha (1997); Grover, Jeong, Kettinger, and Teng (1995); Hammer (1990); Davenport and Short (1990) have been selected. Performance indicators gathered from the mentioned literature have been used to develop a new metric to measure SC performance under the guidance of SCOR model (SCC, 2009).

SC performance have been evaluated under the following key performance indicators (KPIs):

- Increased efficiency,
- Improved communication,
- Lower operating costs,
- Increased revenue,
- Reduced cycle times,
- Better collaboration,
- Higher profit margins,
- Higher customer satisfaction,
- Inbound logistics performance,
- Outbound logistics performance, and
- Human Resource Management performance.

Each company has been evaluated for each of these KPIs individually. As a result of these evaluations a score between 1 and 7 has been given for each metric for the company. Also, these KPIs have been used to generate SCOPS evaluation metric, by using ANP analysis as a MCDM tool. This was one of the main goals of the thesis.

To be used as criteria in ANP model KPIs have been named as performance measurement criteria (for evaluating SCPOS) with code $PerCi$ where $i = 1,2,...,10$. For example variable $PerC3$ refers to the evaluation value of performance KPI "*Lower Operating Costs*". Full list of overall performance measurement criteria have been given in Appendix 1.

Among the KPIs listed above; Supply Chain flexibility evaluation had not been defined as a variable. Even it has been shown as a KPI in the literature (Gunasekaran and Spalanzani, 2012), main purpose of the thesis is to investigate the effects of flexibility on SC performance, and effects of ERP on SC flexibility separately. So the effects related with flexibility analyzed individually and more detailed.

Each company's SCOPS have been calculated by using the KPI evaluation scores and ANP results. Then, individual SCOPS values have been used to measure the effects of ERP and BPR on the SC performance in this questionnaires statistical analysis.

Same KPIs in this questionnaire has also been used in the second (flexibility evaluation) questionnaire. In total over 200 companies have been evaluated by using these KPIs during the application phase of the both questionnaires.

3.1.1.2 ERP Implementation Success

Second goal of this questionnaire is to measure the relation between the BPR application and ERP implementation successes. Questions asked for this purpose had the following purposes:

- To learn if the company implemented any ERP software; if so what is the success of this implementation?
- To learn if company applied BPR prior to ERP implementation; if so what is the success of this application?

Face-to-face interviews have been conducted to evaluate the BPR and ERP success scores of the companies. During these interviews companies' successes have been evaluated between 1 and 7.

As a result of these evaluations by using the ERP implementation success, BPR application success and SCOPS; two simple linear regression models have been used to prove the effects of ERP and BPR on the SC performance.

Also Independent Samples t-Test analyses have been performed to compare the companies, which applied BPR prior to ERP and which didn't, to prove the success rate differences of ERP implementations. These tests have also been used to compare the differences in SC performance between the companies that applied BPR and which didn't.

After proving the need for BPR application prior to ERP implementation, and effects of both strategies to the SC performance two more questions remained to be answered: "*What is needed for a successful BPR application*?" and "*What is needed for a successful ERP implementation other than BPR*?". To answer these two questions, which is the last goal of this questionnaire, prerequisites needs to be fulfilled have been gathered from the literature survey for each of these strategies.

Findings of the literature survey required to determine the steps that needs to be followed during the ERP implementation phase have been summarized in Table 1.

Table 1: Prerequisites necessary for successful ERP implementation

ERP Implementation Prerequisites	References
There is a fitment between the company's ERP strategy and the overall business strategy.	Yang, Lin, Pai, and Yeh, (2007); Krammergaard and Rose (2002); Heijden (2001); Davenport (2000); Pliskin and Zarotski (2000); Parr and Shanks (2000); McAfee and Herman (2000); Broadbent and Weill (1997)
ERP implementation related key milestones have been well identified.	Umble, Haft, and Umble (2003); Krammergaar and Rose, (2002); Pliskin and Zarotski (2000); Markus, Axline, Petrie, and Tanis (2000); Markus and Tanis (2000); Sumner (2000); Parr and Shanks (2000); McAfee and Herman (2000)

Table 1 (continued)

Management of the SC has been significantly involved in the ERP implementation phase.	Mandal and Gunasekaran, (2003); Umble, Haft, and Umble (2003); Heijden (2001); Davenport (2000); Pliskin and Zarotski (2000); Grover, Sumner (2000); Parr and Shanks (2000); McAfee and Herman (2000); Laughlin (1999); Maxwell (1999); Krupp (1998); Davenport (1998); Davis and Wilder (1998); Jeong, Kettinger, and Teng (1995); Oden, Langenwalter, and Lucier (1993)
The company has followed a clear and detailed BPR plan.	Motwani, Subramanian, and Gopalakrishna (2005); Umble, Haft, and Umble (2003); Sumner (2000); Parr and Shanks (2000); McAfee and Herman (2000); Minahan (1998); Grover, Jeong, Kettinger, and Teng (1995); Chew, Barton, and Bohn (1991)
Business requirements such as competition can be named as the motive of the ERP implementation.	Parr and Shanks (2000); Sumner (2000); Pliskin and Zarotski (2000); McAfee and Herman (2000); Broadbent and Weill (1997); Chew, Leonard-Barton, and Bohn, (1991)
Software suppliers have provided satisfactory support and assistance.	Krammergaard and Rose (2002); McAfee and Herman (2000); Sumner (2000); Pliskin and Zarotski (2000)
Project team's efforts were satisfactory to implement the project.	Umble, Haft, and Umble (2003); Krammergaard and Rose (2002); Parr and Shanks (2000); Sumner (2000); Pliskin and Zarotski (2000); Laughlin (1999); Minahan (1998); Davis and Wilder (1998)
The benefits of the ERP system have been clearly identified and communicated.	Motwani, Subramanian, and Gopalakrishna (2005); Umble, Haft, and Umble (2003); Nolan (2001); Schragenheim (2000); Travis (1999); Latamore (1999); Laughlin, (1999); Krupp (1998); Radosevich (1997)

Table 1 (continued)

The company has required amount of financial resources for the implementation and long-term utilization of the ERP system.	Nolan (2001); McAfee and Herman (2000)
The company has explicit and well-articulated procedures for system implementation, performance evaluation and utilization.	Motwani, Subramanian, and Gopalakrishna (2005); Umble, Haft, and Umble (2003); Nolan (2001); Brown and Vessey (2001); Langenwalter (2000); Parr and Shanks (2000); Hutchins (1998); Oden, Langenwalter, and Lucier (1993)
Management of SC is ready for the chances that came with the ERP and BPR.	Motwani, Subramanian, and Gopalakrishna (2005); Mandal and Gunasekaran, (2003); Sumner (2000); McAfee and Herman (2000); Pliskin and Zarotski (2000); Parr and Shanks (2000); Grover, Jeong, Kettinger, and Teng (1995)
Responsibility and job definitions of workers before and after BPR have been defined clearly.	Hutchins, (1998); Grover, Jeong, Kettinger, and Teng (1995)
There was a partnership between the company and the ERP software provider for technologic cooperation and education.	Sumner (2000); Hirt (2000); Ross (1999)
For the required education of the end-users necessary support has been given by external experts.	Umble, Haft, and Umble (2003); Hirt (2000); Ross (1999)
The company has the sufficient experience to determine the required ERP implementation strategies.	Brown and Vessey (2001); Sumner (2000); Hirt (2000)
Majority of users have the sufficient skills to use the ERP software.	McAfee and Herman (2000); Sumner (2000); Pliskin and Zarotski (2000)
ERP software has a user-friendly interface.	Davenport (2000)

Table 1 (continued)

For a successful ERP implementation BPR application has been utilized.	Motwani, Subramanian, and Gopalakrishna (2005); Schniederjans and Kim (2003); Umble, Haft, and Umble (2003); McAfee and Herman (2000); Sumner (2000); Pliskin and Zarotski (2000); Minahan (1998); Chew, Barton, and Bohn (1991)

Each implementation prerequisite has been evaluated in the companies, in which the questionnaires applied, by face-to-face interviews with experts in companies. Amount of applicability of each prerequisite has been pointed by using 7-point Likert Scale.

By using the ERP implementation success score, effects of these factors on the success have been measured by Multiple Regression Analysis.

To be used as independent variables in multiple regression model, these prerequisites have been named as ERP success variables with code $ERPVi$ where $i = 1,2,...,17$. For example variable $ERPV2$ refers to the evaluation value of ERP success prerequisite "*Management of the SC has been significantly involved in the ERP implementation phase*". Full list of ERP success evaluation criteria have been given in Appendix 2.

Last evaluation criteria "*For a successful ERP implementation BPR application has been utilized*" haven't been defined as a variable, because the effects of BPR have been measured with different methods. Also variable $ERPV4$ indirectly implies the BPR application issues and measures the effects as a variable.

3.1.1.3 BPR Application Success

After evaluating the ERP implementation strategies of companies and completing the statistical analysis to determine the most important factor next study was to evaluate the BPR application strategies. Findings of the literature survey required to determine the factors that needs to be considered during the BPR application phase have been summarized in Table 2

Table 2: Prerequisites necessary for successful BPR application

BPR Application Prerequisites	**References**
Extensive user involvement in design.	Heijden (2001); McAfee and Herman (2000); Pliskin and Zarotski (2000); Sutcliffe (1999); Grover, Jeong, Kettinger, and Teng (1995); Manganelli (1994); Clement and Van den Besselaar (1993); Hammer and Champy (1993); Park (1990); Lees (1987)
Strong support, commitment and sponsorship from senior management.	Motwani, Subramanian, and Gopalakrishna (2005); Sutcliffe (1999); ProSci (1997); Candler, Palvia, and Zeltmann (1996); Kettinger and Grover (1995); Carr and Johansson (1995); Dixon, Arnold, Heineke, Kim, and Mulligan (1994); Bashein, Markus, and Riley (1994); Manganelli (1994); Hammer and Champy (1993)
Realistic project expectations.	Sutcliffe (1999); Bashein, Markus, and Riley (1994);
Extensive cross-functional memberships between project teams.	Heijden (2001); Davenport (2000); Sieber, Siau, Nah, and Sieber (2000); Lee and Lee (2000); Feldmann (1998); Radosevich (1997); Grover, Jeong, Kettinger, and Teng (1995); Dixon, Arnold, Heineke, Kim, and Mulligan (1994); Bashein, Markus, and Riley (1994)

Table 2 (continued)

Clear vision of project goals.	Motwani, Subramanian, and Gopalakrishna (2005); Heijden (2001); Parr and Shanks (2000); Davenport (2000); Summer (2000); Sutcliffe (1999); Broadbent, Weill, and Clair (1999); Carr and Johansson (1995); Grover, Jeong, Kettinger, and Teng (1995); Bashein, Markus, and Riley (1994); Hammer and Champy (1993)
Growth-oriented goal instead of cost-cutting.	Preissler (2000); Bashein, Markus, and Riley (1994)
Full-time participation of key members of the project.	Bashein, Markus, and Riley (1994)
Adequate budget for the project.	Candler, Palvia, and Zeltmann (1996); Bashein, Markus, and Riley (1994); Hammer and Champy (1993)
Adequate education and training conducted.	Koch (1997); Dixon, Arnold, Heineke, Kim, and Mulligan (1994); Bashein, Markus, and Riley (1994)
Communications with employees during the project.	Preissler (2000); Carr and Johansson (1995); Dixon, Arnold, Heineke, Kim, and Mulligan (1994); Bashein, Markus, and Riley (1994); Hammer and Champy (1993)
Significant portion of CEO's time committed to project.	Sutcliffe (1999); Carr and Johansson (1995); Hall, Rosenthal, and Wade (1993); Hammer and Champy (1993)
Senior executive responsible for the project.	Hall, Rosenthal, and Wade (1993); Manganelli (1994)
Pilot application prior to full implementation.	Hall, Rosenthal, and Wade (1993)

Table 2 (continued)

Following a detailed methodology.	Motwani, Subramanian, and Gopalakrishna (2005); Sutcliffe (1999); Candler, Palvia, and Zeltmann (1996); Kettinger and Grover (1995); Davenport and Stoddard (1994); Manganelli (1994); Hammer and Champy (1993)
Performance measurement before, during, and after the project.	Hall, Rosenthal, and Wade (1993)

Each questionnaire have been filled by a competent people in the company who takes an active role in the BPR application or ERP implementation team or managers of the company according to 7-point Likert scale. Filling of the questionnaires have been done under the supervision of the experts by face-to-face interviews to overcome the possibility of misunderstanding or missing the essence behind the questions.

As the final part of the questionnaire requires companies had been evaluated according to their BPR success scores. By using this score and the prerequisites measured above, Multiple Linear Regression analyses have been conducted to determine the most important factors that affect the BPR implementation success in Turkish enterprises.

To be used as independent variables in Multiple Regression model, prerequisites for BPR application success have been named as BPR success variables with code $BPRVi$ where $i = 1,2,...,15$. For example variable $BPRV2$ refers to the evaluation value of BPR success prerequisite "*Strong support, commitment and sponsorship from senior management*". Full list of BPR success evaluation variables have been given in Appendix 3.

All related calculations and results of each analysis have been explained in the related sections of Chapters 4 and 5.

"BPR Application and ERP Implementation Success" questionnaire have been applied mostly by face-to-face method as mentioned before. This study has been conducted in 180 companies located in Ankara, Istanbul, Eskisehir and Antalya. Only criteria at the selection of these companies were the existence of an ERP system in the company. 143 of these companies agreed to join the study. As a result 80% of return rate has been achieved. 41 of these 143 companies weren't using ERP software; so these questionnaires have been excluded from the analysis. Distribution of the questionnaires can be seen in Figure 7.

The final version of "BPR Application and ERP Implementation Success" questionnaire has been given in Appendix 4.

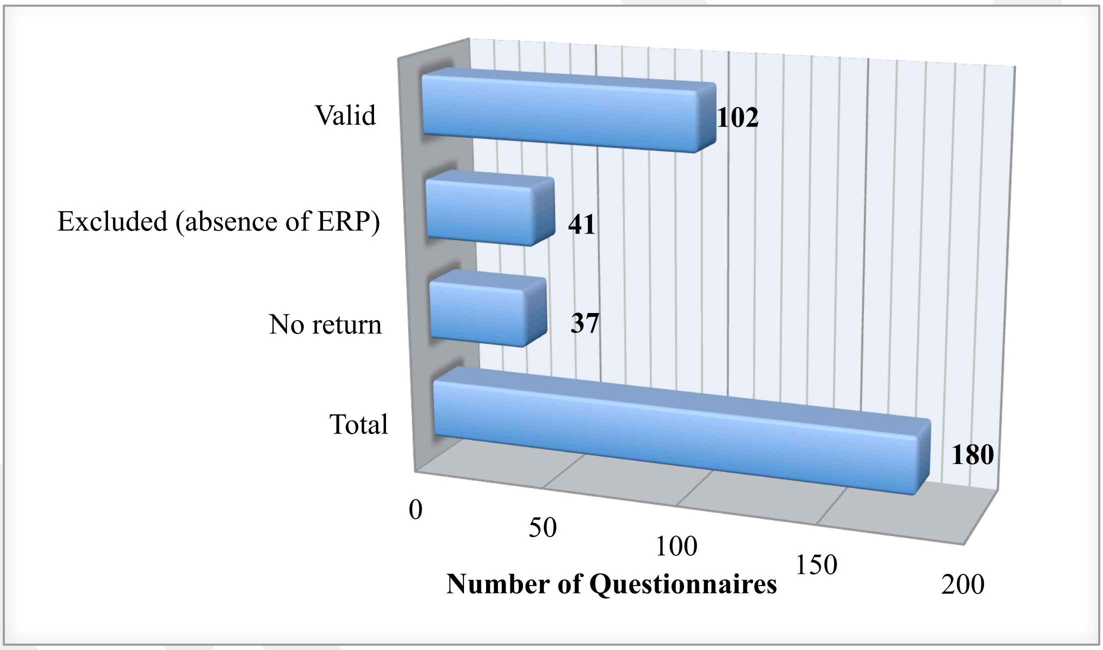


Figure 7: Distribution of "BPR application and ERP implementation success" questionnaires

Basic descriptive statistics related with the general information about the companies, to which the first questionnaire has been applied, have been given in Table 3.

Table 3: Descriptive statistics related with the general company information

		Company Type	Number of Employees	Product Line
N	Valid	102	102	102
	Missing	0	0	0
Mean		1.83	3.27	7.25
Std. Error of Mean		0.122	0.160	0.295
Median		1.00	3.00	9.00
Mode		1	3	10
Std. Deviation		1.235	1.612	2.984
Variance		1.526	2.597	8.905
Range		4	5	9
Minimum		1	1	1
Maximum		5	6	10
Sum		187	334	740

Frequencies of information related with company type have been given in Table 4 and Figure 8 respectively.

Table 4: Frequencies of company type information

Company Type	Frequency	Percent	Cumulative Percent
Manufacturer	66	64.7	64.7
Transporter	7	6.9	71.6
Warehouse	10	9.8	81.4
Service	18	17.6	99.0
Other	1	1.0	100.0
Total	102	100.0	

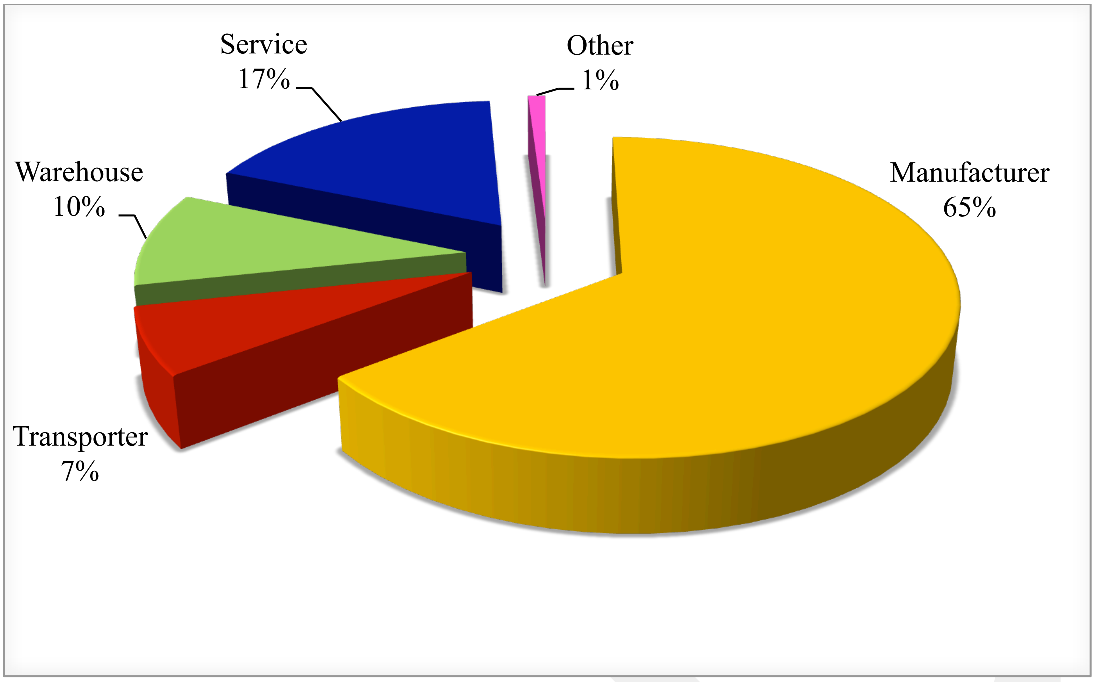


Figure 8: Distribution of company types

According to these results most of the companies to which the questionnaires have been applied have became of manufacturing companies; followed by the service companies. This result was expected because of the availability of ERP systems on manufacturing companies.

Frequency and distribution information related with the number of employees of the companies can be found at Table 5 and Figure 9 respectively. This data have been used to understand the size of companies that has been investigated.

Table 5: Frequencies of company size information

Number of Employees	Frequency	Percent	Cumulative Percent
<50	18	17.6	17.6
50-100	18	17.6	35.3
101-250	22	21.6	56.9
251-500	17	16.7	73.5
501-1000	16	15.7	89.2
>1000	11	10.8	100.0
Total	102	100.0	

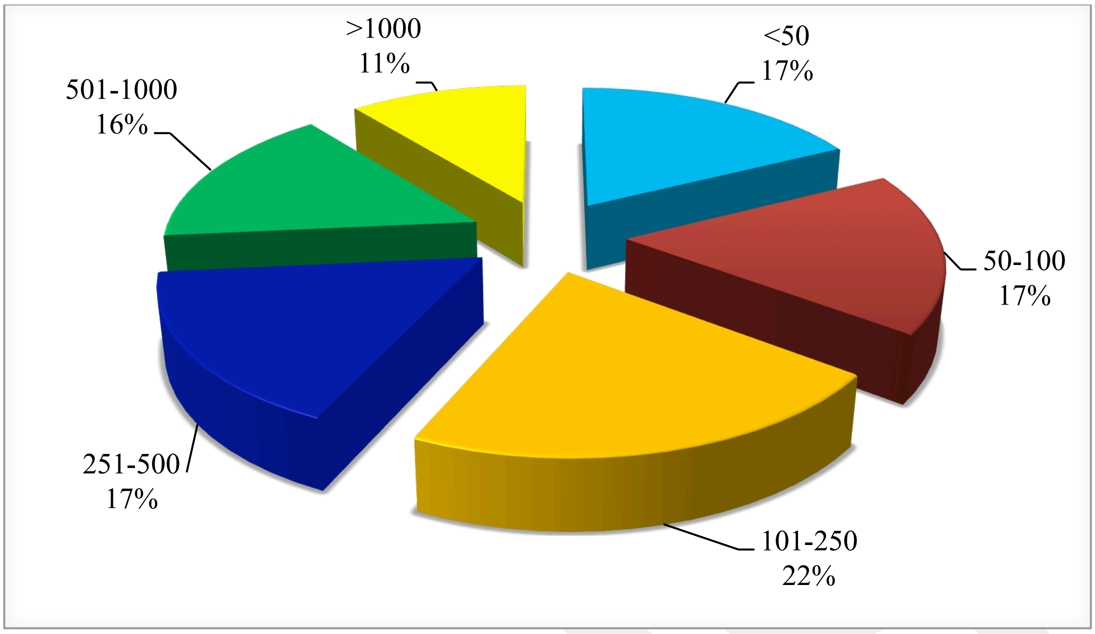


Figure 9: Distribution of employee numbers

This data shows that there is a uniform distribution between the different sized companies. This is ideal for capturing the general structure of Turkish enterprises.

Final general information frequency analysis has been conducted to determine sectoral distribution of companies. Related results of this analysis have been given in Table 6 and Figure 10.

Table 6: Frequencies of product line information

Product Line	Frequency	Percent	Cumulative Percent
Automotive	7	6.9	6.9
Computer/Electronics	4	3.9	10.8
White Goods/Kitchen Appliances	6	5.9	16.7
Construction	4	3.9	20.6
Pharmaceuticals/Health and Beauty	9	8.8	29.4
Chemicals	2	2.0	31.4
Furniture/Home Furnishings	12	11.8	43.1
Textiles/Apparel	6	5.9	49.0
Food	18	17.6	66.7
Other	34	33.3	100.0
Total	102	100.0	

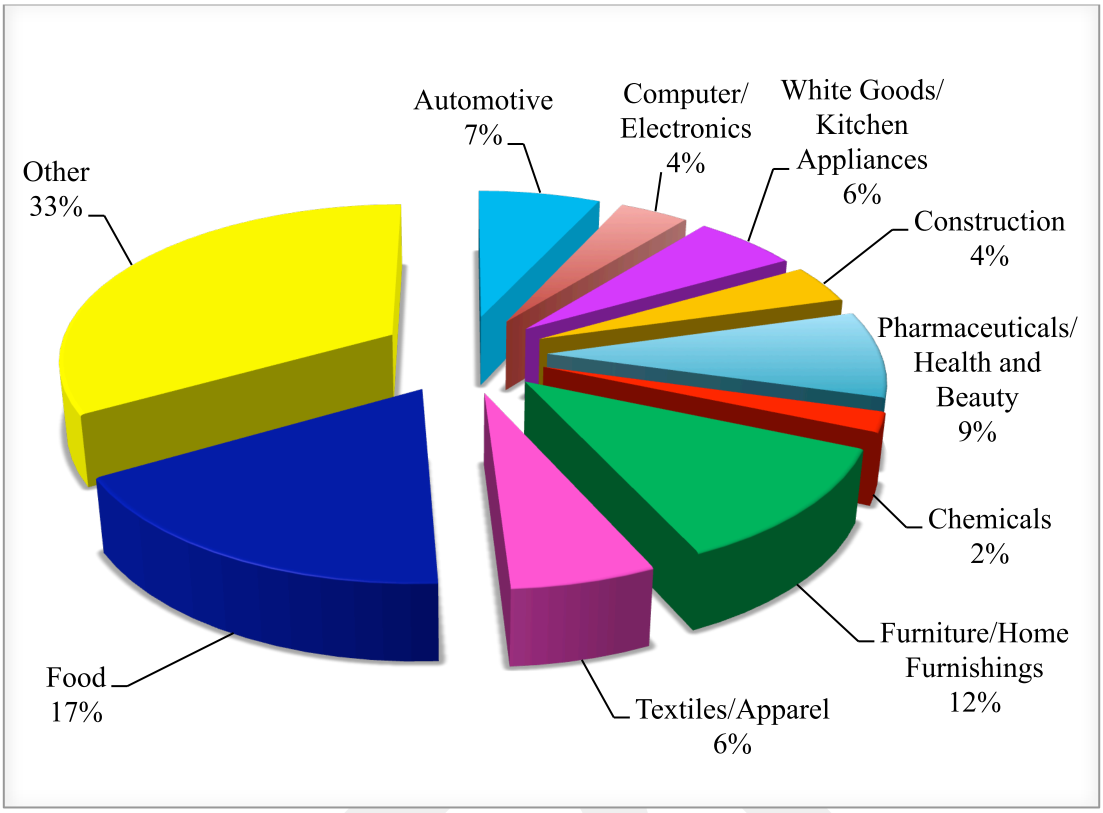


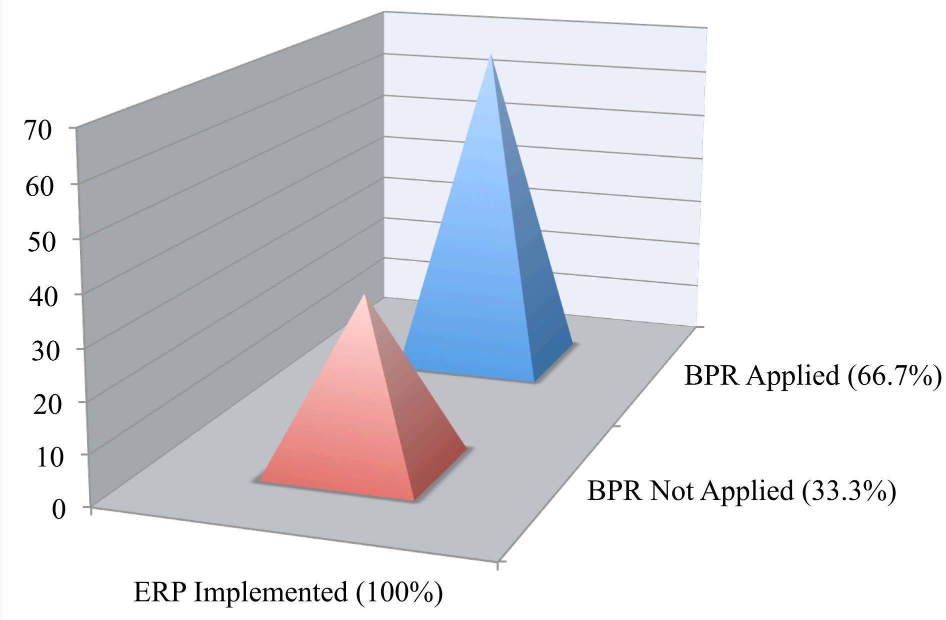
Figure 10: Sectoral distribution of companies

"Other" category which includes most of the service, transportation and warehouse type companies have the most weight in the questionnaire studies; followed by the food and furniture manufacturing sectors.

Successfully applied valid 102 questionnaires have been finally categorized according to existence of BPR application in the companies. Distributions of companies, according to their BPR application choices are given in Table 7 and Figure 11.

Table 7: Availability of BPR

BPR	Frequency	Percent	Cumulative Percent
Not Applied	34	33.3	33.3
Applied	68	66.7	100.0
Total	102	100.0	



	ERP Implemented (100%)
BPR Not Applied (33.3%)	34
BPR Applied (66.7%)	68

Figure 11: BPR application choice of companies

As it can be seen from the results most of the companies choose to apply BPR prior to ERP implementation. This distribution increased the chances of the questionnaire analysis to prove the effects of BPR on ERP and to determine the factors affecting BPR success.

3.1.2 Supply Chain Flexibility: Company Evaluation Questionnaire

Second questionnaire is prepared as the same way with the first one. But in the second questionnaire SC flexibility hierarchy and the factors related with each level of this SC hierarchy took the place of the questions related with the steps of BPR application and ERP implementation. In this questionnaire, five main categories of SC flexibility and the factors affecting each category has been evaluated. By weighting each of these five flexibility categories Supply Chain Overall Flexibility Score (SCOFS) has been calculated for each firm. Since SCOFS is dependent on the score of each category, factors affecting each individual category have been determined by the analysis of this questionnaire. By using these results SC managers can measure their companies flexibility to track the improvements they may achieve in the future and make a benchmarking. Second questionnaire also includes the performance metrics so SCOPS for each firm can be calculated in this questionnaire too as the first one. SCOPS have been analyzed with SCOFS to prove the effect of flexibility in the SC performance. Also in this questionnaire BPR application and ERP implementation successes have been measured. With this data ERP's affects on SCOFS have been measured with the related analysis.

As in the "BPR application and ERP implementation success questionnaire", same questions used to define companies' general structure. Also performance evaluation KPIs are same as the previous questionnaire.

To measure SC flexibility, SC structure has to be inspected with all of its vital levels. As mentioned before, according to SCOR model Supply Chain consists many levels. Flexibility has been defined differently for each level because of the nature of SCM. To make measurement of flexibility possible, first of all, main levels of SC have been defined. Flexibility hierarchy of a SC can be summarized under five categories. These categories have been given in Table 8.

Table 8: Flexibility Hierarchy

Hierarchy Level	**References**
Production Flexibility	Costantino, Dotoli, Falagario, Fanti, and Mangini (2012); Moon, Yi, and Ngai (2012); Malhotraa and Mackelprang (2012); Baç and Erkan (2011); Kara and Kayis (2004); Prater, Biehl, and Smith (2001); Parker and Wirth (1999); Koste and Malhotra (1999); Pagell and Krause (1999); Suarez, Cusumano, and Fine (1996); Suarez, Cusumano, and Fine (1995); Upton (1994); Gerwin (1993); Gupta (1993); Gupta and Sommer (1992); Sethi and Sethi (1990); Gupta and Goyal (1989); Slack (1983)

Table 8: (continued)

Supply Flexibility	Barnes and Liao (2012); Malhotraa and Mackelprang (2012); Chuu (2011); Gosling, Purvis, and Naim (2010); Kumar, Fantazy, Kumar, and Boyle (2006); Swafford, Ghosh, and Murthy (2006); Gosain, Malhotra, and Sawy (2005); Sánchez and Pérez (2005); Lummus, Vokurka, and Duclos (2005); Sanchez and Perez (2005); Narasimhan, Talluri, and Das (2004); Pujawan (2004); Singh and Sushil (2004); Lummus, Duclos, and Vokurka (2003); Young, Sapienza, and Baumer (2003); Otto and Kotzab (2003); Duclos, Vokurka, and Lummus (2003); Mason, Cole, Ulrey, and Yan (2002); Prater, Biehl, and Smith (2001); Gunasekaran (1999); Fisher (1997); Volberda (1997); Nilsson and Nordahl (1995); Sanchez (1995)
Delivery Flexibility	Malhotraa and Mackelprang (2012); Moon, Yi, and Ngai (2012); Chuu (2011); Swafford, Ghosh, and Murthy (2006); Sánchez and Pérez (2005); Pujawan (2004); Pagell and Krause (2004); Prater, Biehl, and Smith (2001); Sabri and Beamon (2000); Christopher (2000); Vickery, Calantone, and Dröge (1999); Beamon (1999); Huppertz (1999); Sethi and Sethi (1990); Slack (1987)
Logistics Flexibility	Prajogo and Olhager (2012); Baç and Erkan (2011); Kumar, Fantazy, Kumar, and Boyle (2006); Pujawan (2004); Duclos, Vokurka, and Lummus (2003); Barad and Sapir (2003); Zhang, Vonderembse, and Lim (2002); Vickery, Calatone, and Droge (1999); Koste and Malhotra (1999); Fawcett and Clinton (1997); Kopczak (1997); Bradley (1997); Fawcett and Clinton (1996); Day (1994); Rao, Stenger, and Wu (1994); Gerwin (1993); Langley and Holcomb (1992); Perry (1991); Sethi and Sethi (1990)

Table 8: (continued)

Information Flexibility	Moon, Yi, and Ngai (2012); Barnes and Liao (2012); Prajogo and Olhager (2012); Qrunfleh and Tarafdar (2012); Baç and Erkan (2011); Chuu (2011); Hartono, Li, Na, and Simpson (2010); Lummus, Volkurka, and Duclos (2005); Christopher, Lowson, and Peck (2004); Aranda (2003); Duclos, Vokurka, and Lummus (2003); Swafford (2003); Lummus, Duclos, and Vokurka (2003); Coronado, Sarthadi, and Millar (2002); Zhang, Vonderembse, and Lim (2002); McAfee (2002); Perez and Sanchez (2001); Lowson, King, and Hunter (1999); Bharadwaj, Sundar, and Konsynski (1999); Bowersox, Stank, and Daugherty (1999); Brown, Gatian, and Hicks (1995); Day (1994); Lambert and Stock (1993); Ody and Newman (1991); Evans (1991)

SC flexibility hierarchy levels have been categorized according the literature survey carried out. According to this survey proposed categorization have been given above. Also factors affecting the flexibility of each level have been collected from the mentioned literature surveys. In addition to the findings of literature survey given in Table 8, at the definition phase of related metrics to evaluate each hierarchical level, flexibility metrics given in the SCOR model (Erkan and Baç, 2011) have also been considered.

Evaluation of each metric that affects each level of flexibility hierarchy have been measured with a 7-point Likert scale for the same reasons explained in the "BRP application and ERP Implementation Success" questionnaire. After evaluating each company under flexibility metrics a general score have been assigned to each hierarchical flexibility level.

To be used as criteria in fuzzy AHP model flexibility hierarchy levels have been named as flexibility evaluation criteria (to evaluate SCOFS) with code $FlxCX$ where X : initial of flexibility level. For example variable $FlxCI$ refers to the evaluation value of flexibility level "*Information Flexibility*". Full list of overall flexibility measurement criteria have been given in Appendix 5.

After completing the evaluation of hierarchical flexibility scores for each company a fuzzy AHP analysis has been conducted to weight the levels of this hierarchy. These weights and the scores calculated for each levels have been used to determine each company's SCOFS. This was the second main goal of the thesis. By using SCOFS companies can answer the "*How Flexible I am?*" question easily by quantitative measurements. While combined with the SCOPS, SCOFS has been used to prove the effects of flexibility on SC performance.

Independent Samples t-Test has also been used to investigate the effects of ERPs existence on SCOPS with the results of this questionnaire. This test couldn't have been performed with the first questionnaire because all companies evaluated in the first questionnaire were the ones that use ERP system. Also, again an Simple Linear Regression model have been built to support the finding in the first questionnaire results about ERPs effects on performance.

In addition to usage of SCOFS, as mentioned before, existence of ERP has been shown as a factor that affects the flexibility of SC. To prove the existence of this effect SCOFS metric had been used in an Independent Samples t-Test to investigate a significant difference between the companies which uses an ERP system and which doesn't. Using the first questionnaire, this analysis couldn't be performed, because all companies were using an ERP system.

Another goal of the thesis was to determine the factors affecting SC flexibility. To determine the most important factors that affect each level in the hierarchy, five different multiple linear regression (MLR) models have been built for the each level of flexibility hierarchy. Detailed explanations and results of each analysis have been given in Chapters 4 and 5.

Explanation of the flexibility hierarchy levels and the criteria related with the evaluation of each level has been defined in the following sections.

3.1.2.1 Production Flexibility

Production flexibility can be defined as the company's ability to change or modify its manufacturing processes to adapt to new circumstances. Production flexibility has been evaluated with six questions:

- We can quickly change our production volume.
- We can change our production volume with low cost.
- We can operate efficiently under different production volumes.
- We can produce extensive variety of products in our facility.
- Our production workers are capable of handling many types of duties.
- When needed, outsourcing demands can be satisfied under reasonable costs and time.

To be used as independent variables in MLR model, each question has been named as production flexibility evaluation variables with code $FlxPVi$ where $i = 1, 2, ..., 6$. For example variable $FlxPV6$ refers to the evaluation value of production flexibility measurement question "*When needed, outsourcing demands can be satisfied under reasonable costs and time*". Full list of production flexibility evaluation variables have been given in Appendix 6.

3.1.2.2 Supply Flexibility

Supply flexibility represents the company's effectiveness and efficiency in changing its supply channels and/or suppliers if needed because of concerns such as cost, quality, delivery times, product availability/range, etc. Supply flexibility has been evaluated with nine questions:

- We have more than one supplier for our most purchased products.
- We can change one supplier with another with low cost.
- We can change one supplier with another within short time.
- We can change one supplier with another without an important compromise on the qualities of raw materials, spare parts and design.

- Our suppliers are ready to accommodate the changes we requested on the product variety, supply volume, etc.
- Our production efficiency and profitability won't be affected by the changes in production volume because of the supply problems.
- Our suppliers can adapt to different order quantities and delivery frequencies.
- Changes in the supply delivery schedules can be managed with cost and time effective manners.
- Changes in the delivery times of suppliers can be handled with low cost.

To be used as independent variables in MLR model, each question has been named as supply flexibility evaluation variables with code $FlxSVi$ where $i = 1,2,...,9$. For example variable $FlxSV4$ refers to the evaluation value of production flexibility measurement question "*We can change one supplier with another without an important compromise on the qualities of raw materials, spare parts and design*". Full list of supply flexibility evaluation variables have been given in Appendix 7.

3.1.2.3 Delivery Flexibility

Delivery flexibility reflects the company's ability to change its planned delivery variables such as delivery schedules, destinations, order volumes etc. according to updated customer demands. Delivery flexibility has been evaluated with eleven questions:

- We can adapt to the changes in the delivery times that are requested by the customers.
- We can adapt to the changes in the delivery locations that are requested by the customers.
- We can adapt to the changes in the delivery amounts that are requested by the customers.
- We can satisfy low volume orders from our customers.
- We can satisfy frequent delivery orders from our customers.

- We can satisfy variety of special requests of our customers about the deliveries.
- We can handle different delivery plans without any difficulty for different kinds of products.
- We can deliver one or more of our customer's order(s) by variety of channels.
- Changes in the order delivery schedules can be managed with cost and time effective manners.
- If there had been a delay in the order delivery, we can manage costs, which were caused because of the delay, effectively.
- Changes in the order volume and type can be managed with cost and time effective manners.

To be used as independent variables in MLR model, each question has been named as delivery flexibility evaluation variables with code $FlxDVi$ where $i = 1,2,...,11$. For example variable $FlxDV1$ refers to the evaluation value of production flexibility measurement question "*We can adapt to the changes in the delivery times that are requested by the customers*". Full list of supply delivery evaluation variables have been given in Appendix 8.

3.1.2.4 Logistics Flexibility

Logistics flexibility can be defined as the physical aspect of the distribution efforts of the company. It represents the company's ability to change its physical network according to required changes. Logistics flexibility has been evaluated with five questions:

- We have more than one distribution channel for different kind of products and services.
- If required by he competition we can change our physical distribution channels easily.
- We can change our distribution channels with the minimum amount of effect on logistics performance.

- Changes in logistics channels can be made with low cost.
- Changes in logistics channels can be made in a short time and agilely.

To be used as independent variables in MLR model, each question has been named as logistics flexibility evaluation variables with code $FlxLVi$ where $i = 1,2,...,5$. For example variable $FlxLV2$ refers to the evaluation value of production flexibility measurement question "*If required by he competition we can change our physical distribution channels easily*". Full list of logistics flexibility evaluation variables have been given in Appendix 9.

3.1.2.5 Information Flexibility

Information flexibility, also referred as spanning flexibility, reflects the company's ability to gather and distribute information among the different levels of SC fast and accurate. Information flexibility has been evaluated with eleven questions:

- We can share information with our major suppliers very quickly.
- By the use of Information Technologies (IT), automatic information sharing with the major suppliers is possible.
- Real-time information sharing is possible with our major suppliers.
- Our major suppliers are ready to share information with us to adapt the changes caused by our demands.
- To support the changing requirements, commonality and prevalence of Information Systems (IS) is adequate.
- Flow rate/speed of information throughout our Supply Chain is satisfactorily high.
- Required hardware and software changes by the IT systems can be done easily.
- Integration of third party applications to existing IS can be done with a high efficiency ratio.
- Managing the information requested can be done with low cost and short time.

- IT application installations and maintenances can be done with low cost and in short time.
- Under the need of changing environmental requirements, updates and upgrades of existing IT applications can be done with low cost and in short time.

To be used as independent variables in MLR model, each question has been named as information flexibility evaluation variables with code $FlxIVi$ where $i = 1, 2, ..., 11$. For example variable $FlxIV5$ refers to the evaluation value of production flexibility measurement question "*To support the changing requirements, commonality and prevalence of Information Systems (IS) is adequate*". Full list of information flexibility evaluation variables have been given in Appendix 10.

Each of these questions above have been evaluated with the managers in the company under the supervision of an expert and pointed between 1 and 7. Also evaluation and scoring of each flexibility hierarchy level have been done during the interviews.

"Supply Chain Flexibility" questionnaire has been applied to 133 firms. Most of these firms were the same companies in the first questionnaire study that were using an ERP system. Since this time there were no criteria in the selection of companies, as the existence of ERP, they have been selected randomly. 105 of these companies agreed to joint the study. So the return rate was about 79%. 7 of the applied questionnaires have been excluded from the analysis. Remaining 98 questionnaires have been used for the calculations. Distribution of these numbers is given in Figure 12.

The final version of "Supply Chain Flexibility" questionnaire has been given in Appendix 11.

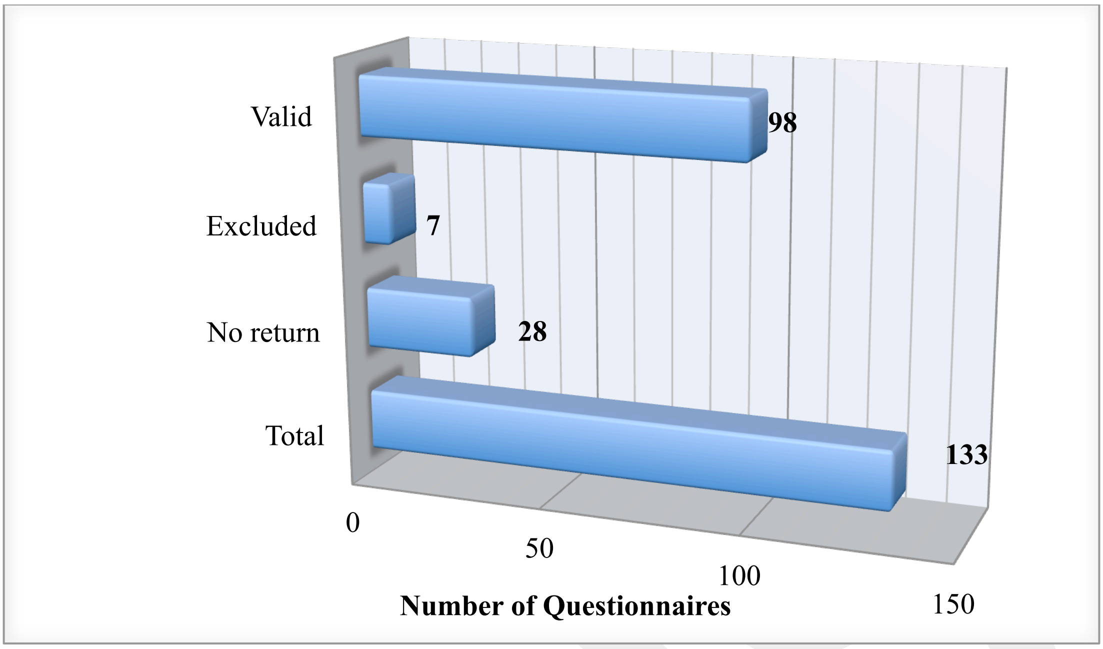


Figure 12: Distribution of "Supply Chain Flexibility" questionnaires

Basic descriptive statistics related with the general information about the companies, to which the second questionnaire has been applied, have been given in Table 9.

Table 9: Descriptive statistics related with the general company information

		Company Type	Number of Employees	Product Line
N	Valid	98	98	98
	Missing	0	0	0
Mean		1.64	3.30	6.89
Std. Error of Mean		0.126	0.154	0.323
Median		1.00	3.00	8.00
Mode		1	3	10
Std. Deviation		1.246	1.528	3.201
Variance		1.552	2.334	10.245
Range		4	5	9
Minimum		1	1	1
Maximum		5	6	10

Frequencies of information related with company type have been given in Table 10 and Figure 13.

Table 10: Frequencies of company type information

Company Type	Frequency	Percent	Cumulative Percent
Manufacturer	77	78.6	78.6
Transporter	1	1.0	79.6
Warehouse	0	0	79.6
Service	19	19.4	99.0
Other	1	1.0	100.0
Total	98	100.0	

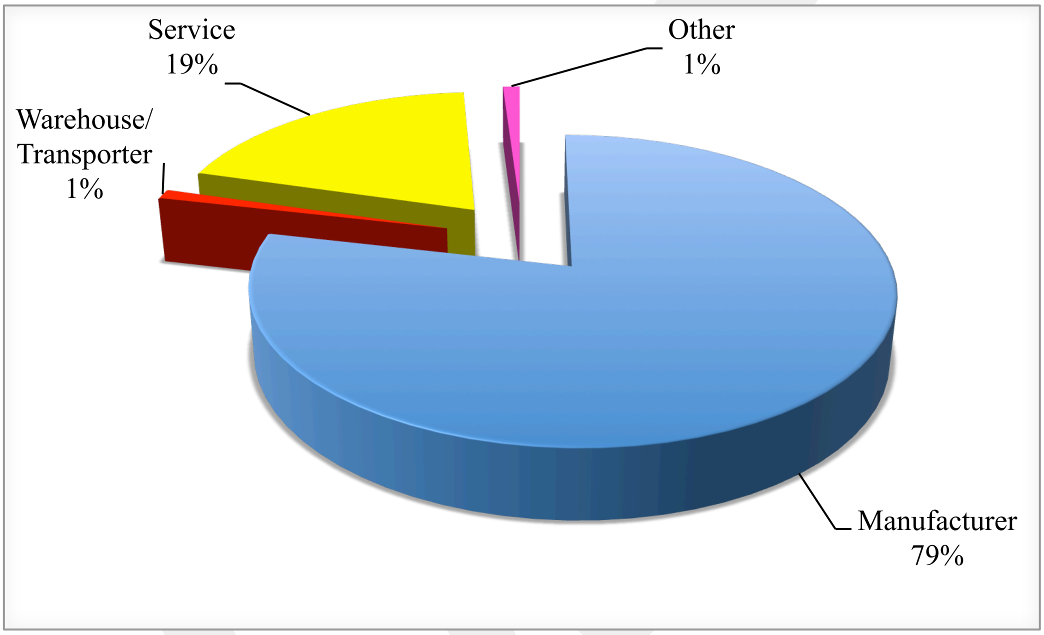


Figure 13: Distribution of company types

According to these results most of the companies to which the questionnaires have been applied have became of manufacturing companies; followed by the service companies. Distribution results are similar with the first questionnaire. This result was expected because of the efforts to select the same or similar companies for the second questionnaire study. Also availability of ERP system was a criterion in the selection of companies to investigate the effects of ERP on the SC flexibility.

Frequency information related with the number of employees of the companies can be found at Table 11 and Figure 14. This data have been used to understand the size of companies that has been investigated.

Table 11: Frequencies of company size information

Number of Employees	Frequency	Percent	Cumulative Percent
<50	11	11.2	11.2
50-100	23	23.5	34.7
101-250	24	24.5	59.2
251-500	19	19.4	78.6
501-1000	8	8.2	86.7
>1000	13	13.3	100.0
Total	98	100.0	

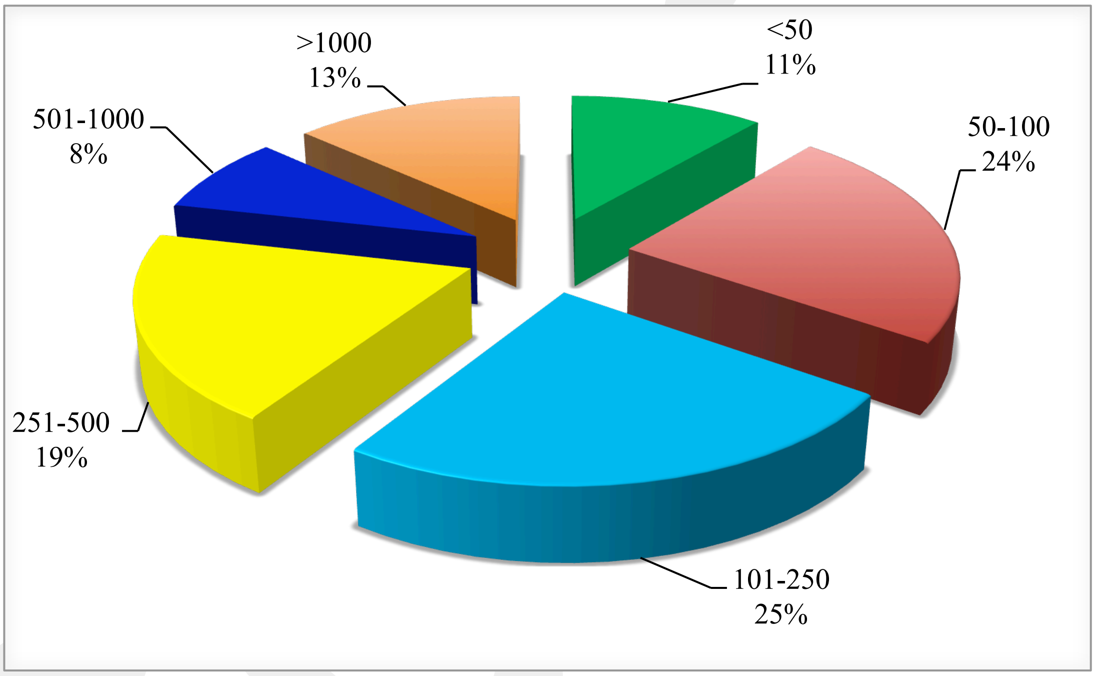


Figure 14: Distribution of employee numbers

This data shows similar result with the first questionnaire. But the number of rather smaller firms has been increased.

Final general information frequency analysis has been conducted to determine sectoral distribution of companies. Related results of this analysis have been given in Table 12 and Figure 15.

Table 12: Frequencies of product line information

Product Line	Frequency	Percent	Cumulative Percent
Automotive	6	6.1	6.1
Computer/Electronics	6	6.1	12.2
White Goods/Kitchen Appliances	4	4.1	16.3
Construction	18	18.4	34.7
Pharmaceuticals/Health and Beauty	4	4.1	38.8
Chemicals	4	4.1	42.9
Furniture/Home Furnishings	4	4.1	46.9
Textiles/Apparel	5	5.1	52.0
Food	9	9.2	61.2
Other	38	38.8	100.0
Total	98	100.0	

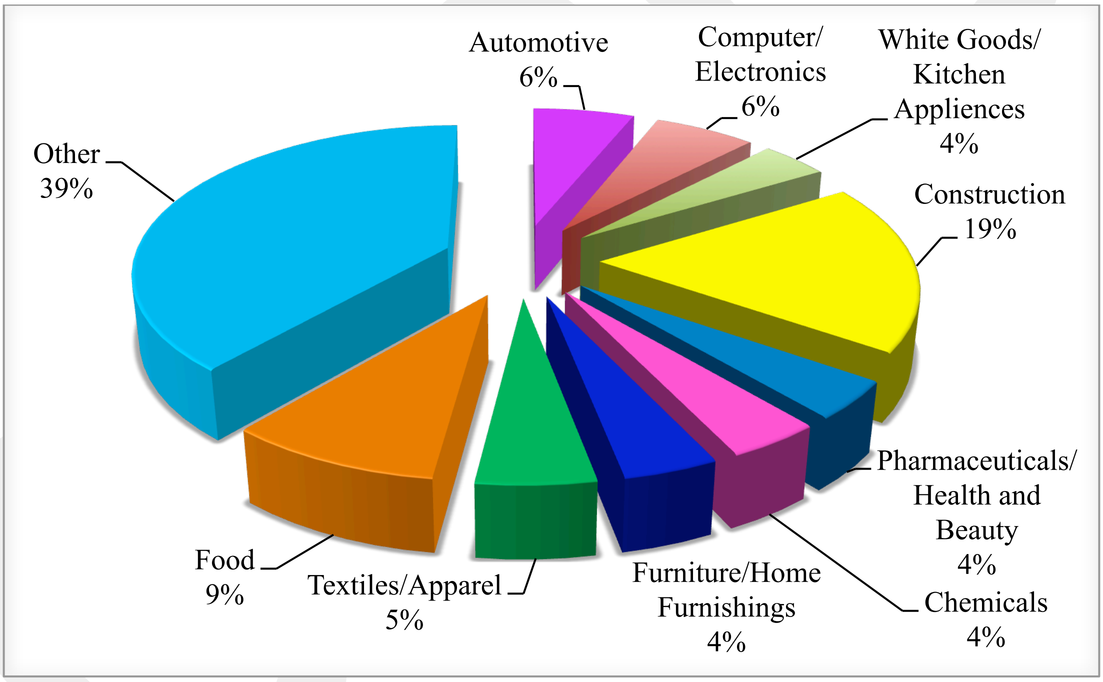


Figure 15: Sectoral distribution of companies

“Other” category which includes most of the service, transportation and warehouse type companies have the most weight in the questionnaire studies; followed by the construction and food manufacturing sectors.

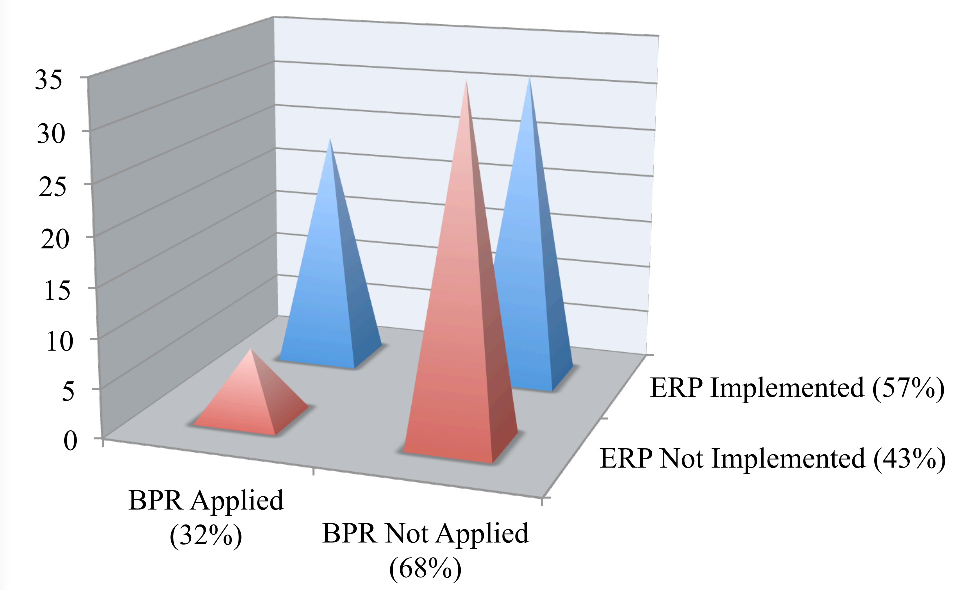
98 successfully applied questionnaires have been finally categorized according to existence of BPR application and existence of ERP implementation in the companies. Distributions of companies, according to their BPR application and ERP implementation choices are given in Table 13 and Table 14 respectively. This distribution has been visualized in Figure 16.

Table 13: Availability of BPR

BPR	Frequency	Percent	Cumulative Percent
Not Applied	67	68.4	68.4
Applied	31	31.6	100.0
Total	98	100.0	

Table 14: Availability of ERP

ERP	Frequency	Percent	Cumulative Percent
Not Implemented	42	42.9	42.9
Implemented	56	57.1	100.0
Total	98	100.0	



	BPR Applied (32%)	BPR Not Applied (68%)
ERP Not Implemented (43%)	7	35
ERP Implemented (57%)	24	32

Figure 16: BPR and ERP availabilities in the companies

As it can be seen from the data above ERP existence ratio is similar with the non-existence ratio. This situation is ideal for inspecting the affects of ERP implementation on SC flexibility. The number of companies, which applied BPR is not much so same analysis in the first questionnaire that aims to prove BPR application effects on ERP implementation success, haven't been repeated in this questionnaire.

After the collection of data via questionnaire studies conducted has been completed, last data needed for statistical analysis and MCDM models was the expert evaluations. For this purpose expert evaluation questionnaires have been used.

3.1.3 Expert Evaluation Questionnaires for Supply Chain Overall Performance Score (SCOPS) Calculation with ANP Analysis

Required KPIs to evaluate SC performance have been gathered from the literature. Each company has been scored under these metrics during the face-to-face interviews. Second phase of overall performance evaluation is to weigh the KPI metrics according to their effects on the SC overall performance. For this purpose decision maker opinions have been used. These experts have been selected from three different sectors; coming from academic society, manufacturing sector and service sector.

A pair-wise comparison of each of the 11 criteria (a list can be found in Appendix 1) has been requested from the experts. These evaluation matrices are required for the ANP analysis. Details of this analysis have been discussed in the following sections.

In addition to the pair-wise comparison questionnaire to reveal the relationships between each KPI, also another questionnaire has been applied to determine the interdependencies between these KPIs.

Expert evaluation questionnaires for SCOPS calculation have been given in Appendix 12.

3.1.4 Expert Evaluation Questionnaires for Supply Chain Overall Flexibility Score (SCOFS) Calculation with Fuzzy AHP Analysis

Supply Chain flexibility hierarchy defined as a result of literature survey has been used to calculate SCOFS. For this calculation each company have been evaluated for each level of flexibility. To calculate SCOFS, fuzzy AHP technique requires pairwise comparisons of each level according to their effects on overall SC flexibility.

Same decision makers, who evaluated the SCOPS expert questionnaires, from academic society, manufacturing and service sectors have been selected as decision makers. These experts made the pair-wise comparisons of 5 flexibility hierarchies with overall SC flexibility in mind.

Expert evaluation questionnaire for SCOFS calculation have been given in Appendix 13.

3.1.5 Expert Evaluation Questionnaires for Selecting Performance Investment Strategies

For the final part of the thesis an ANP analysis is needed to select the best strategy (BPR, ERP, and Flexibility) for performance increment. For this purpose BPR, ERP, and Flexibility have to be compared according to their effects on the performance. In this ANP analysis SCOPS have been used as a goal where BPR application success, ERP implementation success and SCOFS are the alternatives. To do such an analysis for the last time expert evaluations have been used.

Same decision makers, who evaluated the SCOPS and SCOFS expert questionnaires, from academic society, manufacturing and service sectors have been selected as decision makers again. SCOPS comparison results have been used from the first expert questionnaire for the performance criteria weightings. These experts made the pairwise comparisons of 3 performance strategy alternatives under each 11 of the performance metrics.

Expert evaluation questionnaire for selecting the performance investment strategies have been given in Appendix 14.

3.2 Mathematical and Statistical Models

Method of data collection and the way it had been interpreted have been explained in the previous section. In this section MCDM models and statistical analyses that had been used in the analysis phase will be explained. Summary of the analyses performed and related data that had been used in the analyses have been summarized in Figure 17.

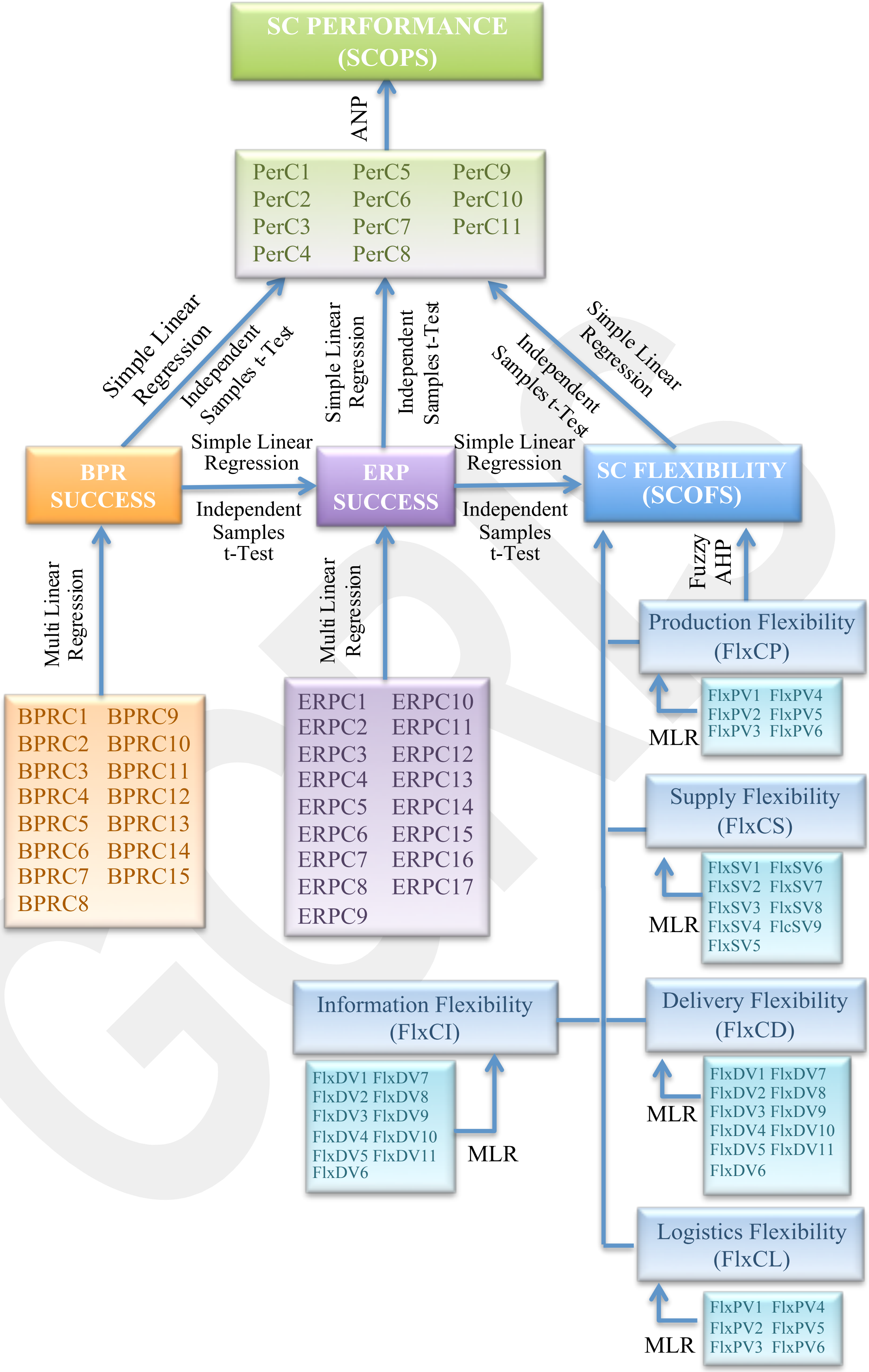


Figure 17: Framework of methodology – Part 1

As it can be seen from the figure different mathematical and statistical approaches have been used in the analyses of data collected with six questionnaires. These methods are:

- Analytic Network Process (ANP),
- Fuzzy Analytic Hierarchy Process (fuzzy AHP),
- Simple Linear Regression (SLR),
- Multiple Linear Regression (MLR), and
- Independent Samples t-Test.

The work demonstrated in Figure 17 belongs to the studies, which aims to prove the relations between performance based strategic options and their effects on the SC performance. For this purpose two measurement tools have been developed in this study: SCOPS and SCOFS, which was the main goal of the thesis.

Final goal of the thesis is to weigh the strategic performance investment alternatives according to their importance. Required analysis for this purpose has been carried out by expanding the ANP model used in Figure 17. Structure of this study, to achieve the final goal of the thesis, has been demonstrated in Figure 18.

With the goal for improving SC performance that has been evaluated by eleven criteria; strategic investment alternatives is being evaluated as shown in Figure 18. This model structure belongs to ANP model. Results of the first two levels of this hierarchy have been used to create SCOPS. Details related with structure of the model and the calculations will be explained in Chapter 6.

Figure 18: Framework of methodology – Part 2

Framework of the methodology used in the thesis, which has been visualized in the Figures 17 & 18, has connections among most of its items and the analysis that have been used. Because of these relations it can be said that the models built in this study have a hybrid structure.

3.2.1 Hybrid Model Approach Used in the Thesis

In the analysis performed fuzzy AHP and ANP models have been used as MCDM tools. Fuzzy analysis has been preferred for its ability to handle uncertainties, which makes it a feasible tool to evaluate flexibility hierarchy. As mentioned before definition of flexibility is confusing and rating each flexibility hierarchy is a more complex procedure. For these reasons Fuzzy AHP analysis has been chosen for the SC flexibility related evaluations, where ANP has been used to evaluate SC performance metrics by considering their interdependencies. MLR models, SLR models and Independent Samples t-Test analyses have also been used as statistical methods for the related evaluations. In the most part of analysis conducted these MCDM and statistical analyses have been used together (Figure 17). Output of one model has been used as an input in another.

First category hybrid model used was "*Hybrid Fuzzy AHP / Multiple Linear Regression*" model. This model has been used to calculate SCOFS. Flexibility hierarch levels have been weighted by using fuzzy AHP analysis and the factors affecting each level of this hierarchy have been determined by using Multiple Linear Regression models. As a result of this analysis SCOFS have been introduced to evaluate SC flexibility and the important metrics that affects SCOFS have been determined.

Second hybrid model used in the thesis was "*Hybrid Simple Linear Regression / Fuzzy AHP / ANP*" model. This model proves the affects of flexibility on SC performance. SC performance has been measured by SCOPS that was created by ANP analysis. Simple Linear Regression model has been built to prove the relation between SCOPS (by ANP model) and SCOFS (by fuzzy AHP model).

Third category hybrid models used were "*Hybrid ANP / Independent Samples t-Test / Simple Linear Regression*" model. These models have been used to prove the effects of BPR application and effects of ERP implementation on SC performance. SCOPS was the dependent variable in the model which was calculated with ANP analysis. Effects of BPR and ERP on SCOPS have been determined by the use of Independent Samples t-Tests & Simple Linear Regression models.

Fourth hybrid model used in this study was "*Hybrid Fuzzy AHP / Independent Samples t-Test / Simple Linear Regression*" model. This analysis has been used to prove the effects of ERP on the SC flexibility. SCOFS has been used as a dependent variable and the difference on SCOFS caused by ERPs existence have been investigated with the Independent Samples t-Test and its impact have been measured with Simple Linear Regression model.

Final hybrid model used in the thesis was "*Hybrid ANP / Fuzzy AHP / Multiple Linear Regressions"* model. This model has been used for selecting and weighting the performance alternatives for strategic investment evaluations firstly. Main goal is to maximize the SCOPS value and the alternatives were BPR, ERP and flexibility (Figure 18). Among these alternatives flexibility has been measured by SCOFS that was calculated by fuzzy AHP. SCOFS have been used as an alternative in the ANP analysis this time (evaluation criteria and their weighting part in the ANP analysis is same with the SCOPS calculation ANP analysis). ERP implementation and BPR application successes have been calculated by using the MLR equations calculated for each. By using this hybrid model, Total Supply Chain performance can be measured according to its relation with the BPR, ERP and flexibility performances.

Before explaining the calculations performed, literature surveys related with the MCDM models and statistical analysis used in the thesis have been given in the following sections.

3.2.2 Multi Criteria Decision Making (MCDM) Approaches

MCDM is a term, which describes the whole formal approaches used to make decision-making easy for complicated troubles. The purpose of MCDM is to unity measurement processes with value judgments by trying to make the inevitable subjectivity more explicit in complicated troubles (De Lange et.al., 2012). The fundamental aspect of MCDM is related with deciding the best alternative from a set of competing options that are considered with a set of criteria (Liaoa and Kao, 2010).

There are various approaches to MCDM, some of them can be explained like follows (Belton and Stewart, 2002):

- The real form of MCDA is programming the goal and reference point techniques.
- The well-known types of MCDM are multi-attribute analytical hierarchy process (AHP) and value function (MAVF).
- Game theory approaches.

There are many methods available for solving multi-criteria decision-making problems. But AHP, which was come up with Saaty in 1970's, is one of the most practical methods in the literature (Aydın and Kahraman, 2012).

3.2.2.1 Analytic Hierarchy Process (AHP)

Instead of making a decision, AHP gives a result, which is the best suitable answer for the problem's needs (Erol and Kılkış, 2012). Vargas and Saaty (1991) define AHP as a strong and flexible multi-criteria decision-making model that can be used to solve unstructured problems in a different kind of decision making approaches. These decision making approaches can be listed from simple personal decisions to the complicated intensive decisions in most of the areas such as management science, economics, politics, finance and sports.

AHP is a tool of multi-criteria decision analysis that can be applied when there is a problem including so many objectives and criteria. It can be applied to different kind of problems in most of the areas such as business, healthcare, industry or education (Mohajeri and Amin, 2010). The power of this method and its reliability are the evidences that why it has a widespread use (Al-Hawari et.al., 2011). By using AHP method, a decision maker could make estimations, prioritize and choose from among a set of alternatives (Stein and Ahmad, 2009).

AHP is generally a non-linear framework for applying both deductive and inductive thoughts by not using the syllogisms. So that it is possible to take the factors into consideration simultaneously, give permission to the feedback and make numerical trade-offs to do a synthesis (Rouyendegh and Erkan, 2012).

The fundamental though of AHP is to separate the decision problem into a hierarchy in order to comprehend sub-problems easily, so that, they can be analyzed independently. After the hierarchy is created, the decison maker (DM) evaluates the different elements of the hierarchy. The method is to compare the elements by using pair-wise comparison. The DM can use the objective data about the elements and also the subjective thoughts about the relative meanings and significance of elements. As a tool of DM, the AHP converts these evaluations through numerical values so that it can be possible to make comparisons over the whole range of the problem. Every element in the hierarchy has a numerical weight, and this allows various and sometimes immeasurable elements to be compared between each other in a rational way. This model makes the AHP more advantageous than the other decision-making methods. And finally, numerical priorities are calculated for every decision options. These numbers indicates the relative ability of alternatives to realize the decision purpose (Mayyas et.al., 2011). After this short summary of AHP, it is possible to give the main steps of this method:

Step-1: The first step of AHP is related with describing the problem and determining its purpose. The hierarchical structure of AHP includes goal, objectives, attributes and alternatives. These are a variety of elements which are interested in a special decision problem and a diverse combination of these elements that can be used to represent the problem (Ojha et.al., 2010). In most cases, the decision hierarchy includes the objective level, the criteria level, the sub-criteria level, and so on in many levels as per the requirement of the problem (Bagla and Gupta, 2011).

Step-2: The second step of the AHP process is related with forming a pair-wise comparison between two elements at a time. While making comparisons, it is needed to make a series of judgments in order to prioritize all the elements in lower levels of the hierarchy (Mayyas et.al., 2011). The prediction of priorities from pair-wise comparison matrices is the most important issue of the AHP (Hun, Lan, and Wang, 2011). Pair-wise comparison matrices contain numerical judgments assigned for each criterion, sub criterion and alternative (Barker and Zabinsky, 2011).

According to Saaty (1980), this method gives a chance to individuals to select a value between 1 and 9, according to Table 15, to rate the strength of the relationship between items. So that a pair-wise comparison matrix can be established in order to calculate the related eigenvalues and the eigenvectors. The largest eigenvector will be analyzed by using the evaluation criteria via orders of values, so that the appropriate evaluation criteria can be selected (Chiu et.al., 2010).

Table 15: The Saaty's 1-9 scale for AHP (Saaty, 1980)

Importance Intensity	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgment slightly favor one over another
5	Essential or strong importance of one over another	Experience and judgment strongly favor one over another
7	Very strong importance of one over another	An activity is strongly favored and its dominance demonstrated in practice
9	Extreme importance of one over another	Importance of one over another affirmed on the highest possible order
2, 4, 6, 8	Intermediate values	Used to represent compromise between the priorities listed above

Step-3: The third step of the AHP process is related with checking the consistency of the weights. If the matrices in the AHP are not consistent, it should be revised the weights and the pair-wise comparison (Mayyas et.al., 2011). Pair-wise comparison matrix is shown as the following equation (Piltan et.al., 2012):

$$A = \left[a_{ij} \right] = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix} \tag{1}$$

In this pair-wise comparison matrix that has been given in Equation 1, the column and row are represent the alternatives and they must be formed according to the criteria number. When the importance of alternatives in each matrix has been determined, the overall significance of each alternative can be calculated. In this matrix the a_{ij} entry describes the relative importance of i^{th} criterion to j^{th} criterion (Piltan et.al., 2012). Then priorities are computed by normalizing every column of the matrix, to derive the normalized primary right eigenvector, the priority vector;

$$A \times w = \lambda_{max} \times w \tag{2}$$

According to this formula; A is the comparison matrix; w is the principal eigenvector; λ_{max} is the maximal eigenvalue of matrix A (Dambatta et.al., 2009).

Matrix A is reciprocal; that is $a_{ji} = a_{ij}^{-1}$, and all of its diagonal elements are uniform; that is $a_{ij} = 1$, for $i = j$. Given this reciprocal property, only $n(n-1)/2$ actual pair-wise comparisons were needed for an $n \times n$ matrix. Saaty's method calculates W as the basic right eigenvector of matrix A. The data of pair-wise comparison matrices are translated into the certain values and the normalized weight vector $w = (w_1, w_2, \ldots, w_n)$ is obtained (Zhang et.al., 2012).

To examine the consistency of the pair-wise comparison matrix A, t is needed to compute the maximum eigenvalue (λ_{max}) and eigenvector (W_i). The maximum eigenvalue (λ_{max}) should be appropriate to the eigenvector, so that they become the relative weight values in the evaluation criteria (Chiu et.al., 2010).

$$W_i = \frac{\left[\prod_{j=1}^{n} a_{ij}\right]^{\frac{1}{n}}}{\sum_{i=1}^{n}\left[\prod_{j=1}^{n} a_{ij}\right]^{\frac{1}{n}}} \tag{3}$$

When the pair-wise comparison matrix is established, it is possible to calculate the priority vector of the factors for each level. If λ turns into the eigenvalue of A, then W will be the eigenvector of A (Mohajeri and Amin, 2010).

$$(A - \lambda I) \times W = 0 \tag{4}$$

The approximate computation of the maximum eigenvalue (λ_{max}) can be done by multiplying pair-wise comparison matrix A with priority vector W, acquiring vector

W, and taking each factor in W to prioritize the factors in the W' vector (Bagla and Gupta, 2011).

$$A \times W = W' \qquad \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} \times \begin{bmatrix} W_1 \\ W_2 \\ W_3 \\ W_n \end{bmatrix} = \begin{bmatrix} W_1' \\ W_2' \\ W_3' \\ W_n' \end{bmatrix} \tag{5}$$

At the end of the equation, the found number can be used to compute the average value, which will become the maximum eigenvalue (λ_{max}) (Chiu et.al., 2010).

After making all pair-wise comparisons, the eigenvalue (λ_{max}) is used to compute the consistency index (CI). In Saaty (1990), it is suggested that the largest eigenvalue (λ_{max}) will be;

$$\lambda_{\max} = \left(\frac{1}{n}\right) \times \left(\frac{W_1'}{W_1} + \ldots + \frac{W_n'}{W_n}\right) \tag{6}$$

or

$$\lambda_{\max} = \sum_{j=1}^{n} a_{ij} \frac{W_j}{W_i} \qquad i = 1, 2, \ldots, n \tag{7}$$

Where, (λ_{max}) is the basic or largest eigenvalue of positive real values in a judgment matrix; W_j is the weight of the jth factor; and W_i is the weight of the ith factor (Saaty, 1990).

Consistency in the evaluations of decision maker is controlled in terms of the 'Consistency Index' (CI) and 'Consistency Ratio' (CR). The consistency of the decision maker's judgments is measured by computing CI, which is calculated by the following formula (Al-Hawari et.al., 2011):

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{8}$$

CR can be computed with the following equation (Vega et.al., 2011):

$$CR = \frac{CI}{RI} \tag{9}$$

As the comparisons are accomplished by personal or subjective judgments, some degree of inconsistency may occur (Mezughi et.al., 2012). Hence, CR is applied when the possibility that the judgments of matrix are randomly generated. If the CR values were more than 0.1, the models are automatically discarded; it will be necessary to revise the subjective judgment (Yalçın et.al., 2011). The value of the 'Random Consistency Index' (RI) is the result of a large number of simulation runs. It differentiates according to the order of matrix (Mayyas et.al., 2011). Some RI values can be seen in Table 16:

Table 16: Random Consistency Index (*RI*) (Saaty, 1980)

N	1	2	3	4	5	6	7	8	9	10	11	12
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48

Step-4: The fourth and the last step of the AHP process is to synthesize the results. And then, it should be predicted the last decisions which are related with the results of the procedure and selected the alternative with the highest priority (Mayyas et.al., 2011). It may be possible to make a sensitivity analysis, in order to understand the robustness of the chosen alternative to changes in the judgments decided by the DM (Al-Hawari et.al., 2011).

In the AHP, as it was explained, the individual choices are indicated as comparison judgments and their intensity was calculated with a ratio scale (Mikhailov, Didehkhani, and Sadi-Nezhad, 2011). In the classical formulation of the AHP, human's judgments are seen as a crisp number between 1 and 9 (Ibrahim, Mohamed, and Atwan, 2011). The use of fuzzy numbers can be preferred rather than the use of crisp numbers. Furthermore, even if the meaning of a word is well described, there can be some limitation criterion which are not well explained and make it difficult to provide the final judgment (Ahari et.al., 2011).

Although it is famous and easy in concept, AHP method can be criticized because it cannot overcome the natural uncertainty and ambiguity that is related with the guidance of the decision maker's sensation to crisp values (Dağdeviren and Yüksel, 2008). Despite the aim of AHP is to understand and apply the knowledge and opinion of expert, the classical AHP still cannot exactly represent the human thoughts (Lee, Tzeng, and Chiang, 2011).

3.2.2.2 Fuzzy Analytic Hierarchy Process (AHP)

Fuzzy AHP is the improved and synthesized version of AHP method where the fuzziness of the decision-making is expected (Muralidhar, Ravindranath, and Srihari, 2012). The complicated decision-making problems can be stated by ambiguity and uncertainty of the decision elements. So that applying the fuzzy set theory can be seen an inherent way to cope with uncertainty, imprecision, ambiguity and vagueness in decision-making processes (Mikhailov, Didehkhani, and Sadi-Nezhad, 2011). The usage of fuzzy set theory gives a chance to the decision makers to include unquantifiable information, non-finished information, non-obtainable information and partially ignorant facts into decision model. Despite fuzzy AHP requires tedious computations, it is possible to capture a human's assessment of uncertainity when complicated multi-criteria decision making problems are expected (Dağdeviren and Yüksel, 2008). The choices in AHP should necessarily be human judgments, which come from human assessments, thus fuzzy approaches make it possible to do more explicit and true description of the decision-making processes (Ahari et.al., 2011). In addition to the advantages of AHP, fuzzy AHP represent the human thoughts, facilitating of handling qualitative and quantitative information, applying the hierarchical structure, pair-wise comparison, reduced inconsistency, and forms priority vectors. (Ibrahim, Mohamed, and Atwan, 2011).

The word fuzzy means vagueness. Fuzziness occurs when boundary of a piece of information is not clear (Mishra and Thakar, 2012). Various authors try to develop different fuzzy AHP methods. All these methods can be described as systematic approaches to an alternative selection of the problem by using the fuzzy set theory concept (Zadeh, 1965) and analysis of hierarchical structure. To overcome the vagueness in information and the basic fuzziness of human choices, fuzzy set theory was created by Zadeh in 1965 (Şen, Şen, and Başlıgil, 2010).

The relationship between an element and a set is either 'belong to' or 'not belong to', under a classical crisp set. The function of the membership is either 0 or 1. But, crisp sets may not be sufficient to explain all the inherent phenomena, while the fuzzy set membership function can provide an obvious explanation (Lee and Li, 2011). Although the crisp set has only one membership function; the fuzzy set has unlimited membership functions. In the fuzzy approach, fuzzy data should undergo defuzzification to have explicit characteristics. Defuzzification can be described as a method that converts fuzzy data into explicit data. It does not have a fixed form, and may have different versions according to problems and data. (Che, 2010).

Fuzzy sets theory has capability of reflecting real world. They are strong mathematical tools in order to model the ambiguous systems in industry, the nature and humanity; and also the facilitators in decision making at the lack of complete and certain information (Naghadehi, Mikaeil, and Ataei, 2009).

These are the different fuzzy AHP methods that have been developed;

Van Laarhoven and Pedrycz (1983): The first study in fuzzy AHP can be seen in Van Laarhoven and Pedrycz (Büyüközkan, Kahraman, and Ruan, 2004). They propose an algorithm that is the improved version of Saaty's AHP method. They describe the weights through the AHP method and use the triangular fuzzy numbers and the computation steps that are the same as in crisp AHP (Ahari et.al., 2011). They also used the Lootsma's logarithmic least square method in order to obtain fuzzy weights and fuzzy performance scores. So they incorporated the concept of triangular membership functions to replace the certain weight ratios between criteria (Huang, 2011). There are some disadvantages that there may not be always a solution to the linear equations and even for a small problem, the computational requirement is tremendous (Van Laarhoven and Pedrycz, 1983).

Buckley (1985): Buckley determined fuzzy priorities of comparison ratios with trapezoidal membership functions (Büyüközkan, Kahraman, and Ruan, 2004). While extending the Saaty's AHP method, he utilizes the geometric mean method to obtain fuzzy weights and performance scores. So that it is possible to facilitate the improvement of the fuzzy case and it guarantees a sole solution to the reciprocal comparison matrix (Buckley, 1985).

Boender et.al. (1989): Boender presented a more powerful way to the normalization of the local weights. He modifies the method of Van Laarhoven and Pedrycz. The ideas of multiple decision makers can be adopted. (Huang, 2011).

Chang (1996): Chang presented an opinion for handling fuzzy AHP, by using the triangular fuzzy numbers for pairwise comparison scale of fuzzy AHP, and by using the method for the synthetic extent values of the pairwise comparisons (Büyüközkan, Kahraman, and Ruan, 2004). The important sides of Chang method are that the computational needs are relatively low. It uses the steps of crisp AHP. It allows using only triangular fuzzy numbers and it does not involve additional operations (Chang, 1996).

Cheng (1996): This method indicates the scores of performance by membership functions, uses entropy concepts to compute aggregate weights, builds fuzzy standards, the computational needs is not enormous and entropy is used when possibility of distribution is known. This method is related with both probability and possibility measures (Cheng, 1996).

Nowadays, the fuzzy AHP methods can be applied in various areas. Some of the numerous applications are reported over the last few years that include supplier selection, evaluation of computer companies, multi criteria inventory classification, consultant selection, bridge construction, expatriate assignment, and many others (Mikhailov, 2004).

For a better understanding of fuzzy AHP, introduction of fuzzy sets and fuzzy numbers is necessary.

Fuzzy numbers are the natural generalizations of ordinary numbers. The membership of an ordinary number like $\ddot{a}$ can be shown with:

$$\mu_{\ddot{a}}(x)\begin{cases}1 & ;\text{ if } x=a\\ 0 & ;\text{ if } x\neq a\end{cases} \tag{10}$$

Therefore, any real number can be stated as a fuzzy number (Sheikhi et.al., 2012). There are varied types of fuzzy membership functions, such as; monotonic, triangular, and trapezoidal. The simplest and more convenient fuzzy numbers are triangular fuzzy numbers (Mishra and Thakar, 2012).

Each triangular fuzzy numbers (TFN) has linear representations on its right and left side and its membership function can be described as (Ataei et.al., 2012):

$$\mu\left(x\middle|\tilde{M}\right)=\begin{cases}0, & x\le l,\\ \dfrac{(x-l)}{(m-l)}, & l\le x\le m,\\ \dfrac{(u-x)}{(u-m)}, & m\le x\le u,\\ 0, & x>u.\end{cases} \tag{11}$$

A tilde '~' will be placed above a symbol if it represents a fuzzy set. In the fuzzy extension of the AHP, the weights of the nine level fundamental scale are stated by the triangular fuzzy numbers (Zhu, et.al., 1999). They are the special classification of fuzzy number whose membership is described as three real numbers, expressed as $(l/m, m/u)$ or (l, m, u) (Chatterjee and Mukherjee, 2010). The parameters l, m and u, indicate the smallest probable value, the most promising value, and the largest possible value that describe a fuzzy event (Naghadehi, Mikaeil, and Ataei, 2009). The terms such as 'large', 'medium', and 'small' indicate the capture of a range of numerical values (Liao, 2011). These are the limitation of the possible evaluation field (Lamata, 2004).

A fuzzy number should always be given by its corresponding right and left representation of each degree of membership (Ataei et.al., 2012):

$$\tilde{M}=\left(M^{l(y)},M^{r(y)}\right)=\left(l+(m-l)y,u+(m-u)y\right),\quad y\in[0,1] \tag{12}$$

Where $l(y)$ and $r(y)$ denote the left side representation and the right side representation of a fuzzy number (Reza, Mohammad, and Reza, 2011).

Fuzzy numbers indicate the membership grade ranging between 0 and 1 as illustrated in Figure 19. $\tilde{M}$ is a fuzzy number if only $\tilde{M}$ is normal and convex fuzzy set of x (Kabir and Hasin, 2012).

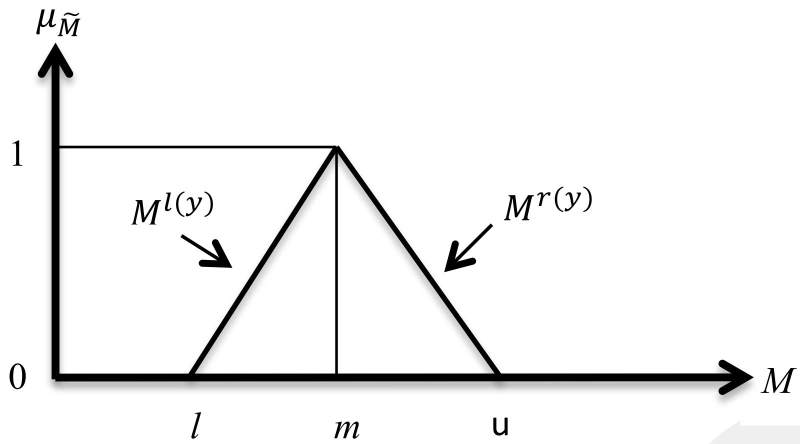


Figure 19: A triangular fuzzy number, $\tilde{M}$ (Wang and Chin, 2008)

There are various operations on TFN (Rouyendegh, 2012), but these common operations have been demonstrated as below:

$$\widetilde{M}_1 \oplus \widetilde{M}_2 = (l_1, m_1, u_1) \oplus (l_2, m_2, u_2) = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \quad (13)$$

$$\widetilde{M}_1 \ominus \widetilde{M}_2 = (l_1, m_1, u_1) \ominus (l_2, m_2, u_2) = (l_1 - u_2, m_1 - m_2, u_1 - l_2) \quad (14)$$

$$\widetilde{M}_1 \otimes \widetilde{M}_2 = (l_1, m_1, u_1) \otimes (l_2, m_2, u_2) \approx (l_1 \times l_2, m_1 \times m_2, u_1 \times u_2) \quad (15)$$

$$\widetilde{M}_1 \oslash \widetilde{M}_2 = (l_1, m_1, u_1) \oslash (l_2, m_2, u_2) \approx (l_1/u_2, m_1/m_2, u_1/l_2) \quad (16)$$

$$\widetilde{M}_1^{\ -1} = (l_1, m_1, u_1)^{-1} \approx (1/u_1, 1/m_1, 1/l_1) \quad (17)$$

On the operations demonstrated above $\widetilde{M}_1$ and $\widetilde{M}_2$ are two positive TFNs (Lee, et.al. 2009).

In the thesis, TFNs are used to represent subjective pair-wise comparisons of the judgments of experts between the alternatives such as equally, moderately, strongly and extremely. The triangular fuzzy conversion scale used to transform such linguistic values into fuzzy scales (Baygi, Zolfani, and Rezaeiniya, 2011). The evaluation model of this thesis is shown in Table 17.

Table 17: Fuzzy scale of preferences (Anagnostopoulos, et.al., 2007)

Linguistic Variables	Crisp AHP Scale	Fuzzy AHP Scale	
		TFS	Reciprocal TFS
Equally Preferred (EqP)	1	(1, 1, 1)	(1, 1, 1)
Equally to Moderately Preferred (Eq-MP)	2	(1, 2, 3)	(1/3, 1/2, 1)
Moderately Preferred (MP)	3	(2, 3, 4)	(1/4, 1/3, 1/2)
Moderately to Strongly Preferred (M-SP)	4	(3, 4, 5)	(1/5, 1/4, 1/3)
Strongly Preferred (SP)	5	(4, 5, 6)	(1/6, 1/5, 1/4)
Strongly to Very Strongly Preferred (S-VSP)	6	(5, 6, 7)	(1/7, 1/6, 1/5)
Very Strongly Preferred (VSP)	7	(6, 7, 8)	(1/8, 1/7, 1/6)
Very Strongly to Extremely Preferred (VS-ExP)	8	(7, 8, 9)	(1/9, 1/8, 1/7)
Extremely Preferred (ExP)	9	(8, 9, 9)	(1/9, 1/9, 1/8)

After the brief explanations of AHP, fuzzy AHP, fuzzy sets, and fuzzy numbers necessary information and detailed steps of Chang's (1996) fuzzy AHP method will be explained. This method selected to be used in the fuzzy AHP calculations of the thesis.

Among the various AHP methods pertaining to fuzziness, Chang's extent analysis model is the most famous and chosen one (Heo, Kim, and Cho, 2012). The steps of this method are similar to the classical AHP and relatively less complex than the other fuzzy AHP methods (137, Zolfani, and Rezaeiniya, 2011). In the thesis, a modified type of "*Chang's Extent Analysis Method*" (1996) had been applied. Similar to the study of Kabir and Hasin (2012); a modified fuzzy AHP methodology have been used in the thesis, which includes pair-wise comparisons of criteria, rather than alternatives. Because, main goal of using fuzzy AHP in this study is to weight criteria for developing a SC overall flexibility evaluation score; not to make any alternative comparison or selection.

Before explaining the steps of extent analysis method of Chang on fuzzy AHP, it should be explained by the meanings of terms.

For example, $X = \{x_1, x_2, \ldots, x_n\}$ is an object set and $U = \{u_1, u_2, \ldots, u_n\}$ is a goal set. Every object is taken and also analyzed for every purpose, which symbol is g_i therefore; m number of the extent analysis for every object can be seen as below (Chang, 1992):

$\widetilde{M}_{gi}^{1}, \widetilde{M}_{gi}^{2}, \ldots, \widetilde{M}_{gi}^{m}, \quad i = 1,2,3, \ldots, n$ (Kabir and Hasin, 2012) (18)

where all the $\widetilde{M}_{gi}^{j}$ $(j = 1,2,3, \ldots, m)$ are TFN's and $\widetilde{M}(x)$ is the TFN membership function (Dağdeviren and Yüksel, 2008).

The steps of Chang's extent analysis is as follows:

Step-1 (Ataei et.al., 2012): The fuzzy synthetic extent values with respect to i^{th} object is defined as

$$S_i \approx \sum_{j=1}^{m} \tilde{M}_{gi}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} \tilde{M}_{gi}^{j} \right]^{-1} \tag{19}$$

To calculate $\sum_{j=1}^{m} \tilde{M}_{gi}^{j}$ perform the fuzzy addition operation of m extent analysis values for a special matrix like:

$$\sum_{j=1}^{m} \tilde{M}_{gi}^{j} = \left(\sum_{j=1}^{m} l_j,\ \sum_{j=1}^{m} m_j,\ \sum_{j=1}^{m} u_j \right) \tag{20}$$

and to calculate $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} \tilde{M}_{gi}^{j} \right]^{-1}$ perform the fuzzy addition operation of $\tilde{M}_{gi}^{j}$ $(j = 1,2,\ldots,m)$ values like:

$$\sum_{i=1}^{n} \sum_{j=1}^{m} \tilde{M}_{gi}^{j} = \left(\sum_{i=1}^{n} l_i,\ \sum_{i=1}^{n} m_i,\ \sum_{i=1}^{n} u_i \right) \tag{21}$$

and then calculate the inverse of the vector as:

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m}\tilde{M}_{gi}^{j}\right]^{-1}=\left(\frac{1}{\sum_{i=1}^{n}u_i},\ \frac{1}{\sum_{i=1}^{n}m_i},\ \frac{1}{\sum_{i=1}^{n}l_i}\right) \tag{22}$$

Step-2 (Dağdeviren, Yüksel, 2008): The level of probability of $\tilde{M}_2=(l_2,m_2,u_2,)\geq\tilde{M}_1=(l_1,m_1,u_1,)$ is described as:

$$V\left(\tilde{M}_2\geq\tilde{M}_1\right)=sup\left[min\left(\mu_{\tilde{M}_1}(x),\mu_{\tilde{M}_2}(x)\right)\right] \tag{23}$$

And this can be equivalently showed as follows:

$$V\left(\tilde{M}_2\geq\tilde{M}_1\right)=hgt\left(\tilde{M}_1\cap\tilde{M}_2\right)=\tilde{M}_2\left(d\right)=\begin{cases}1, & \text{if } m_2\geq m_1,\\ 0, & \text{if } l_1\geq u_2,\\ \dfrac{l_1-u_2}{\left(m_2-u_2\right)-\left(m_1-l_1\right)}, & \text{otherwise.}\end{cases} \tag{24}$$

where d is the ordinate of the highest intersection point D between $\mu_{\tilde{M}_1}$ and $\mu_{\tilde{M}_2}$ as shown in Figure 20:

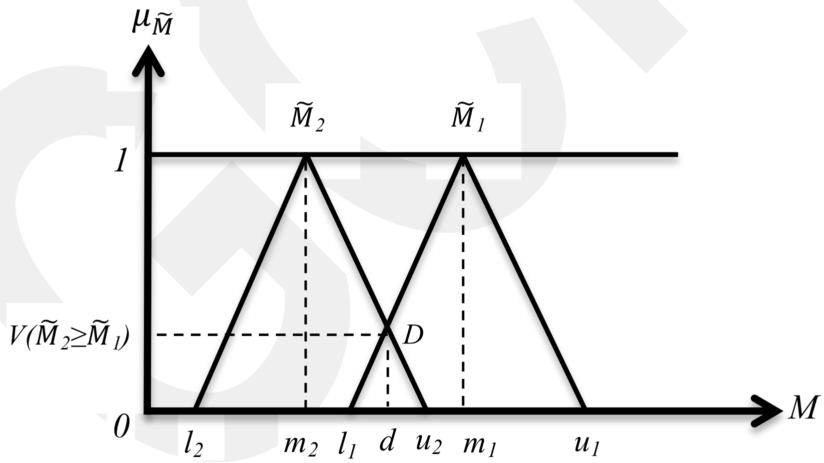


Figure 20: The intersection between $\tilde{M}_1$ and $\tilde{M}_2$ to compare $\tilde{M}_1$ and $\tilde{M}_2$, both the values of $V\left(\tilde{M}_1\geq\tilde{M}_2\right)$ and $V\left(\tilde{M}_2\geq\tilde{M}_1\right)$

Step-3 (Kabir and Hasin, 2012): Find the weight vector by taking the minimum of the vectors for each criterion: The level of probability for a convex fuzzy number that is greater than k convex fuzzy numbers $\widetilde{M}_i$ $(i = 1,2,\ldots,k)$ can be described as;

$$V\left(\tilde{M} \geq \tilde{M}_1, \tilde{M}_2, \ldots, \tilde{M}_k\right) = V\left[\left(\tilde{M} \geq \tilde{M}_1\right) \text{ and } \left(\tilde{M} \geq \tilde{M}_2\right) \text{ and} \ldots \left(\tilde{M} \geq \tilde{M}_k\right)\right] \\ = \min V\left(\tilde{M} \geq \tilde{M}_i\right), \quad (i = 1,2,3,\ldots,k) \tag{25}$$

Assuming that $d'(A_i) = minV(S_i \geq S_k)$ for $k = 1,2,3,..,n; k \neq i$; weight vector can be calculated as:

$$W' = \left(d'(A_1), d'(A_2), \ldots, d'(A_n)\right)^T \tag{26}$$

where $A_i = (i = 1,2,3,\ldots,n)$.

Step-4 (Mishra and Thakar, 2012): By normalizing, the weight vectors that are normalized are (assuming that $d(A_i) = minV(S_i \geq S_k)\ for\ k = 1,2,3,\ldots,n;\ k \neq i$);

$$W = \left(d(A_1), d(A_2), \ldots, d(A_n)\right)^T \tag{27}$$

where W is a non-fuzzy number.

In fuzzy AHP, first of all, a comparison of the criteria and alternatives' importance weights must be done. Because of that, there must be linguistic terms and their equivalent fuzzy numbers which indicate comparison measures. For the first step, a comparison should be made about the criteria, the alternatives, and the weight calculation. Hence, both the assessment of the criteria according to the main purpose and the assessment of the alternatives for these criteria must be studied carefully. Finally, after all these evaluation processes, it will be possible to calculate the weights of the alternatives (Vosooghi, Fazli and Mavi, 2012).

3.2.2.3 Analytic Network Process (ANP)

ANP, which is the generalization of the AHP, has been proposed by Saaty (1996). The ANP can be accepted as one of the most widely used multiple criteria decision making method like AHP (Lee, Kim and Park, 2012). The ANP is based on the knowledge and experience of the experts in the field (Shiue and Lin, 2012). Setting priorities among aims and also all tangible/intangible criteria and using the ratio scale of human judgment are the most important characteristics that makes ANP easier to be used by the decision makers (Ghajar and Najafi, 2012). Application of the ANP has been increasing to many strategic management frameworks. Because for strategic management, there is also an increasing need of employing sophisticated mathematical modeling. Such as strengths, weaknesses, opportunities and threats (SWOT) analysis, the balanced scorecard system or the strategic management concept framework (Lee, Kim and Park, 2012). The use of the ANP is increasing because of its effectiveness in allowing for complex interrelationships between attributes (Hu, 2010).

The ANP can be described as a comprehensive framework for the analysis that of public, governmental and corporate decisions (Khadivi and Fatemi Ghomi, 2012). ANP can be applied in all the quantitative and qualitative data analysis. It is possible to solve the dependence and feedback relationships between elements by using the ANP method (Che, Chiang and Che, 2011). In other words, it can indicate the best alternative via integrating the interconnections among criteria, alternatives, and feedback into the decision system. (Ghajar and Najafi, 2012).

ANP is a qualitative tool for solving strategic decision making problems. It is related with the process of eliciting managerial inputs and it facilitates the communication among the decision makers (Shiue and Lin, 2012). It will be very simple to assign a score from a person's memory that appears reasonable. ANP is an advanced method that can make qualitative judgments. The way of that is to use the reciprocal pair-wise comparisons (Öztaysı, Kaya and Kahraman, 2011).

It can be said that there are three main aims of the ANP model. First of all, it is generally used to solve a decision problem and choose the best alternative that is related with the criteria. The second aim of ANP is to prioritize the interrelated elements in the framework. And finally, it tries to capture indirect influences among elements and produce their relative importance in the network (Kim et.al., 2011).

If necessary to describe the ANP model, this explanation would be useful: If the symbol of network is N, then in this network every component is shown as C. Thus, the network (N) equals $\{C_a, C_b, C_c, \ldots, C_n\}$ and $\{\{C_a, C_a\}, \{Ca, C_b\},$

$\{C_a, C_b\}, \ldots, \{C_a, C_n\}\}$. This indicates the set of pair-wise relation between components of the network (Kone and Buke, 2007).

In recent years, the number of pair-wise comparisons has been increasing. Although the calculation process of ANP takes more time, it is preferred because of its proximity to real situations (Yazgan, Boran and Goztepe 2009).

ANP has some important differences than AHP. The derivation of the ANP priority weights is different from more traditional methods (Kone and Buke, 2007). It is possible to make a comparison between classical AHP and ANP methods. In most of the decision-making processes, it is very significant to regard the interdependent relationship among criteria that can be seen in many real life problems. Although the AHP is restrictive to solve problems, it is not necessary for ANP to create this strictly hierarchical structure. Therefore, ANP can see the problems that have complex interrelationships among criteria, and also among dependences and feedbacks. But the ANP applications are more limited than AHP, because of its complexity and high computational time. (Das and Chakraborty, 2011).

As a comparison, the ANP uses some methods that were applied in AHP such as pairwise comparison and hierarchical structures. ANP also improves a few new concepts, for example dependence, feedback, control and strategic criteria, benefits, opportunities, costs and risks (Bobylev, 2011).

The major difference between AHP and ANP is a supermatrix form that allows ANP to handle the interrelationships between the decision levels and attributes by obtaining the composite weights (Dağdeviren and Yüksel, 2010).

The hierarchies that both AHP and ANP are used can also be seen in the following figures below (Milani et.al., 2012):

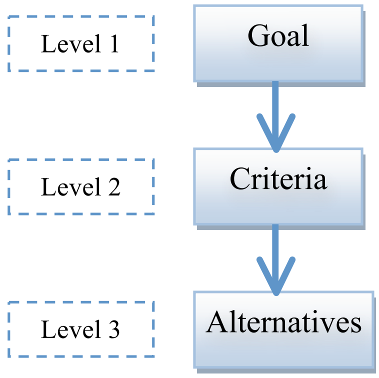


Figure 21: Hierarchy in AHP method

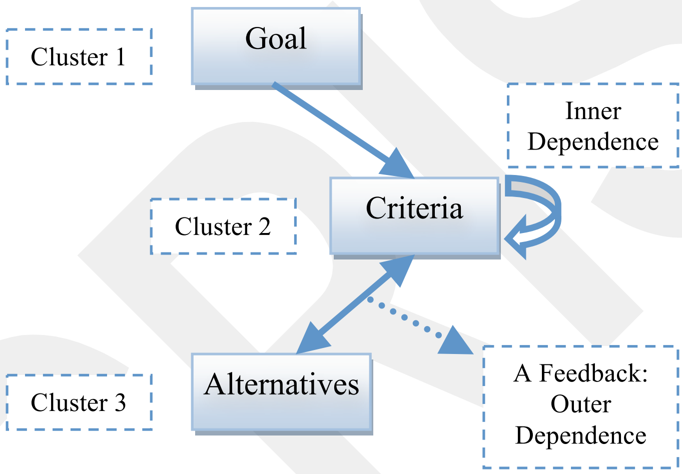


Figure 22: Hierarchy in ANP method

The ANP develops the AHP to problems with dependence and feedback. It replaces the AHP's hierarchy method with a network. So that it can analyze the complex interrelationships among decision elements. In other words, by considering the interdependency among elements, ANP creates relative importance of elements or priorities in a complex network model (Lee, Kim and Park, 2012).

The term of 'outer dependence', which is shown in ANP figure, indicates the dependency among clusters. It means that outer dependency is the interaction between items in one cluster and also items of other clusters. The other term is 'inner dependence' and this refers the effect of one item in a cluster to another item in the same cluster. At the situation of inner dependence, it can be seen the return of the arrow to the same criterion cluster, that comes out of a criterion cluster (Anık and

Baykoç, 2008). While the links between elements within the same cluster describe as inner dependencies, the links between a parent element in one cluster and in another cluster can be described as outer dependencies (Çelebi, Bayraktar and Bingöl 2010).

The ANP is related both interactions and feedbacks within the elements' clusters, namely inner dependence and also between clusters namely outer dependence. This kind of feedback is good for understanding the complex effects of interplay in human society, especially in an environment of risk and uncertainty (Khadivi and Fatemi Ghomi, 2012).

After completed the explanations and the literature review related with the ANP, application steps of the method can be explained as given below:

Step-1: Model Construction: On the step of model construction, first of all, the problem should be clearly identified. After that, it can be decomposed into network as a rational system (Lee and Lee, 2012). To make a better estimation of problem in order to reach the goal, decision makers should determine related factors under all circumstances. In the ANP, the control hierarchy method helps to this determination process. If the influencing relations are complicated, some sub criteria will be suggested and then some associated clusters and their elements can be listed (Shih et.al., 2012).

In the network, nodes correspond to clusters. The elements of a cluster can interact with each of the elements of another cluster. And each elements corresponds to a decision criterion (Kirytopoulos et.al., 2011). The relationships between the elements are represented by arcs with directions (Lee, Kim and Park, 2012). The criteria, the alternatives and the interdependencies among them are stated by the decision makers (Kirytopoulos et.al., 2011). The way that they use is brainstorming or by undertaking other appropriate methods (Lee and Lee, 2012).

Step-2: Pairwise Comparison Matrices and Priority Vectors: Applying the main scale of AHP, each cluster has pairs of the decision elements. So clusters and elements are compared according to their influence on another cluster or element (Kirytopoulos et.al., 2011). After a series of pair-wise comparisons of clusters or elements, the DM should answer their contribution to their particular upper level criteria (Das and Chakraborty, 2011).

Moreover, Interdependencies among a cluster's elements must also be examined pair-wise; an eigenvector represents the influence of each element on other elements. The relative importance values are determined by using Saaty's nine-point scale, as it was mentioned about while explaining the AHP. In the ANP, if an element takes a score of 1, this means that there is an equal importance between the two elements and if an element takes a score of 9, this indicates the extreme importance of one compared to another one (Lee and Lee, 2012).

If there is an outer dependence feedback relationship between the cluster alternatives and the criteria cluster, the pair-wise comparisons of criteria should be made for each alternative. In both situations, given a square comparison matrix A, the influence of individual elements in the matrix on a control criterion can be found by using the eigenvector method (Milani et.al 2012). As it can be seen in the AHP chapter in Equation (2), pair-wise comparison in the ANP also uses the same equation (Lee and Lee, 2012):

So that the framework of a matrix, and a local priority vector which is derived as an estimate of the relative importance associated with the elements or clusters, can be compared. Like AHP, the consistency index (*CI*) and consistency ratio (*CR*) are used as a tool in order to verify the consistency of the pair-wise comparison matrix (Das and Chakraborty, 2011). Their formulas can be seen in the AHP chapter.

It is a commonly used method to normalize each weight vector so that the sum of its elements becomes one. In ANP, the next weight vectors are referred to as local priority vectors (Milani et.al 2012). Thus, the eigenvector method is used to obtain local priority vectors for each pair-wise comparison matrix. The matrix containing the weights of all clusters is defined as "Clusters' Priority Matrix" (Kirytopoulos et.al., 2011).

Step-3: Supermatrix Formation: In the application period, the supermatrix has some characteristics that are similar with the Markov chain process. Both of them try to obtain global priorities in a system by using interdependent influences. To create a successful matrix, the local priority vectors should be entered in the appropriate columns (Yazgan and Üstün, 2011). It aims to be used as a unifying framework for priorities in hierarchy and in systems with feedback (Babaesmailli et.al., 2012). At the end, each segment of the matrix shows a relationship between two nodes or components or clusters in the system (Shiue and Lin, 2012).

There are two types of supermatrix. The former is the unweighted supermatrix which columns are not stochastic. In order to get a stochastic matrix, second type of matrix, firstly each column should be summed into one, and then the corresponding cluster priority must multiply the unweighted supermatrix's blocks (Bayazit and Karpak, 2007). The latter is a kind of matrix, which is called as weighted supermatrix. It has capacity to find the degree of the influences (Karpak and Topcu, 2010).

Like constructing the standard AHP, making a weighted supermatrix needs to weight the clusters. In order to create a weighted supermatrix, the blocks of the unweighted supermatrix should be identified with the priorities of the clusters. The weighted supermatrix is also called as column stochastic (Smith-Perera et.al., 2010), which means that the sum of each column in the super-matrix must be one (Hsu et.al., 2012).

As it is explained in the second step of the ANP, if the consistency test of a comparison matrix is resulted positively, the derived priorities from the comparison matrix are added as parts of the columns of the supermatrix of the network. If it results negatively, the comparison matrix must be revised by experts (Ergu et.al., 2011). When the differences between corresponding elements of a row can be less than a very small number, the process has to be converged. Thus, the supermatrix has a successive power (Karpak and Topcu, 2010). The supermatrix is a partitioned matrix that each submatrix is constituted from a set of relationships between the levels, as can be seen by the decision maker's model (Hsu et.al., 2012).

The elements are prepared both vertically and horizontally by clusters. The priorities of the elements should be read from the vertical columns (Kirytopoulos et.al., 2011). The cluster weight matrix is the dimension $n \times n$ (n is the number of clusters). Nodes are compared within each cluster and in relation to the whole other nodes in related clusters. The supermatrix blocks' organize the columns of the nodes by the clusters that they belong (Banai and Wakolbinger 2011). The influence that other is not concerned. It means that each column of the supermatrix is not column stochastic. As a solution method, it needs to regard each hierarchy as an element, pair-wise compare according to a certain hierarchy, and then compute corresponding priorities

(Wei and Bi, 2008). Finally, the supermatrix is multiplied with the cluster weights so that the columns become stochastic denoted by W (Banai and Wakolbinger 2011).

The resulting relative importance weights that are called as eigenvectors in pair-wise comparison matrices are placed within a supermatrix. So that it can be seen the whole interrelationships of all elements in the system (Smith-Perera et.al., 2010). The main structure of the supermatrix can be explained as given below (Kirytopoulos et.al., 2011):

$$
W = \begin{array}{cc} & \\ & \\ c_1 & \begin{array}{c} e_{11} \\ e_{12} \\ \vdots \\ e_{1n_1} \end{array} \\ c_2 & \begin{array}{c} e_{21} \\ e_{22} \\ \vdots \\ e_{2n_2} \end{array} \\ \vdots & \vdots \\ c_N & \begin{array}{c} e_{N_1} \\ e_{N_2} \\ \vdots \\ e_{Nn_N} \end{array} \end{array}
\begin{array}{c}
\begin{array}{cccc} c_1 & c_2 & \cdots & c_N \\ e_{11}e_{12}\cdots e_{1n_1} & e_{21}e_{22}\cdots e_{2n_2} & \cdots & e_{N1}e_{N2}\cdots e_{Nn_N} \end{array} \\
\begin{bmatrix} W_{11} & W_{12} & \cdots & W_{1N} \\ W_{21} & W_{22} & \cdots & W_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ W_{N1} & W_{N2} & \cdots & W_{NN} \end{bmatrix}
\end{array} \quad (28)
$$

In this matrix, c_i indicates the i^{th} cluster, e_{ji} denotes the j^{th} element of the i^{th} cluster and W_{ik} is a block matrix that consists of priority weight vectors of the influence of the element in the i^{th} cluster with respect to the k^{th} cluster (Smith-Perera et.al., 2010). The local priority vectors that are found in the second step of the ANP are grouped and located in convenient positions in the supermatrix (Lee and Lee, 2012). According to Saaty (1996), the three level of hierarchy can be shown as in the matrix given below:

$$
W_n = \begin{bmatrix} 0 & 0 & 0 \\ W_{21} & W_{22} & 0 \\ 0 & W_{32} & I \end{bmatrix} \quad (29)
$$

In this matrix, 'W_{21}' is a vector that shows the goal's impact over the criteria, 'W_{32}' is a matrix that represents the criteria's impact over each of the alternatives, 'I' is the identity matrix, and '0' represents the elements that have no influence over the matrix (Lee and Lee, 2012). If there is an interrelationship of the elements in a cluster or between two clusters, the zeros in the supermatrix can be changed via a matrix (Jajimoggala, Kesava Rao and Beela, 2011).

Step-4: The limit supermatrix and the selection of best alternatives: To obtain the limit, it needs to raise the matrix to powers. If the matrix is not column stochastic, the limit may not converge (Sagır and Ozturk, 2010). The weighted supermatrix is raised to limiting powers to get the global priority weights, thus the most significant criterion and the best alternative are acquirable (Wei and Bi, 2008). The raising of the supermatrix can be formulated as $2k + 1$. In this formula, k represents an arbitrarily large number that enables the convergence of the matrix. When the whole elements of W^{2k+1} are equal to the whole elements of W^{2k} $\left(W_{ij}^{2k+1} = W_{ij}^{2k}\right)$ with a certain precision, the stopping criterion for iterations can be satisfied. The decimal of this precision is generally from 2 to 6. The result of this matrix is the limit matrix. Thus the decision maker can analyze the results and select the best alternatives (Kirytopoulos et.al., 2011).

In the limit matrix, it is possible to obtain limiting priorities by multiplying the weighted supermatrix. This can be done by multiplying the weighted supermatrix by itself until its columns stabilize. The new matrix is named as limit supermatrix and can be shown as in Equation (30) (Babaesmailli et.al., 2012).

$$W^{\infty} = \lim_{k \to \infty} W^{k} \tag{30}$$

The limiting priorities can be seen as the corresponding column values to each cluster and their elements (Chen et.al 2012).

The weighted supermatrix should be multiplied, because it is wanted to catch whole possible paths that affect the transmission (Kirytopoulos et.al., 2011). If the created supermatrix covers the whole network, in the normalized supermatrix, the alternatives' priority weights can be found in the alternatives' column (Yazgan and Üstün, 2011). Conversely, if a supermatrix is formed of only the interrelated components, in order to obtain the overall priorities of the alternatives, some additional calculations are needed. So that, the alternative that has the largest overall priority can be selected. (Lee and Lee, 2012).

3.2.3 Regression Models

Regression analysis is one of the oldest statistical methods in the area of mathematical statistics. The earliest form of the linear regression was the least squares method that was used by Legendre in 1805 and by Gauss in 1809 (Yan and Su, 2009).

Regression analysis is used to predict the value of one variable on the basis of other variables. This may be the most commonly used statistical technique, because almost all companies and government institutions try to forecast some variables that are vital for them. (Okereke, 2011)

In statistics, there are many techniques for data analysis, but the regression is the only analysis that takes into account the effect of other variables. The purposes of using this technique can be listed as; data description, prediction, parameters estimation and control (Montgomery, Peck, and Vining, 2001).

This technique describes the relationship between the variables to be forecast, which is called the dependent variable. The related variables are called independent variables. The dependent variable is denoted Y and the independent variables are denoted $X_1, X_2, \ldots, X_k$ (k is the number of independent variables) (Keller, 2011).

There are three types of regression: Simple linear regression, multiple linear regression and non-linear regression (Yan and Su, 2009). In this thesis, the simple and multiple linear regression models will be used.

3.2.3.1 Simple Linear Regression (SLR) Models

The SLR model has been subject to extensive research in the statistical literature for many years (Thoresen and Laake, 2007). This model can be used in many areas of applications such as marketing, agriculture, survival analysis and biostatistics (Mandal and Samanta, 2007).

The SLR model is used to understand the relationship between two variables (Wooldridge, 2009). It is also defined by assumptions of linearity, homogeneous dispersion and normality (Brant, 2007).

The expression "Simple Linear Regression" refers to regression applications in which there is only one independent and one dependent variable (McClave and Dietrich, 1994). A SLR analysis is useful to predict the value of the dependent variable y, given the value of the explanatory variable, x (Tranmer and Elliot, 2008).

A SLR model is given by the equation (Keller, 2011):

$$y = \beta_0 + \beta_1 x + \varepsilon \qquad (31)$$

Where;

y : Dependent Variable,

x : Independent Variable,

β_0 : y-intercept

β_1 : Slope of the line

ε : Error Variable

The basic variables of SLR are y and x. y is usually called the dependent variable, but it can be called like the explained variable, the response variable, the predicted variable or the regressand; x is called the independent variable, and its other names are the explanatory variable, the control variable, the predictor variable, or the regressor (Wooldridge, 2009).

β_0 is y intercept, β_1 is the gradient or the slope of the regression line and ε is the random error. It is assumed that ε is normally distributed with $E(\varepsilon) = 0$ and a constant variance $Var(\varepsilon) = \alpha^2$ in the simple linear regression (Yan and Su, 2009).

In order to find the best model, there should be accurately considered pre-assumptions to make reliable results of relating two variables. If there are not any considered pre-assumptions, some problems may occur, because the effect of violation of one or more hypothesis is not visible in the final model. It can be seen that there are five hypotheses in relation with regression (Reza and Saleh, 2011):

a. If the dependent variable (y) has linear relationship with the independent variable (x), it is said that model is correct,
b. Data that used for fitting the model is a representative of the desired data.
c. Errors variance is constant (not related to the independent variable (x) or other variables.
d. Errors are independent of each other.
e. Errors have normal distribution. Necessary to meet these assumptions, is determined based on goal of performing regression.

The best performance of SLR models can be seen when the analytical assumptions are met. These assumptions require: linearity in the parameters; independent error terms and the error term to be normally distributed with zero mean and constant standard deviation (Angus, Casado, and Fitzsimons, 2012).

3.2.3.2 Multiple Linear Regression (MLR) Models

MLR model is the second type of linear regression analysis. It can be thought of an extension of SLR, where there are p explanatory variables, In other words, simple linear regression can be seen as a special case of MLR, where $p = 1$. Both of them are 'linear', because in MLR it is assumed that y is directly related to a linear combination of the explanatory variables (Tranmer and Elliot, 2008). As is true for SLR, MLR generates two variations of the prediction equation; one in raw score form and the other in standardized form. These are the extended equations of the SLR models and it still represents the linear regression (Meyers, Gamst, and Guarino, 2005).

MLR method is a statistical method that is used to establish a quantitative relationship between input and target parameters of a linear system or a process, to predict the direction of the effect or understand which parameters have the greatest effect (Civelekoglu et.al., 2007). It tries to study the linear influence of a number of independent variables on a dependent variable. The data of this model should be in a normal distribution at the beginning or in a normal distribution after the change of the variables, and also, the relationship between the independent variables and the dependent variables must be linear (Wang et.al., 2011).

MLR involves more than one independent variable in the model that forms an equation as given below (Tranmer and Elliot, 2008):

$$y_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \ldots + \beta_p x_{pi} + \varepsilon_i \tag{32}$$

where;

y_i : The predicted value of the dependent variable;

β_0 : The constant term;

$\beta_0, \ldots, \beta_p$ are the coefficients relating to explanatory variables to the variables of interest.

Every value of the independent variable 'x' is associated with a value of the dependent variable 'y' (Magar and Jothiprakash, 2011). If a model has the property that no independent variable is a function of the other independent variables, then the signs $(+, -)$ of the coefficients (β_i) show the direction of the change in y as x_i increases, holding other x_i at fixed values. By looking at the coefficients, it is easy to do some analytical interpretation of a multiple regression model. Given the conditions specified above, does it make sense that y declines (negative coefficient) or increases (positive coefficient) with some x variable? If it does not make sense, it means that there is something wrong with the model or the data (Guthery and Bingham, 2007).

With the MLR equation, it is possible to develop next levels of the dependent variable given future predictor indicators. The adequacy of the model can be tested by the analysis of variance approach. In regression analysis, the sum of squares regression $(SSR = \sum_{i=1}^{n} (\hat{y}_i - \bar{y})^2)$ and error sum of squares $(SSE = \sum_{i=1}^{n} \hat{\varepsilon}_i^2)$ decomposed the total sum of squares $(SST = \sum_{i=1}^{n} (y_i - \bar{y})^2)$:

$$SST = SSR + SSE \tag{33}$$

The multiple correlation coefficient R:

$$R^2 = SSR/SST = 1 - SSE/SST \tag{34}$$

This is the degree of association between the independent and dependent variable. It varies between 0 and 1. It is better to be closer the value of 1. The significance of R is that its square R^2 is nearly the decimal fraction of the variation of 'y' accounted by independent variables. As an example, if $R^2 = 0.898$ then 89,8% of the total variance in the data is explained by the model (Reddy and Rao, 1989).

There should be some assumptions for the MLR model. They can be listed as follows (Ostrom, 1990):

- Linearity: The relationship between the predictand and the predictors is linear. If relationships are nonlinear, there are two solutions; the former is to transform the data to make the relationships linear; and the latter is to use an alternative statistical model, such as neural networks or binary classification trees. It is a rule that the MLR model applies to linear relationships.
- Nonstochastic ($x: E(\varepsilon_i x_{ik}) = 0$): The errors are uncorrelated with the individual predictors. This assumption is checked in residuals analysis with scatterplots of the residuals against individual predictors. Violation of the assumption might suggest a transformation of the predictors.
- Zero Mean ($E[\varepsilon_i] = 0$): The expected value of the residuals is zero.
- Constant Variance ($E[{\varepsilon_i}^2] = \sigma^2$): The variance of the residuals is constant.
- Nonautoregression ($E[\varepsilon_i \varepsilon_{i-m}] = 0, m \neq 0$): The residuals are random, or uncorrelated in time.
- Normality: The error term is normally distributed. This assumption must be satisfied for conventional tests of significance of coefficients and other statistics of the regression equation to be valid.

Throughout the analyses carried out in the thesis prerequisites necessary for the regression analysis have been controlled for each data set used in the regression models.

3.2.3.3 Various Regression Related Statistical Analyses

Solution of regression models requires various statistical analyses to be carried out together. IBM SPSS Statistics version 19 has been used for the solution of regression models in the thesis. During the interpretation phase of the outputs of regression results, following indicators have been used:

a. Beta: In the simple measurement error situation (that is $\sigma_{eu} = 0$), the usual estimator of β is given by (Thoresen and Laake, 2007):

$$\hat{\beta}_1 = \left(S_{XX} - \sigma_{uu}\right)^{-1} S_{XY} \tag{35}$$

where S_{XX} and S_{XY} represents the sample variance of x and the sample covariance between x and y respectively. $\hat{\beta}$ can also be written as $\hat{\beta}_{OLS}/\hat{\lambda}$, where $\hat{\beta}_{OLS}$ is the ordinary least squares (OLS) estimator resulting from ignoring measurement error, and reliability ratio can be expressed as:

$$\hat{\lambda} = \left(\hat{\sigma}_{XX} - \sigma_{uu}\right)^{-1} S_{XY} \tag{36}$$

b. R^2 : R-square measures the proportion of the variation in the dependent variable that was explained by variations in the independent variables (Gupta, 2000).

The coefficient of determination R^2 is a measure of the fraction of total variation in Y that can be explained by the regression function:

$$R^2 = \frac{regression\ sum\ of\ squares}{total\ sum\ of\ squares} = \frac{S_{XY}^2}{S_{XX}S_{YY}} \tag{37}$$

$R^2 \in [0,1]$. $R^2 = 1$, when there is a perfect linear relationship between x and y. $R^2 = 0$, when the best fitting regression line has $\hat{\beta}_1 = 0$ i.e. there is no relationship between x and y , so that y is independent of level x.

c. Adjusted R-square: Measures the proportion of the variance in the dependent variable that was explained by variations in the independent variables (Gupta, 2000). According to SPSS manual (IBM, 2010), Adjusted R^2 is calculated as below:

$$R_{adj}^2 = R^2 - \frac{\left(1 - R^2\right)p}{C - p^*} \tag{38}$$

d. Correlation Matrix: When dealing with more than one independent variable, it can be represented the collection of all zero-order correlation coefficients in correlation matrix form. For example; If we determine $k = 3$, independent variables will be $x_1, x_2,$ and x_3 and one dependent variable y. There are $C_2^4 = 6$ zero-order correlations, and the correlation matrix will be as follows (Kleinbaum, Kupper, and Muller, 2007):

$$\begin{array}{c} \\ y \\ x_1 \\ x_2 \\ x_3 \end{array} \begin{array}{c} \begin{array}{cccc} y & x_1 & x_2 & x_3 \end{array} \\ \begin{bmatrix} 1 & r_{y1} & r_{y2} & r_{y3} \\ & 1 & r_{12} & r_{13} \\ & & 1 & r_{23} \\ & & & 1 \end{bmatrix} \end{array} \tag{39}$$

where r_{yj} $(j = 1,2,3)$ is the correlation between y and x_j, and r_{ij} $(i, j = 1,2,3)$ is the correlation between x_i and x_j.

e. Significance: The test of significance is used to understand a coefficient is significantly different from zero or not. If it is not, it means that the explanatory variable does not totally explain the dependent variable.

$$t = \frac{\beta - \beta^*}{se(\beta)} = \frac{\beta - 0}{se(\beta)} = \frac{\beta}{se(\beta)} \tag{40}$$

where β = coefficient value, β^* = hypothesized value (almost always 0), $se(\beta)$ = standard error of β.

Calculated t, value should be compared with a t value taken from a table (at a given significance level, α, with $n-k$ degrees of freedom); where $n=$ number of observations and $k=$ number of parameters estimated / independent variables; $n-k$ = degrees of freedom (Davies, 2011).

SPSS makes the mentioned comparison and gives the p-value automatically. In statistics, p-value should be under 0.10 (=10%) as indicating a variable is significant in 90% confidence interval. p-value of 0.05 mentions a significance level in 95% confidence interval, which is more desirable.

f. Durbin Watson Analysis: The Durbin-Watson analysis is used to test for serial correlation (autocorrelation) in the residuals of relationships containing lagged endogenous variables that are estimated by single or simultaneous equations methods (Nerlove and Wallis, 1966). The test statistic of the Durbin-Watson procedure is calculated as follows:

$$d=\frac{\sum_{t=2}^{n}\left(\varepsilon_t-\varepsilon_{t-1}\right)}{\sum_{t=1}^{n}\varepsilon_t^2} \quad (41)$$

Recall that ε_t represents the observed error term or $(y_t-\hat{y}_t)=y_t-\alpha-\beta x_t$. It can be shown that the value of d will be between zero and four; zero corresponding to perfect positive correlation and four to perfect negative correlation. If the error terms, ε_t and ε_{t-1}, are uncorrelated, the expected value of d is 2 (Stieglitz and Wallis, 1995).

Autocorrelation is a frequent problem that occurs mainly in time series analysis. Since the analyses of the thesis consist of cross-sectional data, a chance to have an autocorrelation is low. But for the validity of the regression results auto correlation has been controlled for the data used in the analyses.

g. Variance Inflation Factor (VIF): VIF value is being used to test for multicollinearity problems and calculated for each independent variable as follows:

$$VIF\left(\hat{\beta}_i\right) = \frac{1}{1-R_i^2} \tag{42}$$

$$Tolerance\left(\hat{\beta}_i\right) = \frac{1}{VIF\left(\hat{\beta}_i\right)} = 1 - R_i^2 \tag{43}$$

It can be seen from the formulas that the higher VIF or the lower the tolerance index means the higher the variance of $\widehat{\beta_i}$ and the greater the chance of finding β_i insignificant. The procedure is to choose each explanatory variable as the dependent variable and regress it against a constant and the remaining explanatory variables. Thus it would get $k-1$ values for VIF (Wooldridge, 2009).

Klein (1962) suggested that when R_i^2 exceeds the overall R^2 of the regression model, multicollinearity exists. In terms of *VIF*s, this suggestion means that the *VIF* of each coefficient should be smaller than $\frac{1}{\left(1-R^2\right)}$ (Verhees, 2005).

h. Heteroscedasticity: If the each error term's variance is not constant over observations, this situation creates heteroscedasticity (Pindyck and Rubinfeld, 2000). The White Test is used for determining heteroscedasticity which can be explained with the steps given below (White, 1980):

For the following model
$$\begin{aligned} Y_i &= \beta_1 + \beta_2 X_2 + \beta_3 X_3 + u_i \\ \sigma^2 &= \alpha_1 + \alpha_2 X_2 + \alpha_3 X_3 + \alpha_4 X_2^2 + \alpha_5 X_3^2 + \alpha_6 X_2 X_3 \end{aligned},$$

- Make the necessary estimations by solving the model,
- Compute the residual $\hat{u}_i = Y_i + \hat{\beta}_1 - \hat{\beta}_2 X_2 - \hat{\beta}_3 X_3$ and square it,

- By using $\hat{u}_i^2$ as dependent variable and X_2, X_3, X_2^2, X_3^2, and $X_2 X_3$ as independent variables, regress the model again,

- Compute the nR^2 value by solving the regression model. If the model is found significant ($nR^2 > X_5^2(a)$, a is the upper percent point on the chi-square distribution with a degrees of freedom of 5), this means that the residuals are heteroscedastic. If not it is homoscedastic.

3.2.4 Independent Samples t-Test Analysis

T-test is a kind of parametric test of statistical significance. If there is a normally distributed dependent variable, the parametric t-tests can be applied (Morgan, Griego, and Gloeckner, 2000). It is used while comparing the mean differences between two groups on an interval or ratio-level dependent variable. The t-test is commonly used to compare the mean of the outcome scores of groups, which are determined to two different conditions. In general, t-test aims understanding the statistical significance of the differences between two means. In order to get successful results, it uses a complex formula (Rubin, 2009).

Special kind of t-test analysis has been used in the thesis, which is named as independent samples t-test. As a kind of t-tests, the independent samples t-test is one of the mostly used statistical tests (Urdan, 2005). The other names of the independent samples t-test are the unrelated t-test or the independent measures t-test (Hinton et.al 2004). This test can be seen as an association between two variables. It is used when there is a need for comparing the means of two independent samples on a given variable (Welkowitz, Cohen, and Ewen, 2006). The major question about the use of the independent samples t-test is 'how much difference is necessary for understanding whether is there a significant difference between the two distributions?' (Smith, Gratz, and Bousquet, 2008).

The groups that are the subject of the independent samples t-test should be independent from each other (Urdan, 2005). The term independent also indicates the compared two groups that do not have any connection between each other. A generally applied way for achieving independent groups is to use random numbers or a coin toss to randomly determine situations to one group or the other (Rubin, 2009). The independent samples t-test can be applied when the samples are unrelated (Hinton et.al 2004). So that the independent samples t-test can be used appropriately (Urdan, 2005).

While using the independent samples t-test, there should be a categorical or nominal independent variable and also an interval basely scaled dependent variable. The score of the dependent variable depends on the value of the independent variable. In the content of the independent variable, there must be only two categories, such as men and women (Urdan, 2005).

Hypothesis testing is an important part of the independent samples t-test. It is also applied to two groups; but there are significant differences between them. The independent samples t-test, two population means are incorporated into the null and alternative hypotheses (Smith, Gratz, and Bousquet, 2008).

After giving the explanations about the independent samples t-test, in the rest of this section information about the necessary calculations will be given. Before applying the independent samples t-test, these assumptions should be controled (Smith, Gratz, and Bousquet, 2008);

- The variable is normally distributed,
- The variances of the groups are assessed as equivalent,
- The score on the dependent variables are independent.

In order to apply the procedure, these assumptions should be met. However, according to some researches the violations of the assumptions may have little effects over the statistical outcomes. In other words, in each group if the participants' numbers are equal, the equal variances' assumption will not be so important. In independent samples t-test also, the little effects over the statistical outcomes can be seen via the violations of the assumption of a normal distribution (Smith, Gratz, and Bousquet, 2008). If the assumptions are met, the formula will be as follows: (Lomax, 2007).

$$t = \frac{\bar{X}_1 - \bar{X}_2}{S_{\bar{X}_1 - \bar{X}_2}} \qquad (44)$$

$\bar{X}_1$: The mean of the first sample

$\bar{X}_2$: The mean of the second sample

$S_{\bar{X}_1 - \bar{X}_2}$: The standard error of the difference between two means

To compute the standard deviation of the sampling distribution;

$$S_{\bar{X}_1 - \bar{X}_2} = S_p \sqrt{\frac{1}{n_1} + \frac{1}{n_2}} \tag{45}$$

S_p : The pooled standard deviation

S_p can be calculated as follows:

$$S_p = \sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}} \tag{46}$$

where,

s_1^2 : The variance of the first sample,

s_2^2 : The variance of the second sample,

n_1 : The size of the first sample,

n_2 : The size of the second sample,

$n_1 + n_2 - 2$: The degrees of freedom of the test.

The formula of $S_{\bar{X}_1 - \bar{X}_2}$ that shows the standard error, is a pooled standard deviation weighted by the two sample sizes. In other words, the variances' of the two samples are weighted by their sample sizes and pooled (Lomax, 2007).

In the SPSS results of the independent samples t-test, there is another test that shows if there is a significant difference in the variances of the two groups. The name of the test is Levene's test for equality of variances. According to the results, if the *p* value is greater than 0.05, it means that the assumed equal variances formula can be used. However, if the *p* value is less than 0.05, the not assumed equal variances formula will be used. The important point of this test is to understand which row should be used in the interpretation of independent samples t-test (Rubin, 2009).

After the Levene's test, null and alternative hypotheses should be examined according to following hypotheses:

H_0 : The population means of the two samples are equal. ($\mu_1 = \mu_2$)

H_1 : The population means of the two samples are not equal. ($\mu_1 \neq \mu_2$)

It can be said that there is a relationship if one population mean (μ_1) is smaller or larger than the other (μ_1). It is always tested H_0, to find that there is *zero* difference between populations (Heiman, 2010). The alternative hypothesis (H_1) represents the conclusion reached by rejecting the null hypothesis (H_0). (Levine, Berenson, and Krehbiel, 2008). When the null hypothesis is true, no difference is expected between the sample means (Smith, Gratz, and Bousquet, 2008).

CHAPTER 4

SUPPLY CHAIN PERFORMANCE AND FLEXIBILTY MEASUREMENT SCORES

Purpose of the thesis is to introduce two new metrics for evaluating overall SC performance and flexibility to determine the factors affecting them. By using these metrics performance and flexibility benchmarking can be done. Furthermore, factors needed to evaluate ERP implementation and BPR application successes have been determined to increase the chance of success. By doing so, improvements in the SC performance and flexibility can be achieved and measured by the metrics developed. Development of Supply Chain overall performance score (SCOPS) and Supply Chain overall flexibility score (SCOFS) have been explained in details in this chapter. Also, SC flexibility hierarchy has been explained and the factors affecting each level in the hierarchy have been determined for the measurements necessary to calculate SCOFS metric.

4.1 Development of Supply Chain Overall Performance Score (SCOPS) metric with ANP Method

Development of a performance metric is important for evaluating the factors that affects SC performance. Standardizing the measurement technique will help the benchmarking of performance by presenting consistent results. In this study, effects on the SC performance of SC flexibility, ERP implementation success and BPR application success are being investigated. To measure these effects first of all an overall performance measurement metric was needed. For this purpose SCOPS metric has been developed. By using SCOPS, factors affecting SC performance can be determined accurately. This metric can also be used to benchmark SC performance to track the improvements acquired.

For the development of SCOPS, different performance metrics are needed. Some experts from manufacturing, service and academic sectors have compared these metrics according to their relative importance. Then after, these pair-wise comparisons have been analyzed with ANP analysis to calculate weights associated with each metric. By using these weights SCOPS have been calculated.

4.1.1 Metrics for Measuring Performance Score

For developing an overall performance measurement metric different performance indicators are necessary to evaluate different parts of SC. There are many individual performance measurement metrics in the literature as mentioned before. Each KPI proposed was developed to focus on a specific performance attribute of the SC. Purpose of this study is to develop a general metric to evaluate overall performance of SC. For this reason, SCOPS became of different SC performance measurement metrics.

In the thesis, as result of literature survey mentioned in *section 3.1.1*, *increased efficiency, improved communication, lower operating costs, increased revenue, reduced cycle times, better collaboration, higher profit margins, higher customer satisfaction, inbound logistics performance, outbound logistics performance, and Human Resource Management performance* have been selected as the KPIs that will be used to calculate SCOPS. These performance metrics have been named according to list given in Appendix 1 for the ease of demonstration of the findings of analyses carried out.

Main purpose of developing the SCOPS is to evaluate the SC performance as a whole. So the measurement of difference in the performance, that was caused by flexibility, ERP and BPR, will be easier and the results will be more understandable. Adding different metrics together to form an overall evaluation metric requires the weighting of these metrics one by one. ANP, as a MCDM tool, was selected for this purpose.

4.1.2 Weighting Performance Metrics by ANP Analysis

Because of the hierarchical structure of the problem handled in the thesis the use of AHP model may seem logical at first. But as it can be seen from the KPI list to evaluate SC performance in Appendix 1, it can be realized that there are some interrelations between some metrics. For example decrease in operating costs (*PerC3*) causes an increment in revenue (*PerC4*) and affects the profit margins (*PerC7*). Such obvious interrelationships and dependencies should be considered while determining the importance weights of these criteria. These interrelations cause the model to be defined as a network structure at the criteria level. Building an ANP model is a perfect MCDM analysis method for this structure and the objective of prioritizing the KPIs since ANP is capable of handling such relationships through supermatrix structure it contains.

Two ANP models have been used throughout the thesis. First model used here has been structured to weight the KPIs to develop SCOPS metric. In this first model there are only criteria and goal clusters; no alternatives exists in this model. By the addition of alternatives to the first model, second ANP model have been built to compare the importance of BPR, ERP, and flexibility on the overall SC performance in the last part of the thesis. So it can be said that the ANP model that will be demonstrated here consists of a particular section of the second ANP model.

ANP model used to develop SCOPS have been built and solved according to following steps:

Step-1: Construction of the model.

First of all, necessary clusters and the nodes corresponding to these clusters have been determined. According to determined clusters and nodes the ANP model built consists of two clusters. First one is the goal and the second one is the criteria. Goal is to develop the SCOPS metric, which refers to the weighting of the KPIs according to their effects on the SC overall performance. Criteria cluster includes the KPIs as individual nodes with interrelations. Structure of the ANP model can be seen in Figure 23.

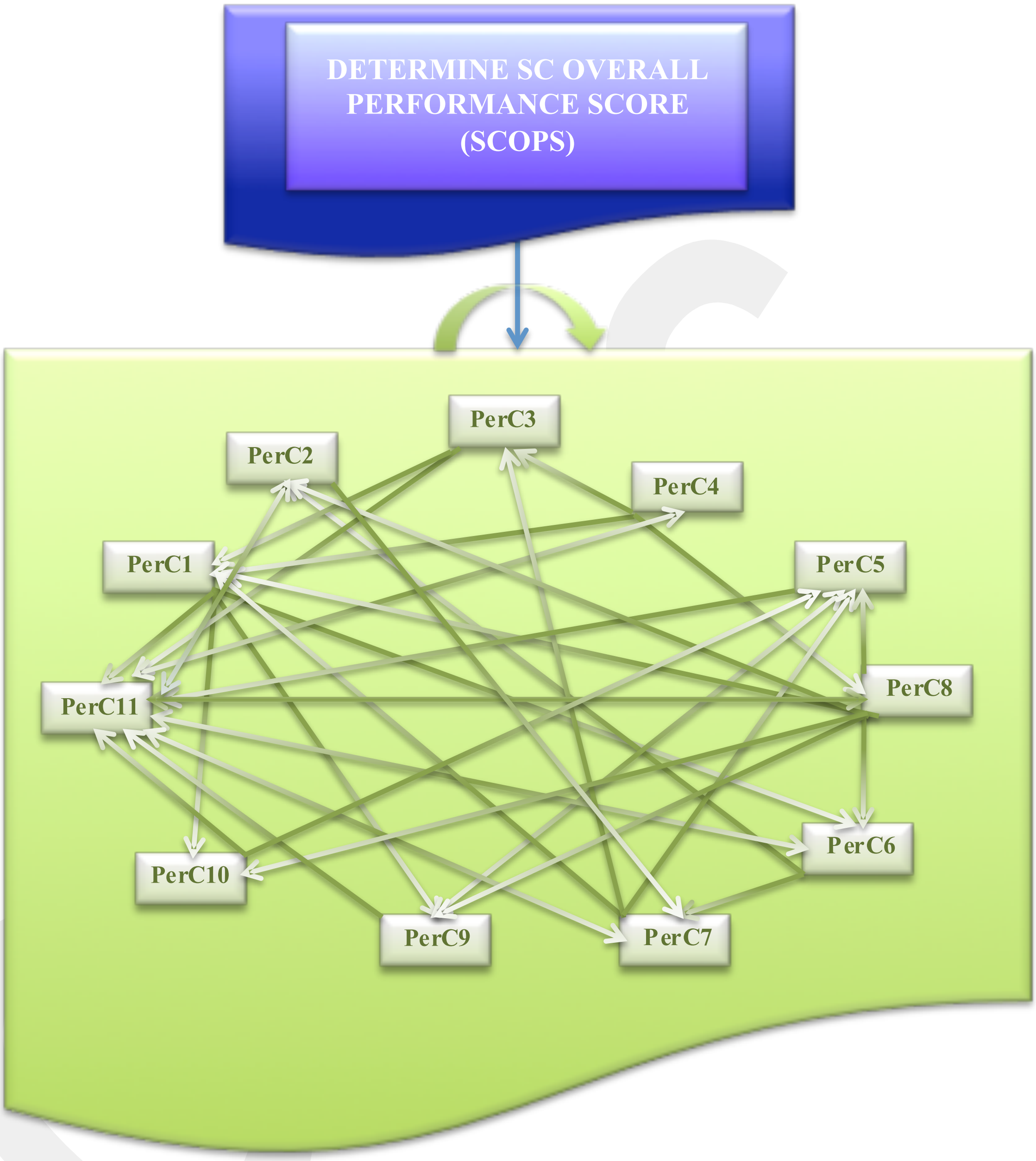


Figure 23: ANP network model structure for developing SCOPS metric

Interdependencies between each criterion node (KPIs) have been determined by the DMs. Details regarding to these relationships will be explained in the next step.

As it can be seen from the model structure, determination of the weights of the KPIs is the main objective to develop the SCOPS metric. By using these KPIs and their weights SC overall performance score can be calculated.

Step-2: Gathering of pair-wise comparisons and interdependency information from experts.

To construct the necessary matrices required by ANP algorithm pair-wise comparisons of each criterion is necessary. For this purpose first expert evaluation questionnaire in Appendix 12 have been applied to DMs from manufacturing industry, service industry and academic society. By the use of mentioned questionnaire, pair-wise comparisons of KPIs have been gathered according to their effect on overall SC performance. Each comparison has been made according to Saaty's (1980) 9-point comparison scale given in Table 15 in section *3.2.2.1*. Results of gathered questionnaires formed a pair-wise comparison matrix in form of:

$$A^k = \left[a_{ij}^k\right] = \begin{bmatrix} 1 & a_{12}^k & \cdots & a_{1n}^k \\ 1/a_{12}^k & 1 & \cdots & a_{2n}^k \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{1n}^k & 1/a_{2n}^k & \cdots & 1 \end{bmatrix} \tag{47}$$

for K DMs and n criteria.

For determining the existence and the degree of interrelationships between the nodes of criteria cluster, second questionnaire in Appendix 12 have been applied to all experts from different sectors in a group meeting. Final interdependency matrix has been formed by the result of the consensus that has been reached by the common decision of experts. Findings of these interrelationships have been summarized in the network model structure given in Figure 23. In the schematic, for example, an arrow pointed from *PerC10* to *PerC8* means that *Per10* has an effect on *Per8* (outbound logistics performance affects customer satisfaction). Details of the interdependencies have been given in Appendix 15.

Step-3: Checking consistency ratios (CR) for each pair-wise comparison matrix created according to questionnaires filled by DMs.

After gathering the experts' evaluation questionnaires of KPIs, a consistency control is necessary. For this purpose, equations (7), (8), and (9) have been used. RI value related with the consistency calculations was selected as 1.51 from Table 16; λ_{max}, CR and CI values have been calculated for each A^k $(k = 1,2,3)$. Manufacturing, service, and academic experts made first, second, and third group of comparisons respectively. Results of consistency ratio calculations can be summarized as in Table 18.

Table 18: Consistency results for ANP criteria pair-wise comparison matrices

	A^1	A^2	A^3
λ_{max}	11.7345	11.5676	11.5959
CI	0.0735	0.0568	0.0596
CR	*0.0486*	*0.0376*	*0.0395*

Since all the CR values are smaller than 0.1; according to Saaty (1998) all pair-wise comparisons made by DMs are consistent.

Step-4: Form the aggregated pair-wise comparison matrix.

For increasing the applicability area of SCOPS metric different DMs from different sectors have been consulted to reflect different point of views. This method requires the evaluations to be made according to group MCDM logic. All DM judgments have to be combined before the ANP analysis to form an aggregated pair-wise comparison matrix (Pandey et.al., 2012). Geometric mean method has been used to acquire the aggregated comparison matrix (Guzzo et.al., 1995; Schrage. 1995).

Let a_{ij}^k be a pair-wise comparison value assigned by k^{th} DM to compare i^{th} and j^{th} criteria. Than the geometric mean of all DMs for that value (a_{ij}^G, where G stands for geometric mean) can be calculated as:

$$a_{ij}^G = \left(\sqrt[K]{\prod_{k=1}^{K} a_{ij}^k} \right) \quad for\ K \text{ DMs} \tag{48}$$

Aggregated pair-wise comparison matrix (A^G) of the criteria cluster of ANP model has been given in Table 19.

Table 19: Aggregated pair-wise node comparisons matrix of criteria cluster in ANP model

Criteria	*PerC1*	*PerC2*	*PerC3*	*PerC4*	*PerC5*	*PerC6*	*PerC7*	*PerC8*	*PerC9*	*PerC10*	*PerC11*
PerC1	1.00000	0.30571	1.25992	0.50000	0.79370	0.30285	0.58480	0.62996	0.30285	0.30285	0.19947
PerC2	3.27107	1.00000	4.12129	1.88207	2.88450	1.65096	1.49380	2.28943	1.25992	1.25992	0.48075
PerC3	0.79370	0.24264	1.00000	0.43679	0.62996	0.23208	0.36840	0.60571	0.30285	0.30285	0.23713
PerC4	2.00000	0.53133	2.28943	1.00000	2.08008	0.36840	0.43679	0.94104	0.43679	0.43679	0.23713
PerC5	1.25992	0.34668	1.58740	0.48075	1.00000	0.27144	0.43679	0.69336	0.38157	0.38157	0.23713
PerC6	3.30193	0.60571	4.30887	2.71442	3.68403	1.00000	1.58740	2.02740	0.69336	0.69336	0.32183
PerC7	1.70998	0.66943	2.71442	2.28943	2.28943	0.62996	1.00000	1.44225	0.87358	0.87358	0.32183
PerC8	1.58740	0.43679	1.65096	1.06266	1.44225	0.49324	0.69336	1.00000	0.60571	0.60571	0.28114
PerC9	3.30193	0.79370	3.30193	2.28943	2.62074	1.44225	1.14471	1.65096	1.00000	1.00000	0.48075
PerC10	3.30193	0.79370	3.30193	2.28943	2.62074	1.44225	1.14471	1.65096	1.00000	1.00000	0.48075
PerC11	5.01330	2.08008	4.21716	4.21716	4.21716	3.10723	3.10723	3.55689	2.08008	2.08008	1.00000

Also consistency controls have also been made for the criteria cluster's aggregated pair-wise comparison matrix (A^G). λ_{max}, CI, and CR values for A^G of flexibility levels are 11.1999, 0.0200, and 0.0132 respectively. Since CR value is less than 0.1 A^G have been found consistent as expected.

After acquiring the aggregated pair-wise comparison matrix of criteria cluster, an AHP model has been solved to calculate the weights of the criteria (Table 20).

Table 20: AHP weights and rankings of SCOPS KPIs

Criteria	Weight	Rank
PerC1	0.15973	2
PerC2	0.04573	10
PerC3	0.18646	1
PerC4	0.10618	4
PerC5	0.14480	3
PerC6	0.05678	7
PerC7	0.06920	6
PerC8	0.09842	5
PerC9	0.05266	8-9
PerC10	0.05266	8-9
PerC11	0.02737	11

This analysis has been done to compare its results with the findings of ANP model to see the effect of interrelations between the KPIs. According to results acquired from AHP model of KPIs; weights have been calculated as given in Table 20. It should be noted that the interrelations between each criterion has not been considered in the AHP analysis.

Step-5: Solve the ANP model and establish supermatrix and limit matrix.

For the solution of the ANP model Super Decisions software version 2.2.3 has been used. Unweighted supermatrix, weighted supermatrix, and limit matrix related with the solution of the ANP model have been given in Appendix 16. Unweighted supermatrix includes all the values of pair-wise comparisons and the interdependencies acquired from the DMs. Since the ANP model solved doesn't include any alternatives cluster weighted and unweighted supermatrix values are computed identical. Since the supermatrix is already normalized with stochastic columns it has been directly raised to sufficient large power until it converges and attains unique weights. So the global weights can be acquired from the final limit matrix.

Weights calculated for the SCOPS by solving the ANP model by using the Super Decisions software have been given in Table 21.

Table 21: ANP weights and rankings of SCOPS KPIs

Criteria	Ideals	Normals	Raw	Ranking
PerC1	0.339221	*0.084013*	0.084013	5
PerC2	0.385836	*0.095558*	0.095558	4
PerC3	0.159867	*0.039593*	0.039593	10
PerC4	0.166667	*0.041277*	0.041277	8
PerC5	0.163457	*0.040482*	0.040482	9
PerC6	0.599047	*0.148363*	0.148363	3
PerC7	0.604017	*0.149594*	0.149594	2
PerC8	0.243590	*0.060329*	0.060329	6
PerC9	0.232751	*0.057644*	0.057644	7
PerC10	0.143267	*0.035482*	0.035482	11
PerC11	1.000000	*0.247665*	0.247665	1

As it can be seen from the 'Normals' column of the ANP results weights required to develop an overall SC performance evaluation metric has been gathered. Distribution of these weights has been given in Figure 24.

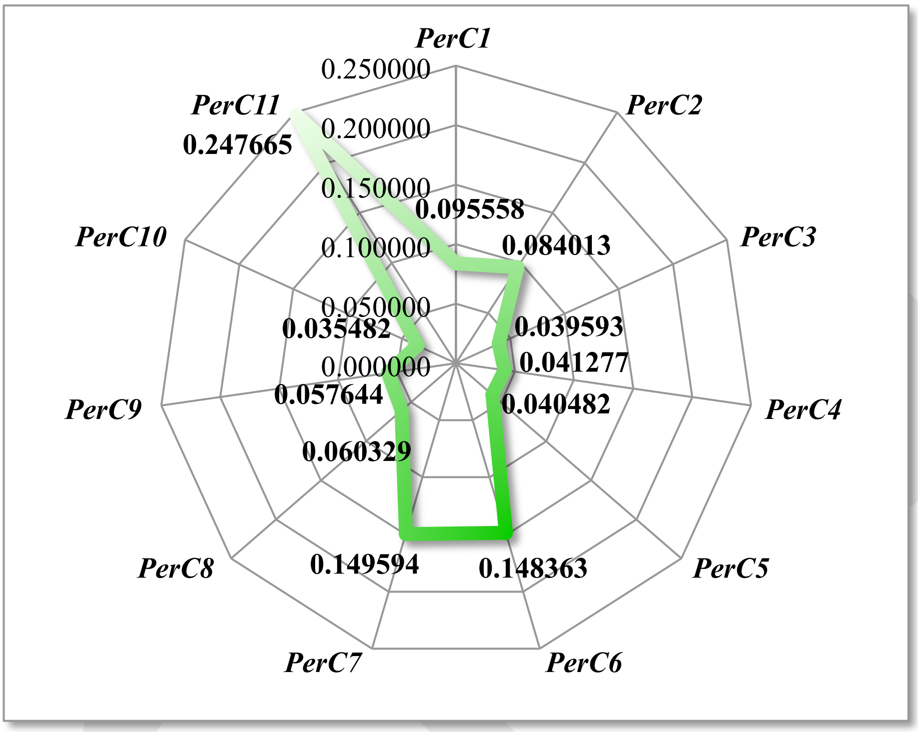


Figure 24: SCOPS weights for SC performance evaluation

To understand the effect of interdependencies a brief comparison of AHP and ANP models will be suitable. As it can be realized by comparing the results of two methods, ranking of the criteria have been drastically changed. According to AHP results *PerC11*, which is Human Resource Management (HRM) performance, was the least important criterion, but ANP model selected *PerC11* as the most important one because of its interrelations with other criteria. This result completely makes sense when it is thought from the aspect of real life applications and the logic of ANP model. Which may carry the least importantly seemed alternative to the top where it should be (Saaty, 1996). Since same pair-wise comparison matrix has been used in both methods; the reason of this change is the interdependencies included in the model. Situations like this are the main reason of the ANP model to be used widely on the weighting procedure of such criteria.

Results of the ANP model seems to suit better to real life situation. To obtain the "learn and grow" organization structure and to unleash the full potential of the employees, HRM's performance is very important. HRM has a considerable effect on many internal processes' performance. These dependencies carry this overlooked criterion to its rightful place. With a well-performed HRM internal process efficiency will raise and as a result of this customer satisfaction and financial values will improve in the favorable way of the company.

HRM performance is a very important performance indicator for the SCM and a source of competitive advantage (Barnes and Liao, 2012). According to ANP results, criteria after the HRM can be grouped in two. First group of factors represents most of the internal processes. Higher profit margins, as an expected result, are needed for the sustainability. Even when thought about it most important goal of some companies in Turkey is to achieve higher profits. To obtain and maintain inter-operability better collaboration and communication is a must in the company. Advantages of SC collaboration have been validated with many studies in the literature (Whitten, Green, and Zelbst, 2012; Barnes and Liao, 2012; Cao and Zhang, 2011). Achieving these will result in better running processes with minimum mistake rates. As the final main representative of the internal processes efficiency is the final factor of the first group. Efficiency summarizes performance of most internal processes as it refers to the input output ratio it is one of the indispensable performance metrics.

According to weights assigned by the ANP analysis, second group of KPIs seems as the complementary and the more specified parts of the first group of metrics. High customer satisfaction is actually one of the other main goals of some companies. Customer satisfaction is being satisfied indirectly when the first category criteria, such as collaboration, have been met. This is the result of interdependencies. Due to system thinking there can't be an output created without an input. So, inbound logistics' performance outperforms outbound logistics and manufacturing related cycle times. Increased revenues, reduced cycle times, and lower operating costs had close weights. They are the primitive conditions of survival. Both of the financial indicators have been represented by the higher profit margins in the first category, so their relative weights are lower. Reduced cycle times, is another indicator of system efficiency an also an indirect part of financial indicators. Reason behind the last ranking of outbound logistics is because of any resulting decrease in the outbound logistics' performance can be recovered by an improvement in the performances of inbound logistics and/or manufacturing.

In general, when inspected carefully second group of criteria are already 'core' group of factors for companies to stay in the market. But, first group of criteria emerge as the factors that makes the difference between the industry-leading firms and the mediocre firms.

4.1.3 Calculating the Supply Chain Overall Performance Score

Up until here all the necessary calculations have been completed to calculate base SCOPS metric. For the further analyses that will be carried out in the thesis SCOPS has been calculated for each questionnaire that has been done in the enterprises for that company. SCOPS calculation has been done for both "BPR application and ERP implementation successes" questionnaire and "Supply Chain flexibility" questionnaire.

As a summary, steps needed for calculating base SCOPS have been given below:

Step-1: Evaluation of the performance of SC according to KPIs given in Appendix 1. Each KPI can be scored according to 7-point Likert scale.

Step-2: By using the normalized weights acquired from the ANP model, multiply each KPI with the related weight to calculate SCOPS according to equation given below:

$$SCOPS = \begin{pmatrix} 0.08413 \times PerC1 + 0.95558 \times PerC2 + 0.039593 \times PerC3 + \\ 0.041277 \times PerC4 + 0.040482 \times PerC5 + 0.148363 \times PerC6 + \\ 0.149594 \times PerC7 + 0.060329 \times PerC8 + 0.057644 \times PerC9 + \\ 0.035482 \times PerC10 + 0.247665 \times PerC11 \end{pmatrix} \quad (49)$$

Development of SCOPS metric was the first goal of the thesis. This metric can be used by SC managers to benchmark performance improvements, which were caused by the changes, occurred in the system. SCOPS given in Equation (49) is actually developed for 'base performance score' determination purposes which can be applied by all companies without any prerequisites like having an ERP system, existence of

BPR application or any kinds of existed flexibility measurement efforts. To evaluate any of these factor's effect on the SC performance; a more detailed formulation of SCOPS has been proposed at the last chapter of the thesis following the completion of all the necessary development of equations. This base SCOPS have been used to evaluate companies' performances in which the questionnaire studies have been carried out. Results of these base performance score calculations have been used in the statistical models to prove the necessary relations and some factors related with the strategic performance investment alternatives.

Base SCOPS metric was also necessary to evaluate SC performance to determine the factors that affects performance such as SC flexibility. To prove that the flexibility has a considerable effect on the SC performance a metric to measure SC flexibility is needed. This is the second objective of the thesis. As mentioned before purpose of the thesis is to develop two evaluation metrics. First metric, which was developed to measure SC overall performance, has been demonstrated. Second one was developed to evaluate SC overall flexibility; named as SCOFS.

4.2 Development of Supply Chain Overall Flexibility Score (SCOFS) Metric by Hybrid Fuzzy AHP / Multiple Linear Regression Model

Flexibility attracts so much attention nowadays because of the increased competition on the global and domestic markets. Enterprises have to own a flexible SC structure to compete with their rivals. As a result of this requirement evaluation and continuous improvement of SC flexibility is vital. To measure SC flexibility first of all understanding the levels in the SC hierarchy is important. Because flexibility covers a wide range of definitions that suits very different parts of the SC. Flexibility of each level and the parts related in that level can be measured with different flexibility metrics; but the purpose of this thesis is to propose a metric that represents the overall flexibility score of the SC. For this purpose SCOFS metric has been developed to evaluate the overall flexibility of SC. By using this metric continuous benchmarking of improvements achieved in the flexibility can be measured and evaluated. SCOFS has also been used to investigate the effects of ERP implementation success on the SC flexibility. In addition to these SCOFS and base

SCOPS have been used together to prove the effect of flexibility on SC performance. For all these reasons an overall SC flexibility evaluation score was needed.

Since SC structure consists of different levels these levels have to be inspected individually from the aspect of flexibility. To do so, factors affecting each level have to be determined to measure the flexibility of each level. For this purpose firstly, MLR models have been built to determine the factors that have effect on the flexibility of each level. After determining the factors affecting flexibility to calculate the overall flexibility score (SCOFS) a fuzzy AHP analysis have been carried out. Fuzzy AHP was needed to weight each level of flexibility hierarch, so that these weights can be used in the calculation of SCOFS.

Since MLR and fuzzy AHP have been used together for the calculation of SCOFS metric, it can be said that the development phase has a hybrid modeling structure. Before explaining the details related with the calculations of SCOFS, it would be appropriate to give more insight to the SC flexibility hierarchy.

4.2.1 Supply Chain Flexibility Hierarchy

There are five main levels in the SC flexibility hierarchy:

- Production flexibility,
- Supply flexibility,
- Deliver flexibility,
- Logistics flexibility, and
- Information flexibility.

These levels and the factors (coded according to Appendices 6-10) have been shown in Figure 25.

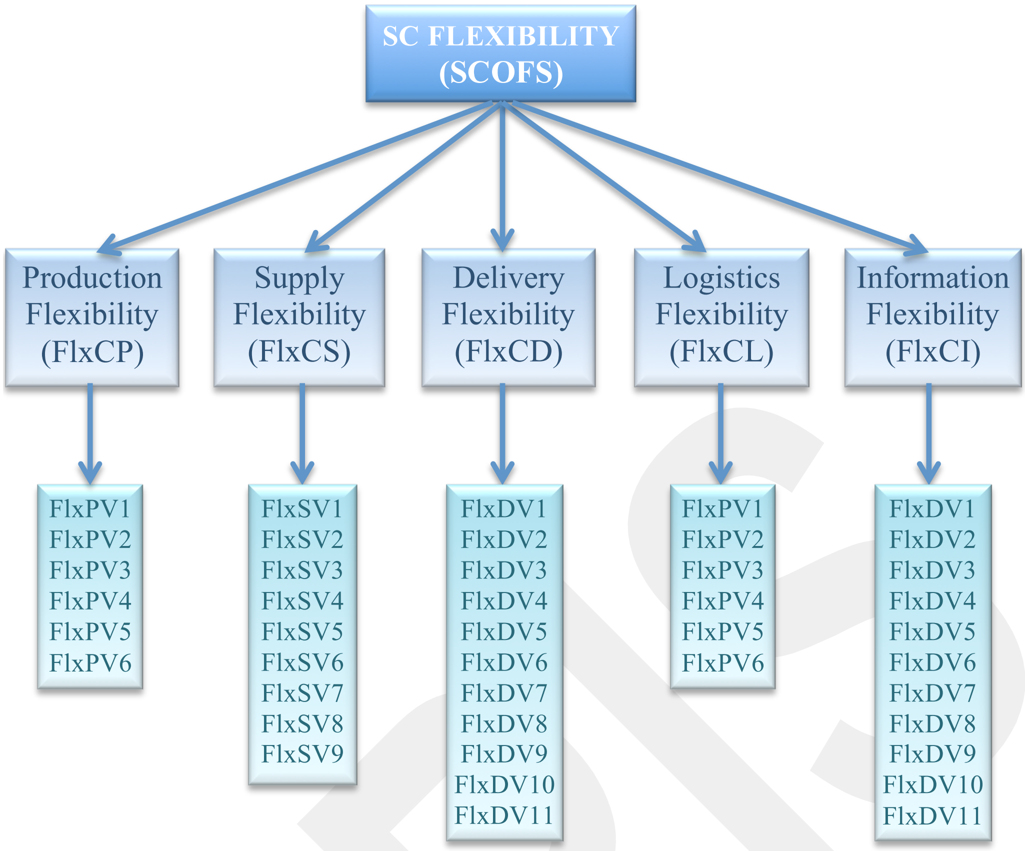


Figure 25: Flexibility hierarchy levels

All these levels cover the SC structure described in the SCOR model (SCC, 2009). For generating SCOFS, each hierarchy level has to be evaluated individually according to some factors to acquire a general evaluation score. For this purpose each level of flexibility have been evaluated by the factors explained in details in section *3.1.2*. Calculations of these evaluations will be explained in the following subsections.

First step of the calculation of SCOFS is to determine the important factors affecting each level in the hierarchy. This specification phase has been carried out with MLR models. After specifying the related factors, second step is to determine the weights of each level and then these weights have been used to calculate the SCOFS metric.

4.2.2 Determining the Factors Affecting Different Levels of Supply Chain Flexibility by Multiple Linear Regression Models

To clarify the factors that affect each level of the flexibility (as listed in section *3.1.2* and coded as given in Appendix 5) a questionnaire study has been done. Factors collected from the literature have been used for this study as mentioned before. Following the completion of the questionnaire applications MLR models have been built for each flexibility level. The reason of these analyses is to specify the important factors affecting flexibility levels in Turkish enterprises. MLR analyses results will also be used in the benchmarking of improvements in the SC flexibility.

Regression models have been used in the factor determination phase, because the perception of the items in the questionnaire affecting each level's flexibility tends to change according to company structure and to the countries. To overcome this issue and more importantly to clarify the real life situation in the Turkish enterprises from the aspect of the awareness of flexibility regression models have been used in the determination phase of the factors. So these results reflect the flexibility structure of Turkish enterprises.

In common of all MLR models a total flexibility score for each level of flexibility have been used as a dependent variable. These scores have been measured during the questionnaire studies for each company. Then, MLR analyses have been carried out to determine the factors affecting these scores in Turkish enterprises. As a result of this analyses factors needed to measure SC flexibility in each level of the hierarchy would have been specified for Turkey.

IBM SPSS Statistics version 19 has been used for the solution of MLR models.

4.2.2.1 Factors Affecting Production Flexibility

First level of SC flexibility hierarchy is the production level. Six factors needed to determine the production flexibility have been given in Appendix 6. Functional form of the MLR model, therefore, is:

$$FlxCP = f(FlxPV1, FlxPV2, FlxPV3, FlxPV4, FlxPV5, FlxPV6) + \varepsilon \qquad (50)$$

MLR analysis in this section has been carried out to select the factors that affect the production flexibility in SC structure of Turkish enterprises. Also the coefficients of the factors will be used in the calculation of the production flexibility score, which then will be used to calculate the SCOFS metric.

Production flexibility ($FlxCP$) as a dependent variable, related results of MLR analysis have been given in Appendix 17. *Stepwise* method for MLR analysis has been used in the creation of regression model. SPSS Statistics software uses *stepwise* algorithm to insert independent variables one by one into the model and checks the *F* value of the model and the p values of variables. This algorithm continues till all the explanatory variables enter the model. Algorithm excludes the variables if they are not making an important contribution to the model. As a result model consists the most important variables. Since the usage purpose of MLR models in the thesis is to specify the factors affecting flexibility levels and to determine the amount of their affects for developing an overall flexibility metric, the contributions of the factors is important for the metric development. In general the main selection criteria of algorithms in the analyses is to include as many variables as possible because of the ease of evaluation phase of overall flexibility. For production flexibility *backward* algorithm, which aims to consist as many variables as possible as long as they have a contribution to the model, also includes the same variables in the model.

Results related with the MLR model of production flexibility such as; model summaries of all the models *stepwise* algorithm built and the coefficients related with these models; Pearson correlations and ANOVA analyses; histogram and normal P-P plot of regression standardized residuals; and finally partial regression plots of each independent variable, which entered in the final model, can be seen in the Appendix 17. Most of this information has been used to check the preliminary conditions of the regression models. Figures provided, have been used to check the normal distribution and linearity conditions and no problems found. Also correlations matrix have been checked for values over 0.8 and none found as a result. ANOVA table also shows that the model is significant (p<0.01) with a high *F* score (also checked with *enter* algorithm).

For each regression model used in the thesis, heteroscedasticity problem in the residuals have been controlled by using White Test (in addition to the control of residual plots). For this purpose, on the run of each model standardized residuals have been saved as a new variable and squared to form a new dependent variable. Then each multiplication and power combination necessary of the independent variables have been calculated to form the new independent variables and regression models solved again. Results of every model, formed according to White Test, in the thesis suggest that the residuals are homoscedastic.

Model summaries of *stepwise* MLR model and information related with the coefficients have been given in Tables 22 and 23 respectively. These tables will be used to interpret the regression model results.

Table 22: Production flexibility MLR model summaries

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.748[a]	.560	.556	1.197	.560	122.268	1	96	.000	
2	.798[b]	.637	.630	1.092	.077	20.193	1	95	.000	
3	.818[c]	.668	.658	1.050	.031	8.827	1	94	.004	
4	.831[d]	.690	.676	1.021	.021	6.395	1	93	.013	
5	.838[e]	.703	.686	1.005	.013	3.992	1	92	.049	1.626

[a]. Predictors: (Constant), *FlxPV3*
[b]. Predictors: (Constant), *FlxPV3, FlxPV4*
[c]. Predictors: (Constant), *FlxPV3, FlxPV4, FlxPV1*
[d]. Predictors: (Constant), *FlxPV3, FlxPV4, FlxPV1, FlxPV6*
[e]. Predictors: (Constant), *FlxPV3, FlxPV4, FlxPV1, FlxPV6, FlxPV5*

As seen from Table 22, *stepwise* algorithm built 5 models in total. Final model (5th model) predicts the 70.3% of change in the dependent variable that was caused by the change in the independent variables according to R^2 value. But in MLR models adjusted R^2 gives more accurate results. As it can be seen from Table 22; by the use of *stepwise* algorithm adjusted R^2 value increases (from 55.6%) with the addition of each independent variable. So the final model correctly predicts 68.6% of the variance in the production flexibility according to adjusted R^2 value. This value is significant in 99% confidence interval with a p value less than 0.01 as mentioned in the ANOVA interpretations. Unpredicted proportion of the change has been explained by the constant in the model. Since there are many variables to define the dependent variable and the questionnaires have been applied to very different sized companies from different sectors it is hard to define all factors to suit all the companies. Since most general factors have been selected as independent variables this proportion of explanation is acceptable (since the prediction level is between 80%-60% it still has a strong prediction capability). Model also seems fine from the aspect of autocorrelation with a Durbin-Watson value of $d = 1.626$ which is in the range of 1.5 to 2.5.

Table 23: Production flexibility factor coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics
		B	Std. Error	Beta			VIF
5	(Constant)	.302	.315		.961	.339	
	FlxPV3	.346	.090	.358	3.829	.000	2.709
	FlxPV4	.143	.071	.160	2.019	.046	1.937
	FlxPV1	.214	.091	.221	2.346	.021	2.755
	FlxPV6	.142	.069	.162	2.060	.042	1.919
	FlxPV5	.160	.080	.136	1.998	.049	1.424

In the final model independent variables *FlxPV3, FlxPV4, FlxPV1, FlxPV6, FlxPV5* entered the model. Factor "*We can change our production volume with low cost*" represented by code *FlxPV2* has been found insignificant according to MLR model results and excluded from the model. Exclusion of this variable can be understood because of the competition requirements in Turkish companies. Instead of lost sales, many companies tolerate the costs of changing volume.

Significance results of independent variables, which have been entered in the final model, can be seen in Table 23. According to these results;

- *FlxPV4:"We can produce extensive variety of products in our facility",*
- *FlxPV1:"We can quickly change our production volume",*
- *FlxPV6:"When needed, outsourcing demands can be satisfied under reasonable costs and time",* and
- *FlxPV5:"Our production workers are capable of handling many types of duties"*

factors have been found to have an effect on dependent variable *"Production Flexibility"* with high statistical significance ($p<0.05$) in the 95% confidence interval. Effect of *FlxPV3:"We can operate efficiently under different production volumes"* has been confirmed with a higher statistical significance ($p<0.01$) in the 99% confidence interval.

As mentioned before in the section *3.2.3.3* to be sure that multicollinearity is not a problem for any specific coefficient; *VIF* value of each coefficient should be smaller than $\frac{1}{1-R^2} = \frac{1}{1-0.703} \approx 3.367$. Since all *VIF* values are smaller than 2.755 these results indicates no problem with multicollinearity.

Since all the data used in the model have been standardized (pointed over 7-point Likert Scale) importance comparisons can be made. According to standardized coefficients (β_i) in Table 23, *FlxPV3* has the most important effect on production flexibility with a coefficient of 0.358, followed by *FlxPV1* with a coefficient of 0.221. *FlxPV6*, *FlxPV4*, and *FlxPV5* follow them with respect to their importance with rather smaller estimated coefficients. Distribution of the factors according to their importance has been given in Figure 26.

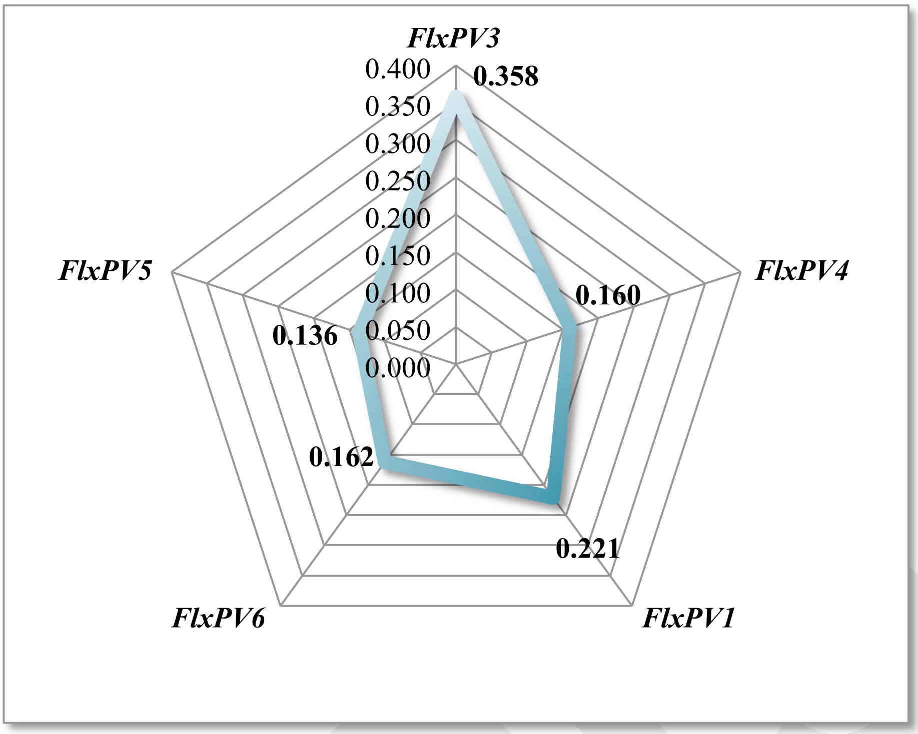


Figure 26: Distribution of production flexibility related factors according to their importance

As a result of MLR analysis, by using the unstandardized coefficients (B), related regression equation for the production flexibility can be written as:

$$\widehat{FlxCP} = \begin{matrix} 0.302 + 0.214 \times FlxPV1 + 0.346 \times FlxPV3 + 0.143 \times FlxPV4 + \\ 0.160 \times FlxPV5 + 0.142 \times FlxPV6 \end{matrix} \qquad (51)$$

To calculate the production flexibility overall score, Equation (51) can be used.

4.2.2.2 Factors Affecting Supply Flexibility

Second level of flexibility hierarchy is the supply flexibility level. All nine of the factors needed to evaluate the supply flexibility have been given in Appendix 7. Functional form of the supply flexibility MLR model can be shown as:

$$FlxCS = f\begin{pmatrix} FlxSV1, FlxSV2, FlxSV3, FlxSV4, FlxSV5, \\ FlxSV6, FlxSV7, FlxSV8, FlxSV9 \end{pmatrix} + \varepsilon \qquad (52)$$

MLR analysis in this section has been carried out to specify the factors that affect the supply flexibility of Turkish companies. Just like the production flexibility MLR model, coefficients of the supply flexibility factors will be used in the calculation of the supply flexibility score, which then will be used to calculate the SCOFS metric.

Results of regression model for Supply flexibility ($FlxCS$) have been given in Appendix 18. *Stepwise* method for MLR analysis has been used in the creation of regression model as the previous analysis. *Backward* algorithm, which aims to consist as many variables as possible as long as they have a contribution to the model, also includes the same independent variables in the final model for MLR results of supply flexibility.

Some outputs related with the regression model of supply flexibility such as; model summaries of all the models *stepwise* algorithm built and the coefficients related with these models; Pearson correlations and ANOVA analyses; histogram and normal P-P plot of regression standardized residuals; and finally partial regression plots of each independent variable, which entered in the final model, have been given in Appendix 18. Given tables and graphs have been used to check the preliminary conditions of regression models. Figures provided, have been used to check the normal distribution and linearity conditions and no problems found as a result. Also correlations matrix have been checked for values over 0.8 and it has been found that there is a correlation over 0.8 between *FlxSV6* and *FlxSV8*. Since both factors includes the monetary effects of supply problems these two factors has a common measurement with different verbal styles. As a result of this, they have been interpreted similarly. SPSS excluded *FlxSV8* in the final model. Other then these two variables all correlations seem fine. ANOVA table also shows that the model is significant (p<0.01) with a high F score (also checked with *enter* algorithm).

Model summaries and coefficient results of *stepwise* MLR model have been given in Tables 24 and 25 respectively.

Table 24: Supply flexibility MLR model summaries

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.807[a]	.652	.648	1.045	.652	179.812	1	96	.000	
2	.865[b]	.749	.743	.893	.097	36.584	1	95	.000	
3	.883[c]	.780	.773	.840	.031	13.326	1	94	.000	
4	.894[d]	.799	.790	.807	.019	8.857	1	93	.004	
5	.900[e]	.811	.800	.787	.012	5.684	1	92	.019	
6	.905[f]	.819	.807	.773	.009	4.322	1	91	.040	1.616

[a]. Predictors: (Constant), *FlxSV1*
[b]. Predictors: (Constant), *FlxSV1, FlxSV3*
[c]. Predictors: (Constant), *FlxSV1, FlxSV3, FlxSV7*
[d]. Predictors: (Constant), *FlxSV1, FlxSV3, FlxSV7, FlxSV6*
[e]. Predictors: (Constant), *FlxSV1, FlxSV3, FlxSV7, FlxSV6, FlxSV4*
[f]. Predictors: (Constant), *FlxSV1, FlxSV3, FlxSV7, FlxSV6, FlxSV4, FlxSV5*

As seen from Table 24, *stepwise* algorithm built 6 models in total. Final model (6th model) predicts the 81.9% of change in the dependent variable that was caused by the change in the independent variables according to R^2 value. But as mentioned before adjusted R^2 gives more accurate results. As it can be seen from Table 24; by the use of *stepwise* algorithm adjusted R^2 value increases (from 64.8%) with the addition of each independent variable. So the final model correctly predicts 80.7% of the variance in the production flexibility according to adjusted R^2 value. This value is significant in 99% confidence interval with a p value less than 0.01 as mentioned before in the ANOVA interpretations. This is an expected result in *stepwise* algorithm results; this algorithm inserts independent variables in the model if and only if they have a significant relation with the dependent variable. Unpredicted proportion of the change has been defined by the constant in the model. However, 80.7% predictability is a very strong relation since it exceeds 80%. So it can be said that the number of independent variables included in the model are satisfactory. Model also seems fine from the aspect of autocorrelation with a Durbin-Watson value of $d = 1.616$ which is between the range of 1.5-2.5.

Table 25: Supply flexibility factor coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics
		B	Std. Error	Beta			VIF
	(Constant)	.220	.225		.981	.329	
	FlxSV1	.179	.086	.173	2.079	.040	3.503
	FlxSV3	.250	.063	.291	4.003	.000	2.668
6	*FlxSV7*	.152	.075	.162	2.009	.048	3.259
	FlxSV6	.156	.068	.152	2.303	.024	2.187
	FlxSV4	.126	.052	.139	2.410	.018	1.681
	FlxSV5	.145	.070	.156	2.079	.040	2.848

In total 6 of 9 independent variables, which are *FlxSV1, FlxSV3, FlxSV7, FlxSV6, FlxSV4, FlxSV5,* entered the final model. Factors *FlxSV2:"We can change one supplier with another with low cost", FlxSV8:"Changes in the supply delivery schedules can be managed with cost and time effective manners",* and *FlxSV9:"Changes in the delivery times of suppliers can be handled with low cost"* have been found insignificant according to *stepwise* algorithm based regression model results and excluded from the model. Changing suppliers is not an easy process because of the economies of scales. Optimum supplier cannot be found with the feasible costs because the whole procedure to select a supplier should be done again and it is a hard process because of the sectorial monopsony power conditions. Changing supplier's outbound logistic related processes is a costly procedure in Turkey since logistics market still didn't reach maturity and outbound logistics is still developing. Exclusion of these variables is also understandable because of the competition in the market. Instead of taking the risk of delaying production because of the changes occurred in the supply schedules, most of the enterprises settle for costly options.

Table 25 shows the significance results of independent variables, which have been entered in the final model. These results showed that independent variables;

- *FlxSV1:"We have more than one supplier for our most purchased products",*
- *FlxSV3:"We can change one supplier with another within short time",*
- *FlxSV7:"Our suppliers can adapt to different order quantities and delivery frequencies",*

- *FlxSV6:"Our production efficiency and profitability won't be affected by the changes in production volume because of the supply problems",*
- *FlxSV4:"We can change one supplier with another without an important compromise on the qualities of raw materials, spare parts and design",* and
- *FlxSV5:"Our suppliers are ready to accommodate the changes we requested on the product variety, supply volume, etc."*

have a significant effect on dependent variable *"Supply Flexibility"* with statistical significances ($p<0.05$) in the 95% confidence interval. Effect of *FlxSV3* has been confirmed with a higher statistical significance ($p<0.01$) in the 99% confidence interval.

As mentioned before in the section *3.2.3.3* to be sure that multicollinearity is not a problem for any specific coefficient; *VIF* value of each coefficient should be smaller than $\frac{1}{1-R^2} = \frac{1}{1-0.819} \approx 5.525$. Since all *VIF* values are smaller than 3.503 these results have no problem with multicollinearity.

Since all the data used in the model have been standardized (pointed over 7-point Likert Scale) importance comparisons can be made according to standardized coefficients (β_i) in Table 25. *FlxSV3* has the most important effect on production flexibility with a coefficient of 0.291, followed by *FlxSV1* with a coefficient of 0.173. *FlxSV7*, *FlxPV5*, and *FlxPV6* follow them with respect to their importance with rather smaller estimated coefficients and finally *FlxPV4* with the least important coefficient. Distribution of the factors, according to their importance determined by standardized coefficients can be seen in Figure 27.

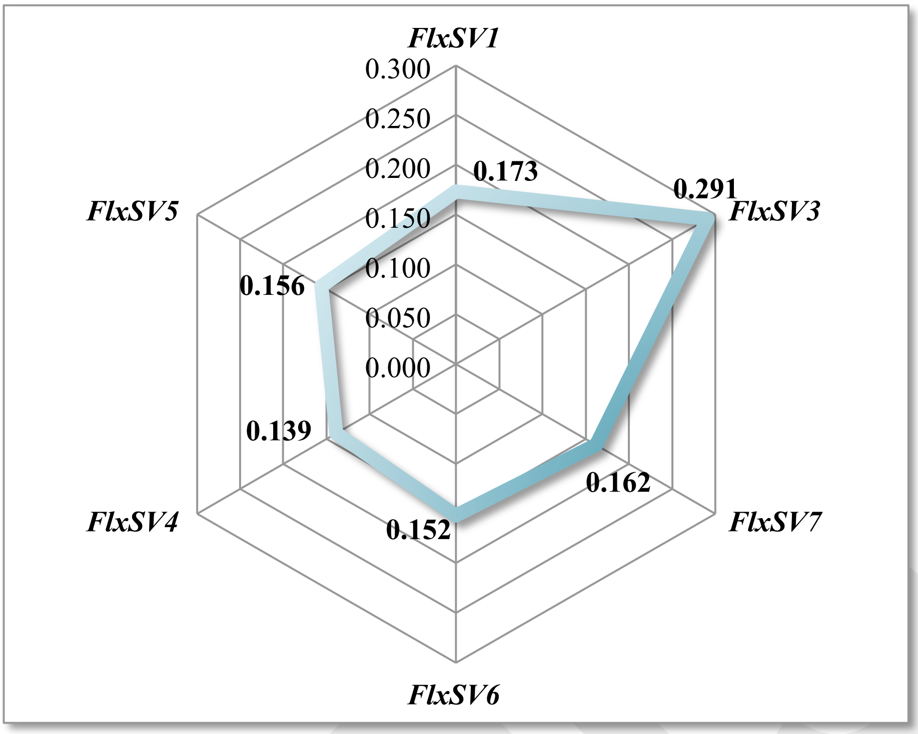


Figure 27: Distribution of supply flexibility related factors according to their importance

As a result of MLR analysis, by using the unstandardized coefficients (B), regression equation related with the supply flexibility can be written as:

$$\widehat{FlxCS} = \begin{matrix} 0.220 + 0.179 \times FlxSV1 + 0,250 \times FlxSV3 + 0.126 \times FlxSV4 + \\ 0.145 \times FlxSV5 + 0.156 \times FlxSV6 + 0.152 \times FlxSV7 \end{matrix} \quad (53)$$

To calculate the supply flexibility overall score, Equation (53) can be used.

4.2.2.3 Factors Affecting Delivery Flexibility

Delivery flexibility is the third level of SC flexibility hierarchy. At this level, eleven factors needed to determine the delivery flexibility. List of these factors have been given in Appendix 8 with their corresponding codes. Functional form of the delivery flexibility MLR model, therefore, is:

$$FlxCD = f\begin{pmatrix} FlxDV1, FlxDV2, FlxDV3, FlxDV4, FlxDV5, FlxDV6, \\ FlxDV7, FlxDV8, FlxDV9, FlxDV10, FlxDV11 \end{pmatrix} + \varepsilon \quad (54)$$

MLR analysis in this section has been carried out to select the factors that affect the delivery flexibility in SC structure of Turkish enterprises. Just like the previous flexibility levels, the coefficients of the factors will be used in the calculation of the delivery flexibility score, which then will be used to calculate the SCOFS metric.

Regression model results, where delivery flexibility ($FlxCD$) is the dependent variable, have been given in Appendix 19. Different than previous models, this time *Enter* algorithm for MLR analysis has been used in the creation of regression model built for delivery flexibility. In the *enter* method of SPSS Statistics software all independent variables enters the model together at once. There is no variable exclusion being made in this algorithm and all results are being computed for the situation where whole variables are in the model. Before applying this method *stepwise* and *backward* methods used to see the significant variables in the model. *Enter* algorithm includes the same variables as the *backward* algorithm but less variables than *stepwise* method. Since the significance of the extra variables included in the model are satisfactory and the calculated adjusted R^2 value is relatively higher than the *stepwise* algorithm; *enter* method have been selected for the solution of the MLR model. The reason behind this selection is the preference of high number of factors in the model for the ease of self-evaluation studies that will be made by the companies and to increase the explanation rate of changes that occurs in the dependent variable.

Results of SPSS *enter* algorithm belongs to the solution of delivery flexibility MLR model such as; Pearson correlations and ANOVA analyses, histogram and normal P-P plot of regression standardized residuals, and partial regression plots of each independent variable, have been given in the Appendix 19. Supplied information has been used to check the preliminary conditions of the regression models. Figures provided, have been used to check the normal distribution and linearity conditions and no problems found. There are some correlation values that exceed 0.8 in the correlation matrix that may indicate some multicollinearity problems. Because of this reason *VIF* values and the tolerances related with this values have been double checked in the coefficients table. As a result, all variables seem clear from any multicollinearity problem. ANOVA table also shows that the model is significant (p<0.01) with a high F score.

Summary of regression model solved with *enter* algorithm and information related with the coefficients have been given in Tables 26 and 27 respectively. These tables will be used to interpret the delivery flexibility hierarch level MLR model results.

Table 26: Delivery flexibility MLR model summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.934[a]	.873	.856	.661	.873	53.526	11	86	.000	2.369

[a]. Predictors: (Constant), *FlxDV11, FlxDV8, FlxDV6, FlxDV4, FlxDV5, FlxDV3, FlxDV10, FlxDV9, FlxDV2, FlxDV7, FlxDV1*

Results in the Table 26 shows that delivery flexibility MLR model predicts the 87.3% of change in the dependent variable that was caused by the change in the independent variables according to R^2 value. Since adjusted R^2 gives more accurate results; it can be said that the independent variables explains the 85.6% of the variance in the delivery flexibility according to adjusted R^2 value. This value is significant in 99% confidence interval with a p value less than 0.01 as mentioned before in the ANOVA analysis. Remaining unpredicted proportion, which is less than 15%, of the change has been defined by the constant in the model. However, 85.6% predictability indicates a very strong prediction capability, similar to the results of supply flexibility model, since it is close to 90%. Model also seems fine from the aspect of autocorrelation with a Durbin-Watson value of $d = 2.369$ that is between 1.5-2.5.

Table 27: Delivery flexibility factor coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics
		B	Std. Error	Beta			VIF
1	(Constant)	.225	.237		.952	.344	
	FlxDV1	.176	.086	.199	2.060	.042	6.292
	FlxDV2	.176	.076	.200	2.315	.023	5.025
	FlxDV3	.179	.075	.189	2.384	.019	4.249
	FlxDV4	.124	.059	.127	2.111	.038	2.443
	FlxDV5	.149	.066	.149	2.254	.027	2.950
	FlxDV6	-.065	.070	-.064	-.932	.354	3.163
	FlxDV7	.239	.080	.269	3.009	.003	5.391
	FlxDV8	-.012	.055	-.013	-.223	.824	2.439
	FlxDV9	.174	.081	.173	2.155	.034	4.339
	FlxDV10	-.185	.068	-.220	-2.717	.008	4.414
	FlxDV11	.018	.069	.019	.255	.800	3.949

In total 8 of 11 independent variables, which are *FlxDV1, FlxDV2, FlxDV3, FlxDV4, FlxDV5, FlxDV7, FlxDV9, FlxDV10* have been proved to have a significant effect on the delivery flexibility. Factors *FlxDV6:"We can satisfy variety of special requests of our customers about the deliveries", FlxDV8:"We can deliver one or more of our customer's order(s) by variety of channels",* and *FlxDV11:"Changes in the order volume and type can be managed with cost and time effective manners"* have been found insignificant according to delivery flexibility model results with a p value over 0.05. Since there are not many differentiated services in the delivery options in Turkey, it is hard to satisfy special customer demands in most cases. Similar to the reasoning made in the supply flexibility, because of the single distribution channel structure in Turkey and because of the outbound logistics is still growing-up it is not possible to change the delivery channels with lower costs in most of the times.

Table 27 shows the significance values of all independent variables. According to these values, independent variables, which have a significant effect on the delivery flexibility score, are:

- *FlxDV1:"We can adapt to the changes in the delivery times that are requested by the customers",*
- *FlxDV2:"We can adapt to the changes in the delivery locations that are requested by the customers",*

- *FlxDV3:"We can adapt to the changes in the delivery amounts that are requested by the customers",*
- *FlxDV4:"We can satisfy low volume orders from our customers",*
- *FlxDV5:"We can satisfy frequent delivery orders from our customers",*
- *FlxDV7:"We can handle different delivery plans without any difficulty for different kinds of products",*
- *FlxDV9:"Changes in the order delivery schedules can be managed with cost and time effective manners",* and
- *FlxDV10:"If there had been a delay in the order delivery, we can manage costs, which were caused because of the delay, effectively"*.

Each one of these variables is statistically significant (p<0.05) in the 95% confidence interval.

There is one unexpected result in the findings of MLR model. Coefficient of independent variable *FlxDV10* have been found negatively correlated with the dependent variable $FlxCD$. People interviewed during the questionnaires thought about "*delay in the deliveries*" as "a factor that indicates the absence of flexibility in the distribution system and thought that there shouldn't be any delays in the deliveries in a flexible SC structure; because the flexibility makes the deliveries to adapt changing conditions under any circumstances. So if a delivery delay happens this indicates lack of flexibility in the SC".

Since some high correlations have been found in the correlation table, multicollinearity problem related with the independent variables have to be investigated. According to information gathered from the literature in section *3.2.3.3*; *VIF* value of each coefficient should be smaller than $\frac{1}{1-R^2} = \frac{1}{1-0.873} \approx 7.874$. Since all *VIF* values are smaller than 6.292, no problem seems to exist regarding multicollinearity. Also Tolerance values of each variable are higher than 0.10 which also indicates there isn't any problems (O'Brien, 2007).

Since all the data used in the model have been standardized (pointed over 7-point Likert Scale), importance comparisons can be carried out according to standardized coefficients (β_i) in Table 27. *FlxDV7* has the most important effect on production flexibility with a coefficient of 0.269, where *FlxDV4* has the least importance with a coefficient of 0.127. Distribution of the factors, according to their importance determined by standardized coefficients can be seen in Figure 28.

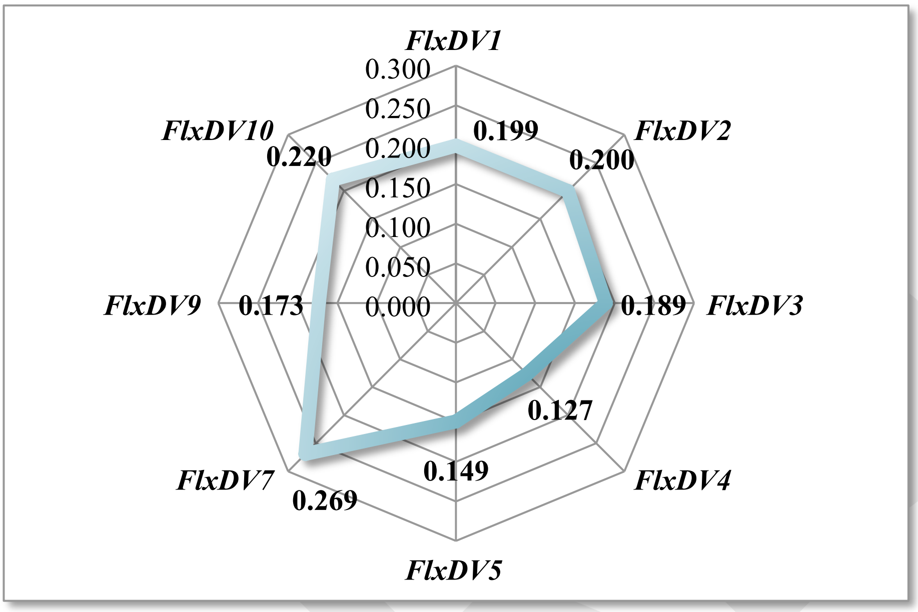


Figure 28: Distribution of delivery flexibility related factors according to their importance

As a result of delivery flexibility regression model analysis, by using the unstandardized coefficients (B), related regression equation can be written as given below:

$$\widehat{FlxCD} = \begin{array}{l} 0.225 + 0.176 \times FlxDV1 + 0.176 \times FlxDV2 + 0.179 \times FlxDV3 + \\ 0.124 \times FlxDV4 + 0.149 \times FlxDV5 + 0.239 \times FlxDV7 + \\ 0.174 \times FlxDV9 - 0.185 \times FlxDV10 \end{array} \quad (55)$$

To calculate the overall delivery flexibility score, Equation (55) can be used.

4.2.2.4 Factors Affecting Logistics Flexibility

Fourth level of SC flexibility hierarchy is logistics flexibility. At this level, five factors used to determine the delivery flexibility. List of these factors have been given in Appendix 9 with their corresponding codes. Functional notation of the regression model of logistics flexibility can be shown as:

$$FlxCL = f\left(FlxLV1, FlxLV2, FlxLV3, FlxLV4, FlxLV5\right) + \varepsilon \quad (56)$$

Regression analysis of logistics flexibility has been done to determine the factors that affect the overall delivery flexibility in SC of Turkish enterprises. Just like the previous flexibility levels, the coefficients of the factors will be used in the calculation of the logistics flexibility score, which then will be used to calculate the SCOFS metric.

Results associated with MLR model, where logistics flexibility ($FlxCL$) is the dependent variable, have been given in Appendix 20. As in the delivery flexibility regression model solution, *Enter* algorithm of SPSS Statistics for MLR analysis has been used again in the solution of regression model built for logistics flexibility. Before applying this method *stepwise* and *backward* methods used to see the significant variables in the final models. As in the *Enter* algorithm, both *stepwise* and *backward* methods included all the independent variables in the regression model as significant predictors. This indifference results in the selection of *enter* algorithm because of the ease of interpreting the results.

Model results of SPSS *enter* algorithm that belongs to the solution of logistics flexibility MLR model such as; Pearson correlations and ANOVA analyses, histogram and normal P-P plot of regression standardized residuals, and partial regression plots of each independent variable, have been given in the Appendix 20. Results supplied have been used to check the preliminary conditions of the regression models. Figures provided, have been used to check the normal distribution and linearity conditions and no problems found. There are some correlation values that exceed 0.8 in the correlation matrix that may indicate some multicollinearity problems. Because of this reason *VIF* values and the tolerances related with this values have been double checked in the coefficients table. As a result, all variables seem clear from any multicollinearity problem. ANOVA table also shows that the model is significant (p<0.01) with a high F score.

Summary of MLR model solved with *enter* algorithm and results related with the coefficients have been given in Tables 28 and 29 respectively. These tables will be used to interpret the logistics flexibility hierarch level regression model results.

Table 28: Logistics flexibility MLR model summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.886[a]	.784	.772	.862	.784	66.851	5	92	.000	1.574

[a]. Predictors: (Constant), *FlxLV5, FlxLV1, FlxLV4, FlxLV2, FlxLV3*

According to MLR model results given in Table 28, independent variables in the logistics flexibility regression model predicts the 78.4% of change in the dependent variable according to R^2 value. Since adjusted R^2 gives more accurate results in MLR models; it can be said that the independent variables explains the 77.2% of the variance in the overall logistics flexibility according to adjusted R^2 value. This value is significant in 99% confidence interval with a p value less than 0.01 as mentioned before in the ANOVA analysis. Remaining unpredicted proportion of the change has been defined by the constant in the model. However, 77.2% predictability indicates a strong prediction ability of independent variables, similar to the results of production flexibility model, since it is higher than 60% and even close to 80%. Model also seems fine from the aspect of autocorrelation with a Durbin-Watson value of $d = 1.574$, which is between 1.5-2.5 range.

Table 29: Logistics flexibility factor coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics
		B	Std. Error	Beta			VIF
1	(Constant)	.409	.230		1.777	.079	
	FlxLV1	.176	.069	.180	2.555	.012	2.110
	FlxLV2	.230	.087	.246	2.664	.009	3.640
	FlxLV3	.206	.100	.204	2.070	.041	4.145
	FlxLV4	.164	.076	.172	2.167	.033	2.696
	FlxLV5	.194	.090	.200	2.149	.034	3.705

In this MLR model, all of the independent variables have been proved to have a significant effect on the logistics flexibility. Table 29 shows the significance values of all independent variables. According to results factors that has an effect on overall logistics flexibility are:

- *FlxLV1:"We have more than one distribution channel for different kind of products and services",*
- *FlxLV2:"If required by he competition we can change our physical distribution channels easily",*
- *FlxLV3:"We can change our distribution channels with the minimum amount of effect on logistics performance",*
- *FlxLV4:"Changes in logistics channels can be made with low cost",*
- *FlxLV5:"Changes in logistics channels can be made in a short time and agilely".*

Independent variables *FlxLV1, FlxLV3, FlxLV4,* and *FlxLV5* are statistically significant ($p<0.05$) in the 95% confidence interval. *FlxLV2* has a p value less than 0.01, which indicates a higher significance in the 99% confidence interval.

Since some high correlations have been found in the correlation table, multicollinearity problem related with the independent variables have to be investigated. According to information gathered from the literature in section *3.2.3.3*; *VIF* value of each coefficient should be smaller than $\frac{1}{1-R^2}=\frac{1}{1-0.784}\approx 4.630$.

Since all *VIF* values are smaller than 4.145, no problem seems to exist regarding multicollinearity. Also Tolerance values are another tool for checking multicollinearity, which can be calculated dividing 1 by *VIF* values for each independent variable. For logistics MLR model, smallest of the tolerance value is 0.241, which is higher than 0.10, indicates that there isn't any problems with multicollinearity (O'Brien, 2007).

Data used in the model have been standardized (pointed over 7-point Likert Scale), so that importance comparisons can be carried out according to standardized coefficients (β_i) in Table 29. *FlxLV2* has the most important effect on production flexibility with a coefficient of 0.246, fallowed by variables *FlxLV3 and FlxLV5* by coefficients of 0.204 and 0.200 respectively. Finally *FlxLV1* and *FlxLV4* have relatively less importance with coefficients of 0.180 and 0.172. Distribution of the factors, according to their importance determined by standardized coefficients has been given in Figure 29.

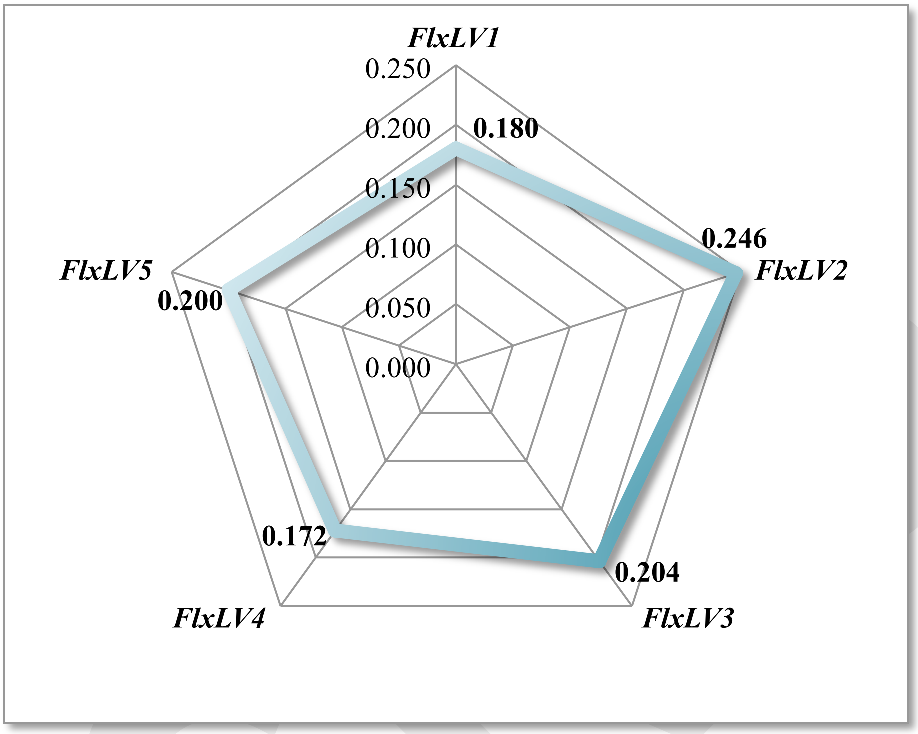


Figure 29: Distribution of logistics flexibility related factors according to their importance

When compared to the supply and delivery flexibilities, companies seem to have a satisfactory flexibility in the logistics. This result is valid for the circumstances in Turkey. Even outbound logistics conditions are restrictive in Turkey because of the immaturity; companies have satisfactory options for pre-planned logistics channel changes. But still it is a costly process to change the established outbound structure under unforeseeable demands and needs. This is why the outbound logistics related factors found insignificant in the previous flexibility hierarchies.

Logistics flexibility regression equation, which has been acquired from the analysis of the results of related MLR model, has been given as:

$$\widehat{FlxCL} = \begin{array}{l} 0.409 + 0.176 \times FlxLV1 + 0.230 \times FlxLV2 + 0.206 \times FlxLV3 + \\ 0.164 \times FlxLV4 + 0.194 \times FlxLV5 \end{array} \qquad (57)$$

To calculate the overall logistics flexibility score, Equation (57) can be used.

4.2.2.5 Factors Affecting Information Flexibility

Information flexibility is the final level of flexibility hierarchy. At this level, eleven factors required to determine the overall information flexibility score. List of these factors have been given in Appendix 10 with their corresponding codes. Functional form of the information flexibility regression model, therefore, can be written as:

$$FlxCI = f\begin{pmatrix} FlxIV1, FlxIV2, FlxIV3, FlxIV4, FlxIV5, FlxIV6, \\ FlxIV7, FlxIV8, FlxIV9, FlxIV10, FlxIV11 \end{pmatrix} + \varepsilon \qquad (58)$$

MLR analysis in this section has been carried out to select the factors that affect the information flexibility of SC structure in the Turkish companies. Just like the previous flexibility levels, the coefficients of the factors will be used in the calculation of the delivery flexibility score, which then will be used to calculate the SCOFS metric.

MLR model results, where information flexibility ($FlxCI$) is the dependent variable, have been given in Appendix 21. This time, different than the other flexibility models, *backward* algorithm for SPSS analysis has been used in the solution of MLR model built for information flexibility. *Backward* algorithm aims to include as many variables as possible as long as they have a contribution to the model. Before applying this algorithm, MLR model had been solved by using *stepwise* and *enter* methods to see the significant variables in the model. *Backward* algorithm includes the same variables as the *enter* algorithm but less variables than *stepwise* method. Since the significances of the extra variables included in the model are satisfactory and the calculated adjusted R^2 value is same with the *enter* algorithm; *backward* method have been selected for the solution of the MLR model. The main reason of this is the same adjusted R^2 value acquired, but with better VIF and Durbin-Watson (d) values. There reason for not selecting the stepwise algorithm is the preference of high number of factors in the model for the ease of self-evaluation studies that will be made by the companies and to increase the explanation rate of changes that occurs (adjusted R^2) in the dependent variable.

Results of SPSS *backward* algorithm related with the solution of information flexibility MLR model such as; model summaries of all the models *backward* algorithm built and the coefficients related with these models; Pearson correlations, and ANOVA analyses, histogram and normal P-P plot of regression standardized residuals, and partial regression plots of each independent variable, have been given in the Appendix 21. Supplied information has been used to check the preliminary conditions of the regression models. Figures provided, have been used to check the normal distribution and linearity conditions and no problems found. There are some correlation values that exceed 0.8 in the correlation matrix that may indicate some multicollinearity problems. Because of this reason *VIF* values and the tolerances related with this values have been double checked in the coefficients table. As a result, all variables seem clear from any multicollinearity problem. ANOVA table also shows that the model is significant ($p<0.01$) with a high F score (also checked with *enter* algorithm).

Model summaries of *backward* MLR model and information related with the coefficients have been given in Tables 30 and 31 respectively. These tables have been used to interpret the model results.

Table 30: Information flexibility MLR model summaries

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.943[a]	.889	.875	.688	.889	62.482	11	86	.000	
2	.943[b]	.889	.876	.684	.000	.004	1	86	.949	
3	.941[c]	.886	.875	.688	-.003	1.961	1	87	.165	1.751

[a]. Predictors: (Constant), *FlxIV11, FlxIV10, FlxIV4, FlxIV6, FlxIV8, FlxIV9, FlxIV5, FlxIV7, FlxIV2, FlxIV3, FlxIV1*
[b]. Predictors: (Constant), *FlxIV11, FlxIV10, FlxIV4, FlxIV6, FlxIV8, FlxIV9, FlxIV5, FlxIV7, FlxIV2, FlxIV1*
[c]. Predictors: (Constant), *FlxIV11, FlxIV10, FlxIV4, FlxIV6, FlxIV9, FlxIV5, FlxIV7, FlxIV2, FlxIV1*

As seen from Table 30, *backward* algorithm built 3 models in total. Final model (3rd model) predicts the 88.6% of change in the information flexibility score that was caused by the changes in the independent variables according to R^2 value. But in

MLR models adjusted R^2 gives more accurate results as mentioned before. As it can be seen from Table 30; by the use of *backward* algorithm adjusted R^2 value doesn't change at all by the exclusion of independent variables in each step, which makes sense when the logic behind adjusted R^2 have been reminded. So, the final model correctly predicts 87.5% of the variance in the information flexibility according to adjusted R^2 value. This value is significant in 99% confidence interval with a p value less than 0.01 as mentioned in the ANOVA interpretations. Unpredicted proportion of the change has been defined by the constant in the model. This part is as small as 12.5%, which indicates the prediction ability of the model is very strong (with an adjusted R^2 value close to 90%). Model also seems fine from the aspect of autocorrelation with a Durbin-Watson value of $d = 1.751$ which is in the range of 1.5 to 2.5 (*enter* algorithm acquired a d value of 1.642).

Table 31: Information flexibility factor coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics
		B	Std. Error	Beta			VIF
3	(Constant)	.059	.177		.332	.740	
	FlxIV1	.234	.091	.230	2.582	.011	6.124
	FlxIV2	.240	.084	.256	2.863	.005	6.208
	FlxIV4	.135	.060	.143	2.241	.028	3.130
	FlxIV5	.161	.070	.173	2.303	.024	4.390
	FlxIV6	.152	.069	.152	2.214	.029	3.628
	FlxIV7	.169	.080	.175	2.114	.037	5.314
	FlxIV9	-.122	.065	-.136	-1.859	.066	4.113
	FlxIV10	-.139	.077	-.144	-1.797	.076	4.973
	FlxIV11	.179	.089	.187	2.011	.047	6.694

In the final model, 7 of 11 independent variables, which are *FlxIV1, FlxIV2, FlxIV4, FlxIV5, FlxIV6, FlxIV7,* and *FlxIV11* have been proved to have a significant effect ($p < 0.05$) on the information flexibility in 95% confidence interval.

Factors *FlxIV3:"Real-time information sharing is possible with our major suppliers", FlxIV8:"Integration of third party applications to existing IS can be done with a high efficiency ratio", FlxIV9:"Managing the information requested can be done with low cost and short time",* and *FlxDV10:"IT application installations and* *maintenances can be done with low cost and in short time"* have been found insignificant according to information flexibility model results with a *p* value over 0.05. In the IT infrastructure of Turkish companies, supplier portal usage rate is low and most of the information that needs to be shared in real-time is handled with phone calls. For this reason IT systems usage is not much for the real-time information sharing. Most Turkish companies are still using legacy B2B procurement systems. These systems have low or no capacity to be integrated with new generation (ERP) systems. Because of this reason it is a costly process to manage the information by integration of the latest IT technologies. Also under current circumstances in Turkey using an Information and Communication Technology (ICT) based software is too expensive, which explains the insignificant variables under the Turkish SC structure.

Table 31 shows the significance values of all independent variables in the final *backward* MLR model. According to these values, independent variables, which have a significant effect on the delivery flexibility score, are:

- *FlxIV1:"We can share information with our major suppliers very quickly",*
- *FlxIV2:"By the use of Information Technologies (IT), automatic information sharing with the major suppliers is possible",*
- *FlxIV4:"Our major suppliers are ready to share information with us to adapt the changes caused by our demands",*
- *FlxIV5:"To support the changing requirements, commonality and prevalence of Information Systems (IS) is adequate",*
- *FlxIV6:"Flow rate/speed of information throughout our Supply Chain is satisfactorily high",*
- *FlxIV7:"Required hardware and software changes by the IT systems can be done easily",* and
- *FlxIV11:"Under the need of changing environmental requirements, updates and upgrades of existing IT applications can be done with low cost and in short time"*.

Multicollinearity problem related with the independent variables in the information flexibility MLR model have to be investigated since some high correlations have been found in the correlation table. According to information gathered from the literature in section *3.2.3.3*; *VIF* value of each coefficient should be smaller than $\frac{1}{1-R^2} = \frac{1}{1-0.886} \approx 8.772$. Since all *VIF* values are smaller than 6.694, no problem seems to exist related with multicollinearity. Also Tolerance values of each variable are higher than 0.10 which also indicates there isn't any problem regarding multicollinearity (O'Brien, 2007).

Since all the data used in the model have been standardized (pointed over 7-point Likert Scale), importance comparisons can be carried out according to standardized coefficients (β_i) in Table 31. *FlxIV2* has the most important effect on production flexibility with a coefficient of 0.256, which is fallowed by *FlxIV2*1 that has a coefficient of 0.230. These two most important factors fallowed by *FlxIV11, FlxIV7, and FlxIV5* with coefficients of 0.187, 0.175, and 0.173 respectively. Factors *FlxIV6* and *FlxIV4* have relatively less importance in the model with coefficients of 0.152 and 0.143 respectively. Distribution of the information flexibility overall score estimation factors; according to their importance determined by standardized coefficients of regression model have been shown in Figure 30.

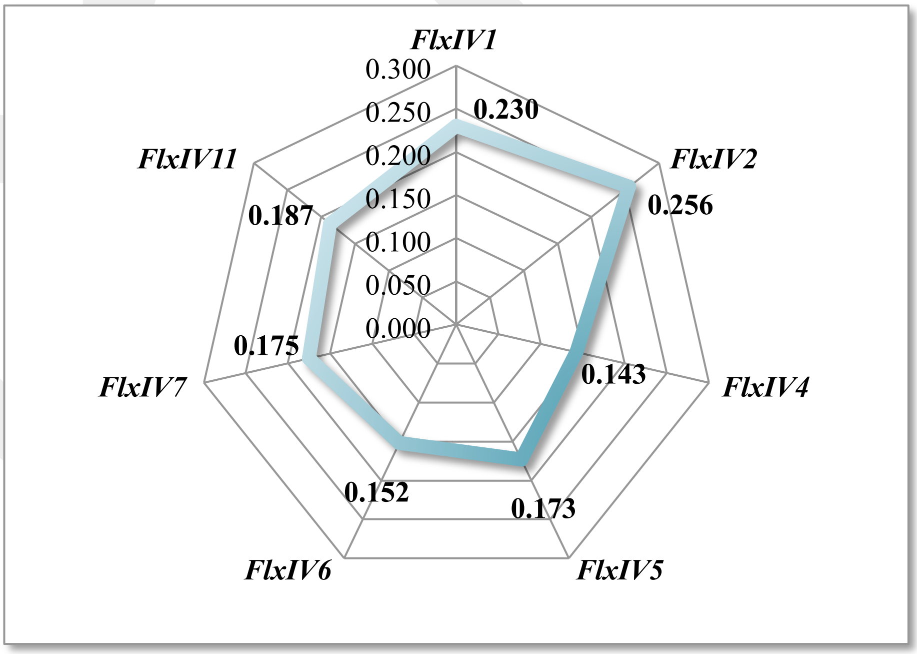


Figure 30: Distribution of information flexibility related factors according to their importance

As a result of information flexibility MLR model analysis, by using the unstandardized coefficients (B), related regression equation for the final flexibility hierarchy level can be written as:

$$\widehat{FlxCI} = \begin{array}{l} 0.059 + 0.234 \times FlxIV1 + 0.240 \times FlxIV2 + 0.135 \times FlxIV4 + \\ 0.161 \times FlxIV5 + 0.152 \times FlxIV6 + 0.169 \times FlxIV7 + 0.179 \times FlxIV11 \end{array} \quad (59)$$

To calculate the overall delivery flexibility score, Equation (59) can be used.

4.2.3 Weighting Flexibility Hierarchy by Fuzzy AHP Analysis

To accomplish the task of developing an overall SC flexibility evaluation metric each level of the flexibility hierarchy have to be weighted according to the importance of their effects. In the previous sections factors affecting each level have been determined by the use of MLR models. Results of the regression models can be used to calculate flexibility score for each level of flexibility hierarchy, but to reach an overall flexibility evaluation score weight of each level should be known. This is where fuzzy AHP model needs to be used. As explained in the literature survey SC flexibility is hard to evaluate because of the variation in terms and difficulty in measurements. Fuzzy AHP is a proved method to deal with uncertainty, imprecision, and vagueness in decision-making process as mentioned in section *3.2.2.2*. This property of fuzzy AHP makes it a perfect tool for comparing levels of flexibility with respect to their effects on the overall SC flexibility.

Use of fuzzy AHP in the thesis is restricted to evaluations of criteria. No alternative comparisons made in the fuzzy AHP model. Because of this structure it can be said that a modified fuzzy AHP approach have been used in this study as mentioned before. Each flexibility hierarchy level has been defined as a criterion in the fuzzy AHP analysis. As a result, it can be said that each criterion has a sub-criteria since each flexibility level became of different factors. But these sub-criteria have been evaluated with MLR models for the reasons explained before. So the sub criteria weighting process is being made by MLR models and the weights of each level is determined by the modified fuzzy AHP analysis. As a result a hybrid fuzzy AHP / MLR modeling approach has been used to calculate SCOFS.

Proposed fuzzy AHP model of the thesis to determine the weights of each flexibility level and its steps are as follows:

Step-1: Identification of the goal and criteria.

To develop an overall SC flexibility evaluation score (SCOFS) weights of each criterion (*FlxCP, FlxCS, FlxCD, FlxCL, FlxCI*) have to be determined according to their effects on SCOFS.

Step-2: Creation of the AHP hierarchy for the model described in *Step 1*.

AHP hierarchy of the SC flexibility is same with the SC flexibility hierarchy given in Figure 25 previously. But the factors used for determining each flexibility level's score have been evaluated with regression models, so these factors have been excluded from the AHP hierarchy. As a result hierarchy evaluated in the fuzzy AHP analysis can be shown as in Figure 31.

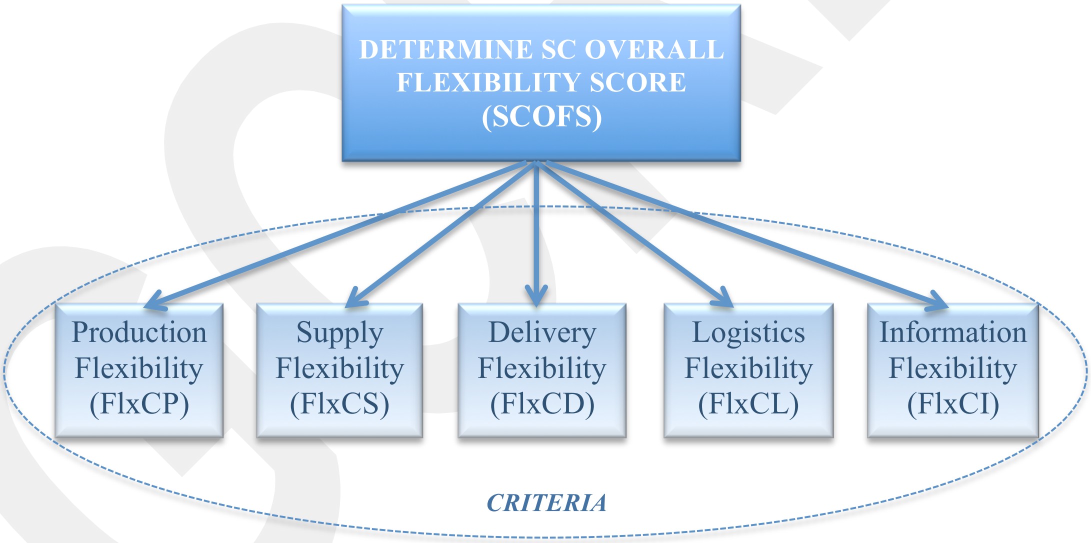


Figure 31: AHP model hierarchy for developing SCOFS metric

Step-3: Gathering expert evaluations for pair-wise comparisons needed to evaluate criteria in linguistic form and converting them into triangular fuzzy numbers.

For this purpose expert judgments questionnaires have been prepared as explained in section *3.1.4*. These questionnaires have been applied to experts from different sectors (manufacturing, service, academic). DMs have been asked to make pair-wise comparisons for each criterion according to linguistic scale proposed by Anagnostopoulos, Gratziou, and Vavatsikos (2007). Details of this scale have been given previously in Table 17 in section *3.2.2.2*. Membership function of the linguistic variables has been shown in Figure 32.

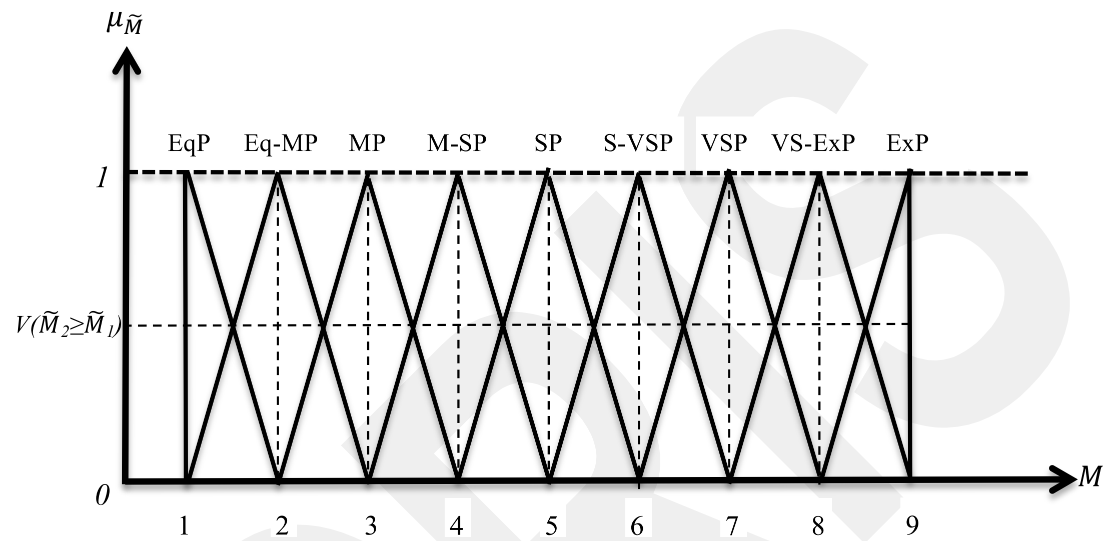


Figure 32: Membership function of linguistic variables used in fuzzy AHP model

By using the linguistic scale based answers gathered with questionnaires and triangular fuzzy numbers given in Table 17; fuzzy pair-wise comparison matrix (where k indicates the k^{th} DM) for K DMs have been created in form of:

$$\tilde{A}^k = \begin{bmatrix} 1 & (l_{12}^k, m_{12}^k, u_{12}^k) & \cdots & (l_{1n}^k, m_{1n}^k, u_{1n}^k) \\ \left(1/u_{12}^k, 1/m_{12}^k, 1/l_{12}^k\right) & 1 & \cdots & (l_{2n}^k, m_{2n}^k, u_{2n}^k) \\ \vdots & \vdots & \ddots & \vdots \\ \left(1/u_{1n}^k, 1/m_{1n}^k, 1/l_{1n}^k\right) & \left(1/u_{2n}^k, 1/m_{2n}^k, 1/l_{2n}^k\right) & \cdots & 1 \end{bmatrix} \tag{60}$$

Step-4: Checking consistency ratios (*CR*) for each DM's linguistic scale pairwise-comparison matrix.

For checking consistency of a fuzzy pair-wise comparison matrix ($\tilde{A}$), crisp AHP matrix (A) of the related pairwise comparison matrix has to be controlled. If A is consistent this means that $\tilde{A}$ is also consistent (Csutora and Buckley, 2001; Buckley, 1985).

For each DM's fuzzy pair-wise judgment matrix ($\tilde{A}^k$), a crisp AHP comparison matrix (A^k) have been created by using the crisp AHP scale given in Table 17 for consistency ratio calculations. By using equations (7), (8), and (9) with the related *RI* value of 1.2 from Table 16; λ_{max}, CR and CI values have been calculated for each A^k $(k = 1,2,3)$. Manufacturing, service, and academic experts made first, second, and third group of comparisons respectively. Results of consistency calculations can be seen in Table 32.

Table 32: Consistency calculations for crisp AHP pair-wise comparison matrices

	A^1	A^2	A^3
λ_{max}	5.0721	5.3227	5.3694
CI	0.0180	0.0807	0.0924
CR	*0.0161*	*0.0720*	*0.0825*

As it can be seen from the results of *CR* values, all judgments are consistent since all of the *CR* values are less than 0.1 (Saaty, 1998).

Step-5: Calculate the aggregated fuzzy pair-wise comparison matrix.

In the DM's judgments' collection phase, more than one expert has been asked to fill the questionnaires. For this reason evaluations have to be made according to group MCDM logic. For this purpose an aggregated fuzzy pair-wise comparison matrix have to be created by combining all individual expert fuzzy pair-wise comparison matrices (Pandey et.al., 2012). Geometric mean method has been used for this purpose (Meixner, 2009; Guzzo et.al., 1995; Schrage. 1995). Formulations of geometric mean on fuzzy numbers have been given below (Klir and Folger, 1988).

Let $\tilde{a}_{ij}^k = \left(l_{ij}^k, m_{ij}^k, u_{ij}^k\right)$ be a fuzzy comparison value assigned by k^{th} DM to compare i^{th} and j^{th} criteria. Than the geometric mean of all DMs for that value ($\tilde{a}_{ij}^G$, where G stands for geometric mean) can be calculated as:

$$\tilde{a}_{ij}^{G} = \left(\sqrt[K]{\prod_{k=1}^{K} l_{ij}^{k}}, \sqrt[K]{\prod_{k=1}^{K} m_{ij}^{k}}, \sqrt[K]{\prod_{k=1}^{K} u_{ij}^{k}} \right) \quad \textit{for } K \text{ DMs} \tag{61}$$

Aggregated fuzzy pair-wise comparison matrix ($\tilde{A}^G$) of the flexibility hierarchy levels has been given in Table 33.

Table 33: Aggregated fuzzy pair-wise comparison matrix in AHP model

Flexibility Level	*FlxCP*	*FlxCS*	*FlxCD*	*FlxCL*	*FlxCI*
FlxCP	(1.00,1.00,1.00)	(0.34,0.69,1.71)	(1.26,2.00,2.88)	(1.44,2.71,4.82)	(1.59,3.78,5.85)
FlxCS	(0.58,1.44,2.92)	(1.00,1.00,1.00)	(1.00,2.29,4.31)	(1.26,2.88,4.93)	(1.82,3.91,5.94)
FlxCD	(0.35,0.50,0.79)	(0.23,0.44,1.00)	(1.00,1.00,1.00)	(1.00,2.62,4.64)	(1.26,3.30,5.31)
FlxCL	(0.21,0.37,0.69)	(0.20,0.35,0.79)	(0.22,0.38,1.00)	(1.00,1.00,1.00)	(1.00,2.08,2.92)
FlxCI	(0.17,0.26,0.63)	(0.17,0.26,0.55)	(0.19,0.30,0.79)	(0.34,0.48,1.00)	(1.00,1.00,1.00)

Also consistency controls have been made for the geometric crisp AHP pair-wise comparison matrix (A^G). λ_{max}, *CI*, and *CR* values for A^G of flexibility levels are 5.1050, 0.0262, and 0.0234 respectively. Since *CR* is less than 0.1 A^G is also consistent as expected.

At this step also an AHP model have been solved to acquire criteria weights to make comparisons later with the findings of fuzzy AHP model. According to AHP model criteria weights have been calculated as given in Table 34:

Table 34: AHP weights and rankings of flexibility hierarchy levels

Flexibility Level	Weight	Rank
FlxCP	0.2833	2
FlxCS	0.3456	1
FlxCD	0.1944	3
FlxCL	0.1089	4
FlxCI	0.0687	5

Rest of the steps belongs to Chang's (1996) extend analysis method.

Step-6: Calculate the fuzzy synthetic extent values for each criterion.

In this step S_1, S_2, S_3, S_4, and S_5 values for *FlxCP*, *FlxCS*, *FlxCD*, *FlxCL*, and *FlxCI* will be calculated respectively by using the equations (19), (20), (21), and (22) given in section *3.2.2.2*. Related calculations have been given as below:

$$S_1 = (5.63, 10.19, 16.26) \otimes \left(\frac{1}{58.51}, \frac{1}{36.06}, \frac{1}{19.63} \right) \approx (0.10, 0.28, 0.83)$$

$$S_2 = (5.66, 11.53, 19.11) \otimes \left(\frac{1}{58.51}, \frac{1}{36.06}, \frac{1}{19.63} \right) \approx (0.10, 0.32, 0.97)$$

$$S_3 = (3.84, 7.86, 12.75) \otimes \left(\frac{1}{58.51}, \frac{1}{36.06}, \frac{1}{19.63} \right) \approx (0.07, 0.22, 0.65)$$

$$S_4 = (2.63, 4.18, 6.41) \otimes \left(\frac{1}{58.51}, \frac{1}{36.06}, \frac{1}{19.63} \right) \approx (0.04, 0.12, 0.33)$$

$$S_5 = (1.87, 2.30, 3.97) \otimes \left(\frac{1}{58.51}, \frac{1}{36.06}, \frac{1}{19.63} \right) \approx (0.03, 0.06, 0.20)$$

Step-7: Calculate the degree of possibilities.

Each degree of possibility of superiorities for synthetic extent values calculated in step 5 have to be calculated according to the equation (24) that was given in section *3.2.2.2*. These calculations have been shown below:

$$V(S_1 \geq S_2) = \left(\frac{(0.10 - 0.83)}{((0.28 - 0.83) - (0.32 - 0.10))} \right) \approx 0.95$$

$$V(S_1 \geq S_3) = 1$$
$$V(S_1 \geq S_4) = 1$$
$$V(S_1 \geq S_5) = 1$$

$$V(S_2 \geq S_1) = 1$$
$$V(S_2 \geq S_3) = 1$$
$$V(S_2 \geq S_4) = 1$$
$$V(S_2 \geq S_5) = 1$$

$$V(S_3 \geq S_1) = \left(\frac{(0.10-0.65)}{((0.22-0.65)-(0.28-0.10))} \right) \approx 0.90$$

$$V(S_3 \geq S_2) = \left(\frac{(0.10-0.65)}{((0.22-0.65)-(0.32-0.10))} \right) \approx 0.84$$

$$V(S_3 \geq S_4) = 1$$

$$V(S_3 \geq S_5) = 1$$

$$V(S_4 \geq S_1) = \left(\frac{(0.10-0.33)}{((0.12-0.33)-(0.28-0.10))} \right) \approx 0.58$$

$$V(S_4 \geq S_2) = \left(\frac{(0.10-0.33)}{((0.12-0.33)-(0.32-0.10))} \right) \approx 0.53$$

$$V(S_4 \geq S_3) = \left(\frac{(0.07-0.33)}{((0.12-0.33)-(0.22-0.07))} \right) \approx 0.72$$

$$V(S_4 \geq S_5) = 1$$

$$V(S_5 \geq S_1) = \left(\frac{(0.10-0.20)}{((0.06-0.20)-(0.28-0.10))} \right) \approx 0.33$$

$$V(S_5 \geq S_2) = \left(\frac{(0.10-0.20)}{((0.06-0.20)-(0.32-0.10))} \right) \approx 0.29$$

$$V(S_5 \geq S_3) = \left(\frac{(0.07-0.20)}{((0.06-0.20)-(0.22-0.07))} \right) \approx 0.47$$

$$V(S_5 \geq S_4) = \left(\frac{(0.04-0.20)}{((0.06-0.20)-(0.12-0.04))} \right) \approx 0.75$$

Step-8: Calculate the weights.

Determine the weight vector for each criterion by finding minimum degree of possibility of superiority of each criterion over another by using the equations (25) and (26).

$$d'(FlxCP) = minV(S_1 > S_2, S_3, S_4, S_5) = min(0.95, 1.00, 1.00, 1.00) = 0.95$$

$$d'(FlxCS) = minV(S_2 > S_1, S_3, S_4, S_5) = min(1.00, 1.00, 1.00, 1.00) = 1.00$$

$$d'(FlxCD) = minV(S_3 > S_1, S_2, S_4, S_5) = min(0.90, 0.84, 1.00, 1.00) = 0.84$$

$$d'(FlxCL) = minV(S_4 > S_1, S_2, S_3, S_5) = min(0.58, 0.53, 0.72, 1.00) = 0.53$$

$$d'(FlxCI) = minV(S_5 > S_1, S_2, S_3, S_4) = min(0.33, 0.29, 0.47, 0.75) = 0.29$$

So the related weight vector is:

$$W' = (0.95, 1.00, 0.84, 0.53, 0.29)^T$$

Step-9: Calculate the normalized weights.

Final step of fuzzy AHP algorithm used in the thesis is to determine the normalized weights according to equation (27). The normalized weight vector is as shown below:

$$W = (0.2630, 0.2764, 0.2334, 0.1464, 0.0808)^T$$

As a result of modified fuzzy AHP model, final normalized weights of each SC flexibility hierarchy has been calculated. Results of this model have been given in Table 35.

Table 35: Normalized modified fuzzy AHP weights and rankings of flexibility hierarchy levels

Flexibility Level	Weight	Rank
FlxCP	0.2630	2
FlxCS	0.2764	1
FlxCD	0.2334	3
FlxCL	0.1464	4
FlxCI	0.0808	5

For some fuzzy AHP models Chang's (1996) extent analysis method calculate weights as 0. Since this situation didn't occur in the model of this study, it can be said that the selection of the method used for the fuzzy AHP analysis was right.

According to these results supply flexibility seems to be the most important level of flexibility hierarchy. This result is understandable because the SC system needs input(s) to produce the necessary output(s). Any problem occurs in the input would affect the rest of the system. For the requirements of Just-in-Time (JIT), mass and agile manufacturing types, supply flexibility is the most important factor.

Supply flexibility is followed closely by production flexibility, which is the core of the SC system. Third importance rate belongs to delivery flexibility, which is related to the distribution of the outputs to the customers. Main three flexibility levels, according to their importance from the aspect of overall SC flexibility, have been specified as the result of the studies carried out. Ranking achieved as the result of fuzzy AHP analysis suits perfectly to Porter's (1985) primary business processes defined as a part of Value Chain model. These three levels are being followed by logistics flexibility and information flexibility levels respectively.

In general it is hard to create new distribution channels in logistics. So the flexibility related with the logistics is low when compared to other flexibility levels. SC system responds to a need of new logistics channels with the flexibility of supply, manufacturing and delivery levels. So it is quite understandable that the ranking of logistics flexibility is lower than the first three levels. The reason of the ranking of information flexibility is due to its priority in the achievement phase and its relations with other factors. As a classical example in B2B procurement, information systems are being set up in the investment phase. In the rest of the processes information flexibility is already settled down. According to Porter's (1985) model information flexibility can be evaluated as the part of the 'support' level. And since IT implementation is a must achievement of this level had already been satisfied in the business companies, and since it's already settled down this level has been neglected to some extent.

Importance distribution of flexibility levels can be seen in Figure 33.

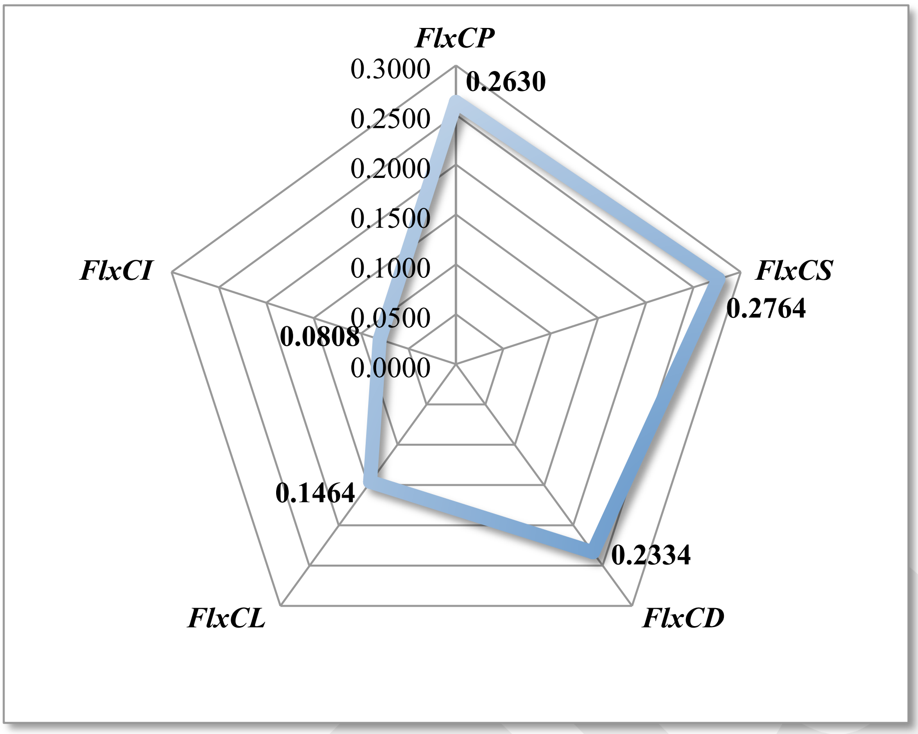


Figure 33: SCOFS weights for SC flexibility evaluation

When the findings have been compared with the results of AHP analysis, no signs of change have been observed at the rank of flexibility hierarchy levels. But the weights of the factors have been changed and seems more accurate from the aspect of their effects on overall SC flexibility because of more realistic distributions of the weights. As a result, it can be said that the use of fuzzy AHP model in the effort of weighting flexibility levels was a good decision.

4.2.4 Algorithm to Calculate the SCOFS metric

Since all the analyses necessary to calculate the SCOFS have been completed, summary of the analysis can be made to explain how to use the SCOFS metric.

SC overall flexibility consists five main levels (weighted with fuzzy AHP analysis), and there are several different factors that affect each level (weighted with MLR models). Because of this hybrid model approach used in the development, to calculate SCOFS following steps have to be followed:

Step-1: Evaluate the flexibility of SC for each flexibility hierarchy level by answering the questions (only the ones stated in the section *4.2.2*, which has a significant effect on the related upper level of the flexibility hierarchy), according to 7-point Likert scale, given in Appendices 6 through 10,

Step-2: Calculate the total score for each flexibility hierarchy level by using the Equations (51), (53), (55), (57), and (59) for the evaluation values of factors found in step 1,

Step-3: Multiply each flexibility hierarchy level's calculated score in step 2, by the related weights calculated with modified fuzzy AHP model according to equation below:

$$SCOFS = \begin{pmatrix} 0.2630 \times FlxCP + 0.2764 \times FlxCS + 0.2334 \times FlxCD + \\ 0.1464 \times FlxCL + 0.0808 \times FlxCI \end{pmatrix} \quad (62)$$

By following these three steps SCOFS metric can be calculated. By using SCOFS managers of the SC can answer the question "How flexible is my enterprise's Supply Chain?" by using a consistent scoring system. By doing so, benchmarking of the system flexibility can be done whenever needed.

Since the main goal of the thesis have been completed by developing two new evaluation metrics to measure overall SC performance and flexibility, further analysis can be carried out to determine the interrelations between different items that have an effect on SC performance and flexibility.

CHAPTER 5

INTERACTIONS BETWEEN PERFORMANCE, FLEXIBILTY, ERP and BPR

In the Chapter 4, SCOPS and SCOFS metrics have been developed. One of the reasons to develop these two metrics is to evaluate the effects of flexibility on SC performance, which therefore means the effects of SCOFS on SCOPS. To make such a comparison first of all SC overall performance and flexibility have to be measured consistently. This phase has been completed. By the development of these two metrics SCOPS and SCOFS calculations have been carried out on the questionnaire results acquired. Two scores have been computed for each company to which questionnaires applied, which means 200 SCOPS and 98 SCOFS calculations.

Second goal of the thesis is to determine the relationships between performance, flexibility, ERP and BPR. By using SCOPS and SCOFS first task is to prove the effects of SC flexibility on the performance of the SC. This analysis has been carried out by using SCOPS (calculated with ANP model), SCOFS (calculated with fuzzy AHP model), and a regression model. By doing so, necessity of flexibility will be clear for an improved SC performance. Next task is to clarify what is needed to obtain flexibility in the SC?

Second task of the second main goal of the thesis is to prove the effects of ERP on SC flexibility. To prove the need of an ERP system to obtain a flexible SC system, a regression model and independent samples t-test analysis have been used with the SCOPS, which was calculated with fuzzy AHP model. After proving the necessity of an ERP system, next question is what is needed for the success of ERP implementation? So a MLR model has been built to determine the factors needed for the success of ERP implementation.

But one vital pre-condition of ERP success is the existence of BPR application prior to implementation phase (Erkan, Baç, and Rouyendegh, 2012). Third task of the second main goal of the thesis is to prove this fact. For this purpose a regression model and independent samples t-test analysis have been carried out. At this time, also a MLR model has been used to determine the prerequisites of BPR application's success.

In addition to the tasks of proving interrelations between different strategies and determining the factors related with each strategy, some regression models and statistical methods have been used to prove the direct effects of each strategy has on the overall SC performance. For example to prove the direct effects of ERP and BPR have on the performance two regression models and two independent samples t-tests have been carried out by using the SCOPS as the dependent variable.

Details related with each analysis summarized above have been given in the following sections.

5.1 Importance and Effects of Flexibility

As mentioned before obtaining a flexible SC is vital for companies to keep their competitive advantage on today's quickly changing market conditions. So the SC flexibility is an important factor of SC performance. To prove the importance of flexibility, its relation with the performance has to be examined.

5.1.1 Determining the Effect of Flexibility on Supply Chain Performance by Hybrid Fuzzy AHP / ANP Model / Simple Linear Regression

To prove the effect of flexibility on the SC performance a regression model has been built. This model uses SCOPS, which has been calculated with ANP model, as a dependent variable; and SCOFS, which has been calculated with fuzzy AHP model, as an independent variable. Because of this structure the model used has a hybrid nature.

Since there is only one independent variable in the regression model it is named as simple linear regression model. Functional form of the SLR model used to prove the effect of SCOFS on SCOPS is as follows:

$$SCOPS = f\left(SCOFS\right) + \varepsilon \tag{63}$$

Enter algorithm used for the solution of the SLR model. Since there is only one independent variable in SLR models, solution of the regression model is independent of the selected algorithm. At the rest of the thesis *enter* algorithm has been used as default for the solution of SLR models.

Solution of the model has been done by using IBM SPSS Statistics version 19 (as the rest of the SLR model solutions from here). Outputs of the model have been given in Appendix 22. Pearson correlation and ANOVA analyses have been used for the interpretation of the model structure; where histogram and normal P-P plot of regression standardized residuals have been used to control the prerequisites of the regression model.

Pearson correlations table shows a significant (p<0.01) correlation higher than 80% between the SCOPS and SCOFS in the 99% confidence interval. ANOVA table shows that the model is significant (p<0.01) with a high F score.

Model summary and coefficient table of SLR model has been given in Tables 36 and 37 respectively. These tables will be used to interpret the model results.

Table 36: SLR model summary to determine the effects of SCOFS on SCOPS

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.844[a]	.712	.709	.83325097	.712	236.821	1	96	.000

[a]. Predictors: (Constant), SCOFS

According to R^2 value model significantly ($p < 0.01$) predicts the 71.2% of changes in the SCOPS value that has been caused by the changes in SCOFS value. Adjusted

R^2 value also confirms the result with a similar value of 70.9% which indicates a strong prediction ability. Both values are significant in 99% confidence interval. Since only one factor has been selected as an independent variable, this proportion of explanation is quite acceptable (since the prediction level is between 80%-60% it still has a strong prediction capability).

Table 37: SCOFS factor coefficient of its effect on SCOPS

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.109	.240		4.616	.000
	SCOFS	.807	.052	.844	15.389	.000

According to related SPSS output, SCOFS factor coefficient table, SCOFS has been found to have an effect on SCOPS with a very high statistical significance (p<0.01) in the 99% confidence interval. By using the standardized coefficient (since both SCOPS and SCOFS have been rated by using 7-point Likert scale) it can be said that the SCOFS has an important effect (with an amount of 0.844) on SCOPS. Since only one independent variable has been used in the regression model there is no need to check the multicollinearity. So this control step will be passed for the rest of SLR models.

According to unstandardized coefficient of SLR model, regression equation of SCOPS related with the SCOFS can be represented as:

$$SC\hat{O}PS = 1.109 + 0.807 \times SCOFS \quad (64)$$

Since the effect of flexibility on the performance has been proved, now the efforts can be headed towards proving the effects of ERP has on the overall flexibility and performance of the SC.

5.2 Importance and Effects of ERP: Evaluating Implementation Success

ERP systems have a costly implementation process. Since the requirements of these systems are so much implementation doesn't always end up successfully. So the factors necessary for the implementation have to be considered carefully to avoid unsuccessful implementation and loosing the investments made on the ERP system (Erkan, Özdemir, and Baç, 2012). However, if implemented successfully ERP systems provide great opportunities to improve SC performance (Erkan, Baç, and Özdemir, 2012).

Analyses carried out in this sections aim to prove the effects of successful ERP implementation has on the SC"s overall performance and flexibility. After proving these effects, factors needs to be considered during the implementation phase will be determined for the success of ERP.

5.2.1 Determining the Effect of ERP on Supply Chain Performance by Hybrid ANP / Independent Samples t-Test / Simple Linear Regression Model

Before investigating the effect of ERP on the SCOFS it would be appropriate to determine its effect on the SC performance measured by SCOPS. For this purpose an independent samples t-test and SLR model have been used. In this hybrid approach ANP model's outputs have been used as an input in the statistical analyses. Both models have been solved by using IBM SPSS statistics version 19. The hypothesis that will be tested by the independent samples t-test can be written as:

H_1: Implementing an ERP system has a positive effect on the overall SC performance.

For the test of this hypothesis, companies have been divided in two; the ones have an ERP system and the ones that have not. Because of the nature of the identified hypothesis, independent samples t-test has been selected as a statistical method (Bendoly and Kaefer, 2004). Test for this hypothesis has been made by using the data acquired with the SC flexibility questionnaire, because the companies in this questionnaire consists of the ones that uses an ERP software and the ones that doesn't use an ERP software. ERP and BPR successes questionnaire only consists the companies that use an ERP system, so the independent samples t-test couldn't be performed by using the data of this questionnaire.

Some findings of the independent samples t-test analysis have been given in Appendix 23.

Levene's Test for Equality of Variances has been considered during the interpretation phase of the findings. Results of the independent samples t-test have been interpreted by assuming unequal variances, since significance value is greater than 0.1 for equal variances, according to Appendix 23. However, same significance values for both equal and unequal variances assumptions have been calculated for the difference in means at the same confidence intervals. So there won't be any difference in the interpretation of analysis results.

Main findings of the analysis have been summarized in Table 38.

Table 38: Independent samples t-test results for the effects of ERP's existence on SCOPS

Hypothesis	ERP (0: not implemented, 1: implemented)	N	SCOPS Mean	Std. Deviation	Std. Error Mean	Independent samples t-test significance (2-tailed)
H_1	0	42	3.7645636	1.35001762	.20831224	.000
	1	56	5.1744832	1.40548727	.18781614	

According to independent samples t-test means of two samples have a statistically significant difference if the 2-tailed significance value is less than 0.05 in the 95% confidence interval (Erkan, Baç, and Daneshvar, 2012). According to analysis, existence of ERP in the companies creates a significant (in 99% confidence interval) difference on the SCOPS measurements of companies. This result confirms the H_1 hypothesis. Companies that don't use ERP software have average SCOPS of 3.7645636; where the companies that have ERP software have average SCOPS of 5.1744832. These scores have been evaluated over 7 points in total. This difference in the SC overall performance scores can be seen in Figure 34.

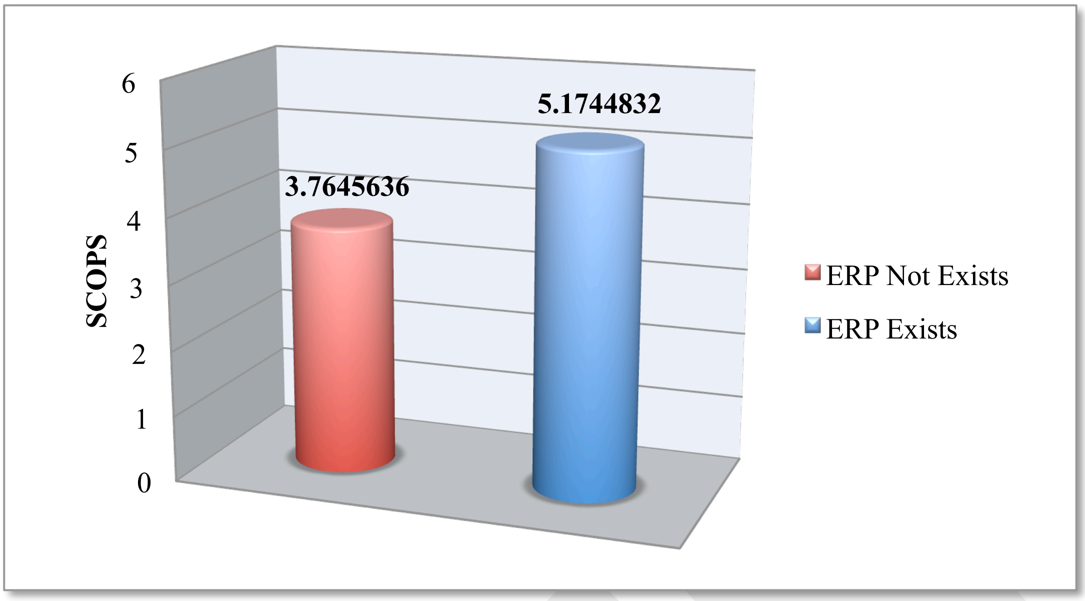


Figure 34: Amount of difference that ERP's existence creates on SCOPS

In addition to the t-test analysis a SLR model has been used to see the change occurs in the performance related with the change in the ERP implementation success. Regression model has the functional form of:

$$SCOPS = f(ERPsuc) + \varepsilon \qquad (65)$$

Some results of the SLR model have been given in Appendix 24. Pearson correlation and ANOVA analyses have been used for the interpretation of the model structure; where histogram and normal P-P plot of regression standardized residuals have been used to control some pre-conditions of the regression model that needs to be satisfied prior to solution.

Pearson correlations table shows a significant (p<0.01) correlation higher than 80% between the SCOPS and SCOFS in the 99% confidence interval. ANOVA table shows that the model is significant (p<0.01) with a high F score.

Detailed results of the regression model related with the ERP's effects on SCOPS have been given in Tables 39 and 40.

Table 39: SLR model summary to determine the effects of ERP on SCOPS

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.894[a]	.799	.797	.54909395	.799	398.475	1	100	.000

[a]. Predictors: (Constant), *ERPsuc*

According to R^2 value model significantly ($p < 0.01$) predicts the 79.9% of changes in the SCOPS value that has been caused by the changes in ERP success' value. Adjusted R^2 value also confirms the result with a similar value of 79.7% which indicates a strong prediction ability. Both values are significant in 99% confidence interval. The prediction level is close to 80%, so the model has a strong prediction capability, which is a preferable result for a SLR model.

Table 40: ERP success factor coefficient of its effect on SCOPS

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.168	.183		6.399	.000
	ERPsuc	.727	.036	.894	19.962	.000

According to the results of SLR model, value of ERP's success has been found to have a significant effect, with a p value less than 0.01, on SCOPS in the 99% confidence interval. By using the standardized coefficient (since both SCOPS and ERP success have been rated by using 7-point Likert scale) it can be said that the ERP has an important effect (with an amount of 0.894) on SCOPS. According to unstandardized coefficient SLR model of SCOPS related with the ERP success can be represented as:

$$SC\hat{O}PS = 1.168 + 0.727 \times ERPsuc \qquad (66)$$

Results of the analysis show that the existence of ERP system causes an increase the SC performance. In addition to this, the amount of performance score increases with the amount of success achieved in the implementation of ERP. The amount of effect that the SCOPS received from SCOFS is relatively higher than the effect of ERP.

But most importantly the effect of ERP is also results indirectly over the flexibility, since ERP also affects the SC flexibility. To prove this effect, necessary analyses have been carried out in the following section.

5.2.2 Determining the Effect of ERP on Supply Chain Overall Flexibility by Hybrid Fuzzy AHP / Independent Samples t-Test Approach / Simple Linear Regression Model

ERP's effects on SC performance have been proved in the previous section, but the effect of ERP in the SC system is not limited with that. ERP's most important role is its nature to turn SC into a more flexible form. ERP system creates the necessary background needed for a flexible SC. Because of this property, ERP has an effect on SC flexibility. Some proportion of the ERP's effect on the performance is the indirect representation of this effect. To prove the relationship between the ERP and the flexibility, an independent samples t-test and a SLR model have been used. In both analyses SCOFS metric has been used to represent SC flexibility. Since SCOFS has been calculated with fuzzy AHP approach, both tests have a hybrid structure.

To be tested in the independent samples t-test, related hypothesis regarding the relation between ERP and flexibility has been defined as:

H_2*:* Implementing an ERP system has a positive effect on the overall SC flexibility.

To test H_2 companies, to which the flexibility questionnaire has been applied, divided in two as the ones that implemented ERP, and the ones that didn't. Some results of the independent samples t-test have been given in Appendix 25.

According to Levene's Test for Equality of Variances, equality of the variances has been rejected wit a p value more than 0.05. Analysis results have to be evaluated under unequal variances assumption, but for both situations the significance values are strong with a p value of 0.01 in the 99% confidence interval, so the choice of variance equality is not restrictive. Summary of the independent samples t-test results has been given in Table 41.

Table 41: Independent samples t-test results for the effect of ERP's existence on SCOFS

Hypothesis	ERP (0: not implemented, 1: implemented)	N	SCOFS Mean	Std. Deviation	Std. Error Mean	Independent samples t-test significance (2-tailed)
H_2	0	42	3.6719560	1.3892559	0.2143668	.001
	1	56	4.7540356	1.6255552	0.2172239	

According to results given in Table 41, H_2 hypothesis has been confirmed (in the 99% confidence interval) with a p value of 0.001 that is less than 0.01. This result implies that there is a statistically significant difference in the SCOFS values of companies between the ones that implemented an ERP system and the ones that didn't. The amount of difference can be seen in Figure 35.

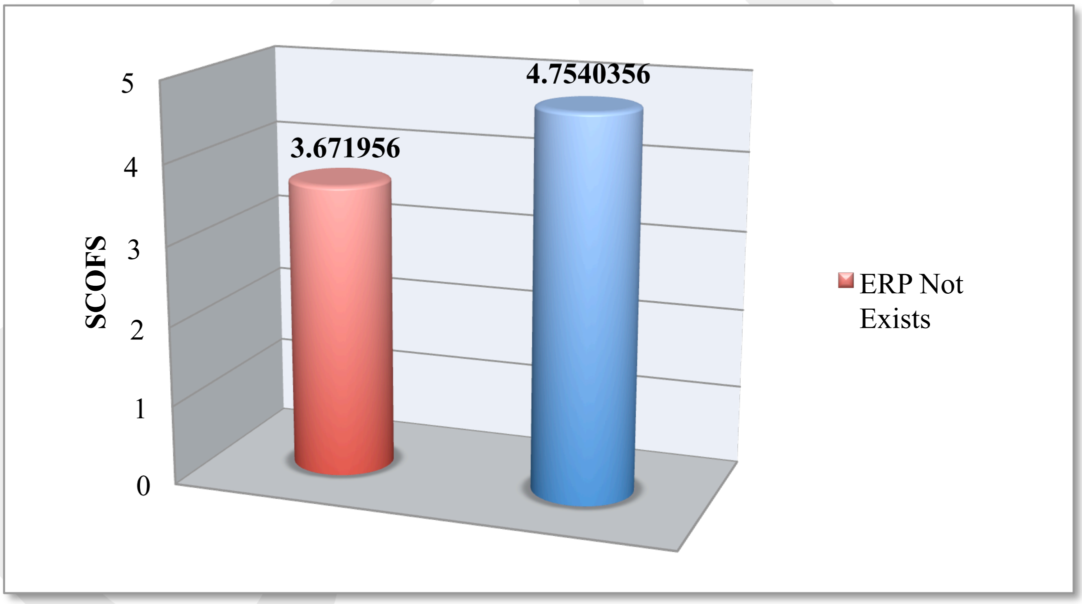


Figure 35: Amount of difference that ERP's existence creates on SCOFS

Amount of change caused by the ERP's existence was higher in the SCOPS. This result is normal because ERP not only affects the SC performance directly but also affects it indirectly by affecting the SC flexibility, which affects the performance directly. To understand the amount of effect that ERP causes on the SCOFS a SLR model has been built to analyze the relation between the SC's overall flexibility and the ERP success rate. This model has a functional form as given below.

$$SCOFS = f\left(ERPsuc\right) + \varepsilon \tag{67}$$

SLR related SPSS outputs have been given in Appendix 26 for preliminary analysis. Pearson correlations table shows a significant (p<0.01) correlation higher than 80% between the ERP success and SCOFS in the 99% confidence interval. ANOVA table shows that the model is significant (p<0.01) with a high F score also in 99% confidence interval. Results associated with the findings of regression model have been given in Table 42 and Table 43.

Table 42: SLR model summary to determine the effects of ERP on SCOFS

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.819[a]	.670	.664	0.9420435	.670	109.766	1	54	.000

[a]. Predictors: (Constant), *ERPsuc*

Regression model significantly predicts the 67% of change occurs in the SC flexibility with a p value less than 0.01 in the 99% confidence interval according to R^2. This result has also been confirmed by the adjusted R^2 value (66.4% of variance can be explained by the variance of ERP success). Since only one factor has been selected as an independent variable this proportion of explanation is acceptable (since the prediction level is between 80%-60% it still has a strong prediction capability).

Table 43: ERP success factor coefficients of its effect on SCOFS

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.906	.300		6.360	.000
	ERPsuc	.646	.062	.819	10.477	.000

According to results given in Table 43, ERP success has been found to have a statistically significant effect on the SC flexibility in 99% confidence interval ($p < 0.001$). Standardized coefficient shows that the changes in the ERP success score have an important effect (0.819) on the SC overall flexibility. By using the unstandardized coefficient, SLR model of SCOFS related with the ERP success can be written as:

$$SC\hat{O}FS = 1.906 + 0.646 \times ERPsuc \qquad (68)$$

These results mean that an increase achieved in the success of ERP implementation results in an increase in the SC performance. Also this achievement of success increases the SC overall flexibility, which also increases the SC overall performance.

Until here effects of flexibility on the performance and the effect of ERP on flexibility has been proved. Also ERP's effect on the performance has been stated. Since for increasing SC performance flexibility is needed and to achieve flexibility in the SC ERP is necessary; what is needed for a successful ERP implementation? Next section answers this question with the related analyses.

5.2.3 Determining the Factors Affecting ERP Implementation Success by Multiple Linear Regression Model

As mentioned before, implementing an ERP system requires many prerequisites for the success of the efforts and capital spent. Above all, main prerequisite is SC's structure to be ready for the change that comes with the ERP. To get the company ready for this change BPR application is vital. So instead of evaluating BPR as factor that affects ERP's implementation success it has been interpreted separately because of its importance and its effect on the SC performance (also a factor related with the BPR has been added in the factors being evaluated to include the effect of BPR in the MLR model).

ERP implementation related success factors have been evaluated in this section. There are 17 factors that affect the implementation success of ERP, which are gathered from the literature survey. List of these factors have been given in Appendix 2. Purpose of the analysis carried out in this section is to determine the factors that have a significant effect on the ERP implementation in Turkish enterprises. To evaluate companies a questionnaire study has been completed as mentioned before. Data acquired in these questionnaires have been used in a MLR model. This model can be written in a functional form as given in the equation below:

$$ERPsuc = f\begin{pmatrix} ERPV1, ERPV2, ERPV3, ERPV4, ERPV5, ERPV6, \\ ERPV7, ERPV8, ERPV9, ERPV10, ERPV11, ERPV12, \\ ERPV13, ERPV14, ERPV15, ERPV16, ERPV17 \end{pmatrix} + \varepsilon \qquad (69)$$

MLR model results have been given in Appendix 27. As it can be seen from the results *stepwise* algorithm has been used because of the number of independent variables defined in the model. Selection of the most significant factors was the main priority in the solution of the regression model. Related model summaries of all the models *stepwise* algorithm built and the coefficients related with these models; Pearson correlations, and ANOVA analyses, histogram and normal P-P plot of regression standardized residuals, and partial regression plots of each independent variable, can be seen in the results. Supplied information has been used to check the preliminary conditions of the MLR model. Figures provided, have been used to check the normal distribution and linearity conditions and no problems found. There are some correlation values that exceed 0.8 in the correlation matrix that may indicate some multicollinearity problems. This is another reason for not selecting the *enter* algorithm for the solution of the MLR model. Because of this reason *VIF* values related with this values have been checked in the coefficients table. As a result, all variables seem clear from any multicollinearity problem. ANOVA table also shows that the model is significant with $p<0.01$ in the 99% confidence interval, which is the natural result of *stepwise* algorithm, with a high *F* score (also checked with *enter* algorithm).

Model summaries of *stepwise* MLR model and information related with the coefficients have been given in Tables 44 and 45 respectively.

Table 44: MLR model summaries of factors effecting ERP implementation success

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.949[a]	.900	.899	.476	.900	902.452	1	100	.000	
2	.968[b]	.937	.935	.381	.037	57.132	1	99	.000	
3	.975[c]	.950	.949	.340	.014	26.650	1	98	.000	
4	.979[d]	.958	.956	.313	.008	18.284	1	97	.000	
5	.981[e]	.963	.961	.296	.005	12.670	1	96	.001	
6	.984[f]	.968	.966	.276	.005	15.155	1	95	.000	
7	.986[g]	.972	.970	.261	.004	12.083	1	94	.001	
8	.987[h]	.975	.973	.247	.003	12.172	1	93	.001	
9	.988[i]	.977	.975	.238	.002	8.172	1	92	.005	
10	.989[j]	.979	.976	.232	.001	6.158	1	91	.015	
11	.990[k]	.980	.978	.225	.001	6.464	1	90	.013	
12	.991[l]	.981	.979	.218	.001	6.724	1	89	.011	
13	.991[m]	.982	.980	.213	.001	5.345	1	88	.023	
14	.992[n]	.983	.981	.209	.001	4.766	1	87	.032	
15	.992[o]	.984	.982	.204	.001	5.067	1	86	.027	1.789

[a]. Predictors: (Constant), *ERPV4*
[b]. Predictors: (Constant), *ERPV4, ERPV10*
[c]. Predictors: (Constant), *ERPV4, ERPV10, ERPV2*
[d]. Predictors: (Constant), *ERPV4, ERPV10, ERPV2, ERPV9*
[e]. Predictors: (Constant), *ERPV4, ERPV10, ERPV2, ERPV9, ERPV3*
[f]. Predictors: (Constant), *ERPV4, ERPV10, ERPV2, ERPV9, ERPV3, ERPV17*
[g]. Predictors: (Constant), *ERPV4, ERPV10, ERPV2, ERPV9, ERPV3, ERPV17, ERPV12*
[h]. Predictors: (Constant), *ERPV4, ERPV10, ERPV2, ERPV9, ERPV3, ERPV17, ERPV12, ERPV11*
[i]. Predictors: (Constant), *ERPV4, ERPV10, ERPV2, ERPV9, ERPV3, ERPV17, ERPV12, ERPV11, ERPV1*
[j]. Predictors: (Constant), *ERPV4, ERPV10, ERPV2, ERPV9, ERPV3, ERPV17, ERPV12, ERPV11, ERPV1, ERPV15*
[k]. Predictors: (Constant), *ERPV4, ERPV10, ERPV2, ERPV9, ERPV3, ERPV17, ERPV12, ERPV11, ERPV1, ERPV15, ERPV7*
[l]. Predictors: (Constant), *ERPV4, ERPV10, ERPV2, ERPV9, ERPV3, ERPV17, ERPV12, ERPV11, ERPV1, ERPV15, ERPV7, ERPV5*
[m]. Predictors: (Constant), *ERPV4, ERPV10, ERPV2, ERPV9, ERPV3, ERPV17, ERPV12, ERPV11, ERPV1, ERPV15, ERPV7, ERPV5, ERPV14*
[n]. Predictors: (Constant), *ERPV4, ERPV10, ERPV2, ERPV9, ERPV3, ERPV17, ERPV12, ERPV11, ERPV1, ERPV15, ERPV7, ERPV5, ERPV14, ERPV16*
[o]. Predictors: (Constant), *ERPV4, ERPV10, ERPV2, ERPV9, ERPV3, ERPV17, ERPV12, ERPV11, ERPV1, ERPV15, ERPV7, ERPV5, ERPV14, ERPV16, ERPV13*

According to Table 44, *stepwise* algorithm built 15 models. With the addition of each independent variable into the model, prediction ability of the model increased according to R^2 (from 90% to 98.4%) and adjusted R^2 (from 89.9% to 98.2%) values. Final model (15th model) predicts the 98.4% of the change in the ERP implementation success score that was caused by the changes in the factors according to R^2 value. But in MLR models adjusted R^2 gives more accurate results as mentioned before. So, the final model correctly predicts 98.2% of the variance in the ERP implementation success according to adjusted R^2 value. This value is significant in 99% confidence interval with a p value less than 0.01 as mentioned in the ANOVA interpretations. Such a prediction rate is so strong so the unpredicted portion of the change can be neglected. Model also shows no signs of autocorrelation with a Durbin-Watson value of $d = 1.789$ which is in the range of 1.5 to 2.5 (*enter* algorithm acquired a d value of 1.772).

Table 45: ERP implementation success factor coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics
		B	Std. Error	Beta			VIF
15	(Constant)	-.436	.105		-4.172	.000	
	ERPV4	.133	.043	.135	3.047	.003	10.750
	ERPV10	.072	.026	.082	2.762	.007	4.867
	ERPV2	.070	.025	.072	2.767	.007	3.675
	ERPV9	.084	.027	.086	3.107	.003	4.184
	ERPV3	.109	.030	.114	3.601	.001	5.472
	ERPV17	.104	.026	.104	3.977	.000	3.706
	ERPV12	.043	.013	.055	3.208	.002	1.587
	ERPV11	.102	.035	.102	2.910	.005	6.687
	ERPV1	.069	.022	.072	3.135	.002	2.844
	ERPV15	.034	.016	.038	2.188	.031	1.626
	ERPV7	.079	.026	.083	3.079	.003	4.013
	ERPV5	.080	.023	.092	3.415	.001	3.973
	ERPV14	.029	.014	.032	2.142	.035	1.214
	ERPV16	.065	.028	.064	2.335	.022	4.046
	ERPV13	.075	.033	.059	2.251	.027	3.767

15 of 17 independent variables have entered the final model. These variables are *ERPV1, ERPV2, ERPV3, ERPV4, ERPV5, ERPV7, ERPV9, ERPV10, ERPV11, ERPV12, ERPV13, ERPV14, ERPV15, ERPV16,* and *ERPV17*. Among these factors;

ERPV13, ERPV14, ERPV15, and *ERPV16* proved to have a significance effect ($p < 0.05$) on the implementation success of ERP in the 95% confidence interval. Rest of the factors proved to be significant with a p value less than 0.01 in the 99% confidence interval.

Factors *ERPV6:"Software suppliers have provided satisfactory support and assistance"* and *ERPV8:"The benefits of the ERP system have been clearly identified and communicated"* have been found insignificant and excluded from the MLR model. ERP software suppliers (vendors) are making the promotions and sales. The solution partners are actually making the implementation. For this reason solution partner's efforts stand out in the Turkish companies from the aspect of implementation support. Because of the lack of up-to-date information and fundamental knowledge about the ERP systems in the companies, at most of the times benefits of the ERP systems miscommunicated and after the implementation phase lots of discussions emerge between the company and the solution partners in Turkey. So the findings of the model makes sense when it is thought for the structure of the way business done in Turkey.

According to significance values calculated in Table 45, factors that effect ERP implementation success in the Turkish enterprises are:

- *ERPV1:"There is a fitment between the company's ERP strategy and the overall business strategy",*
- *ERPV2:"ERP implementation related key milestones have been well identified",*
- *ERPV3:"Management of the SC has been significantly involved in the ERP implementation phase",*
- *ERPV4:"The company has followed a clear and detailed BPR plan",*
- *ERPV5:"Business requirements such as competition can be named as the motive of the ERP implementation",*
- *ERPV7:"Project team's efforts were satisfactory to implement the project",*
- *ERPV9:"The company has required amount of financial resources for the implementation and long-term utilization of the ERP system",*
- *ERPV10:"The company has explicit and well-articulated procedures for system implementation, performance evaluation and utilization",*

- *ERPV11:"Management of SC is ready for the chances that came with the ERP and BPR",*
- *ERPV12:"Responsibility and job definitions of workers before and after BPR have been defined clearly",*
- *ERPV13:"There was a partnership between the company and the ERP software provider for technologic cooperation and education",*
- *ERPV14:"For the required education of the end-users necessary support has been given by external experts",*
- *ERPV15:"The company has the sufficient experience to determine the required ERP implementation strategies",*
- *ERPV16:"Majority of users have the sufficient skills to use the ERP software", and*
- *ERPV17:"ERP software has a user-friendly interface".*

Among these factors most important one seems the factor related with the BPR application. This consequence was an expected result. For that reason further analyses has been carried out to strength this finding.

Negative sign of the constant means that the ERP success score remains to be zero since total sum of other variables' score exceed 0.436 score limit. This result was expected because achieving success in the ERP implementation is a hard process that requires many factors to be considered.

Multicollinearity problem related with the independent variables in the MLR model have to be investigated since some significantly high correlations have been found in the correlation table. According to information gathered from the literature in section *3.2.3.3*; *VIF* value of each coefficient should be smaller than $\frac{1}{1-R^2} = \frac{1}{1-0.984} = 62.5$. Since all *VIF* values are smaller than 62.5, no problem seems to exist related with multicollinearity. Since both the R^2 and adjusted R^2 values are the way over 90%, multicollinearity doesn't pose a problem for this MLR model.

Since all the data used in the model have been standardized (pointed over 7-point Likert Scale), importance comparisons can be carried out according to standardized coefficients (β_i) in Table 45. Distribution of the ERP implementation success estimation factors, according to their importance determined by standardized coefficients of regression model, have been shown in Figure 36.

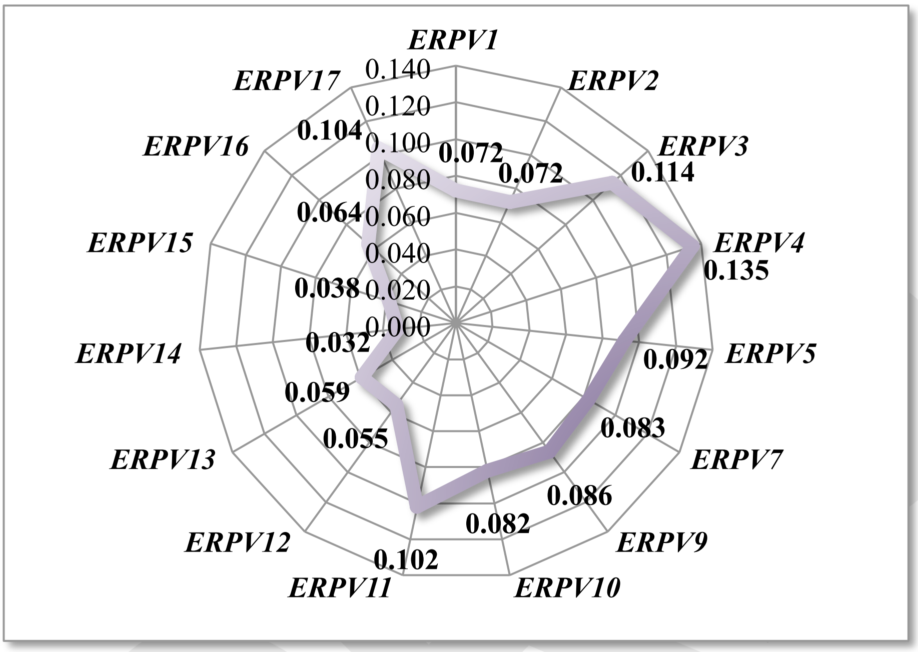


Figure 36: Distribution of ERP implementation success estimation factors according to their importance

As a result of ERP implementation success MLR model, by using the unstandardized coefficients (B), related regression equation for the can be written as:

$$E R\hat{P} suc = \begin{array}{l} -0.436+0.069\times ERPV1+0.070\times ERPV2+0.109\times ERPV3+ \\ 0.133\times ERPV4+0.080\times ERPV5+0.079\times ERPV7+ \\ 0.084\times ERPV9+0.072\times ERPV10+0.102\times ERPV11+ \\ 0.043\times ERPV12+0.075\times ERPV13+0.029\times ERPV14+ \\ 0.034\times ERPV15+0.065\times ERPV16+0.104\times ERPV17 \end{array} \quad (70)$$

By using the factor evaluation scores and the equation given above, ERP implementation success score can be computed.

By the completion of necessary analyses to prove the effects of ERP one last task remained, which is the determination of BPR's effects and the factors effecting application success of BPR.

5.3 Importance and Effects of BPR: Evaluating Application Success

Some part of the analyses until here proved that the flexibility is necessary to increase the performance of SC and ERP is needed to achieve flexibility. Also factors needs to be satisfied for the success of ERP implementation has been specified. But according to literature surveys carried out BPR is stated as a necessity for the success of ERP implementation as mentioned before. In this section BPR's importance will be clarified by proving its effects on the SC performance and ERP implementation success. Finally factors needed for a successful BPR application will be determined.

5.3.1 Determining the Effect of BPR on Supply Chain Performance by Hybrid ANP / Independent Samples t-Test / Simple Linear Regression Model

Before carrying out analyses to prove the effect of BPR on the ERP implementation success, it would be useful to determine the effect of BPR on SC performance to give an insight to its importance. For this purpose, by using SCOPS, a independent samples t-test and a SLR analysis will be used together as a hybrid approach because go the calculation method of SCOPS metric.

Firstly, an independent samples t-test has been carried out to investigate the effects of BPR's existence creates on the SC performance. Hypothesis to be tested in the first analysis can be expressed as:

H_3*:* Existence of BPR application in the SC has a positive effect on the overall SC performance.

To test this hypothesis "BPR application and ERP implementation successes evaluation" questionnaire has been used and the companies has been divided in two as the ones applied BPR and the one that did not. Results of the independent samples t-test used to test the H_3 hypothesis has been given in Appendix 28.

According to Levene's Test for Equality of Variances, equality of the variances has been rejected wit a p value more than 0.05. Analysis results have to be evaluated under unequal variances assumption, but for both situations the significance values are strong with a p value of 0.000 and 0.001 in the 99% confidence interval, so the choice of variance equality is not restrictive. Summary of the independent samples t-test results has been given in Table 46.

Table 46: Independent samples t-test results for the effect of BPR's existence on SCOPS

Hypothesis	BPR (0:not applied, 1:applied)	N	SCOPS Mean	Std. Deviation	Std. Error Mean	Independent samples t-test significance (2-tailed)
H_3	0	34	4.0322529	1.27822905	.21921447	.001
	1	68	4.9540431	1.07283089	.13009986	

Summary of the test results shows that the H_3 hypothesis has been confirmed with a p value of 0.001 in the 99% confidence interval ($p < 0.01$). It can be said that there is a statistically significant difference between the means of SCOPS between the companies in which the BPR has been applied and in which BPR has not been applied. Magnitude of this difference has been visualized in Figure 29.

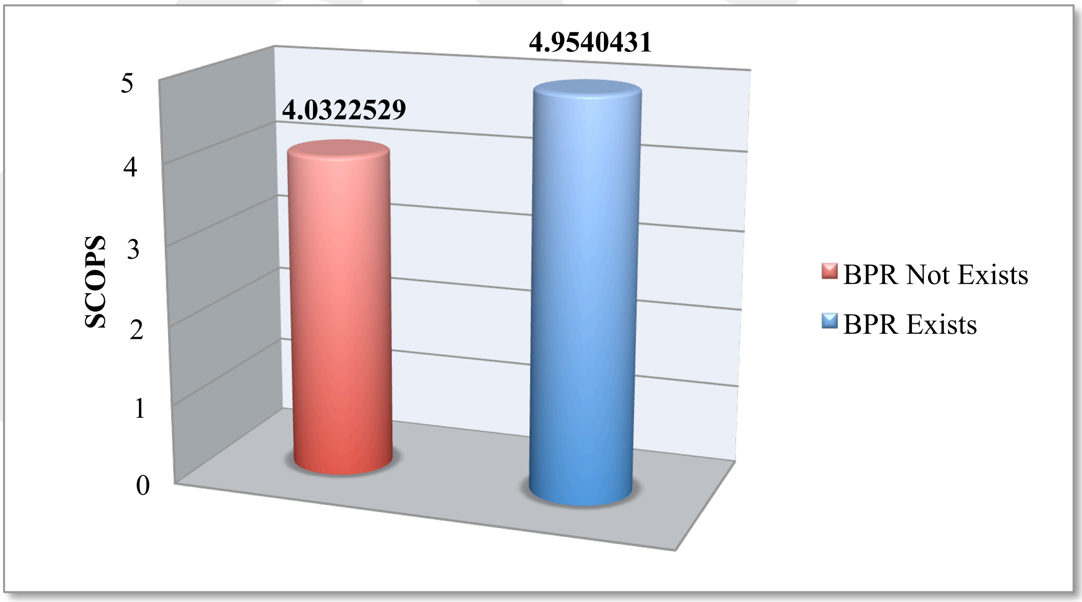


Figure 37: Amount of difference that BPR's existence creates on SCOPS

Amount of change caused by the ERP's existence was higher than the BPR's. This result is normal because BPR not only affects the SC performance directly but also affects it indirectly by affecting the ERP's success, which affects the performance directly. It can be realized that determination of the effects of each item is getting harder when analysis goes deeper. Main reason behind this is the interdependencies of these factors have. This condition will be investigated in the next chapter in details.

To specify the amount of effect that BPR has on the SCOPS a regression model has been used. SLR model here implemented to analyze the relation between the SC's overall performance and the BPR application success rate. This model has a functional form as given below.

$$SCOPS = f\left(BPRsuc\right) + \varepsilon \qquad (71)$$

Some of the SLR model related analyses' results have been given in Appendix 29. Pearson correlation and ANOVA analyses have been used for the interpretation of the model structure; where histogram and normal P-P plot of regression standardized residuals have been used to control the prerequisites of the regression model. Pearson correlations table shows a significant (p<0.01) correlation higher than 70% between the SCOPS and SCOFS in the 90% confidence interval. The reason of this, correlation is less than the correlation values of ERP and SCOFS, is caused because of the BPR's effect is mostly indirect over the ERP success on the SC performance. ANOVA table shows that the model is significant (p<0.01) with a high F score.

Model summary and the related correlations have been given in Tables 47 and 48 respectively.

Table 47: SLR model summary to determine the effects of BPR on SCOPS

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.742[a]	.551	.544	.72420055	.551	81.035	1	66	.000

[a]. Predictors: (Constant), *BPRsuc*

According to R^2 value model significantly ($p < 0.01$) predicts the 55.1% of changes in the SCOPS value that has been caused by the changes in SCOFS value. Adjusted

R^2 value also gives a similar result with 54.4% which indicates a moderate prediction ability. Both values are significant in 99% confidence interval.

Table 48: BPR factor coefficient for its effect on SCOPS

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.741	.261		10.497	.000
	BPRsuc	.470	.052	.742	9.002	.000

Even though using independent samples t-test is a better way to prove the effect of BPR on the SC performance its SLR model also implies that BPR has a significant effect on the SCOPS. According to the results of regression model, value of BPR success has been found to have a significant effect, with a p value less than 0.01, on SCOPS in the 99% confidence interval. By using the standardized coefficient (since both SCOPS and BPR success have been rated by using 7-point Likert scale) it can be said that the BPR has a considerable effect (with an amount of 0.742) on SCOPS. According to unstandardized coefficient SLR model of SCOPS related with the BPR success can be represented as:

$$SC\hat{O}PS = 2.741 + 0.470 \times BPRsuc \quad (72)$$

Results of the analysis show that the existence of BPR causes an increase the SC performance. In addition to this, the amount of increase in the SC performance has a significant relation with the amount of success achieved in the application of BPR. When considered together with the previous findings, the amount of effect that the ERP and flexibility causes on the SCOPS is relatively higher than the effect of BPR. But most importantly the effect of BPR is also results indirectly from its contribution on ERP's success, which affects the SC flexibility that directly affects SC performance. This interrelations acts like a chain. Effects related with BPR's contribution on the ERP success has been explained in the following section.

5.3.2 *Determining the Effect of BPR on ERP Implementation Success by Independent Samples t-Test and Simple Linear Regression Model*

Primary role of the BPR in the SC is the effect it has on the implementation success of ERP. ERP requires a company structure that is ready for the changes it brings along. BPR is the only way to get the SC structure ready for this change, so the ERP can be implemented successfully and it can perform effectively and efficiently, as it should be.

To compare the companies, which applied BPR prior to ERP and the ones that didn't applied BPR prior to ERP implementation have been compared from the aspect of ERP implementation success scores. This analysis has been performed by using the data collected with "ERP implementation and BPR application successes" questionnaire. For this purpose independent samples t-test has been used to analyze the difference of ERP success score means of the companies grouped as the ones that has a BPR and the ones that doesn't. So the hypothesis needs to be tested in this analysis has been expressed as:

H_4: BPR application before the implementation of ERP increases the success score of the implementation (*ERPsuc*).

Results related with the independent samples t-test used to test the H_4 hypothesis has been given in Appendix 30. According to Levene's Test for Equality of Variances, equality of the variances has been rejected wit a *p* value more than 0.05. Analysis results have to be evaluated under unequal variances assumption, but for both situations the significance values are strong with *p* values of 0.000 in the 99% confidence interval, so the choice of variance equality is not restrictive. Summary of the independent samples t-test results has been given in Table 49.

Table 49: Independent samples t-test results for the effect of BPR's existence on ERP success

Hypothesis	BPR application prior to ERP (0:not applied, 1:applied)	N	*ERPsuc* Mean	Std. Deviation	Std. Error Mean	Independent samples t-test significance (2-tailed)
H_4	0	34	3.97	1.425	.244	.000
	1	68	5.19	1.374	167	

Test results show a similarity, from the aspect of magnitude of change in the means, between the effects of ERP's existence creates on the SCOFS. Existence of BPR application, prior to ERP implementation, statistically significantly ($p < 0.01$) and considerably increases the ERP implementation success in the 99% confidence interval. Difference in the means caused by the existence of BPR has been showed in Figure 38.

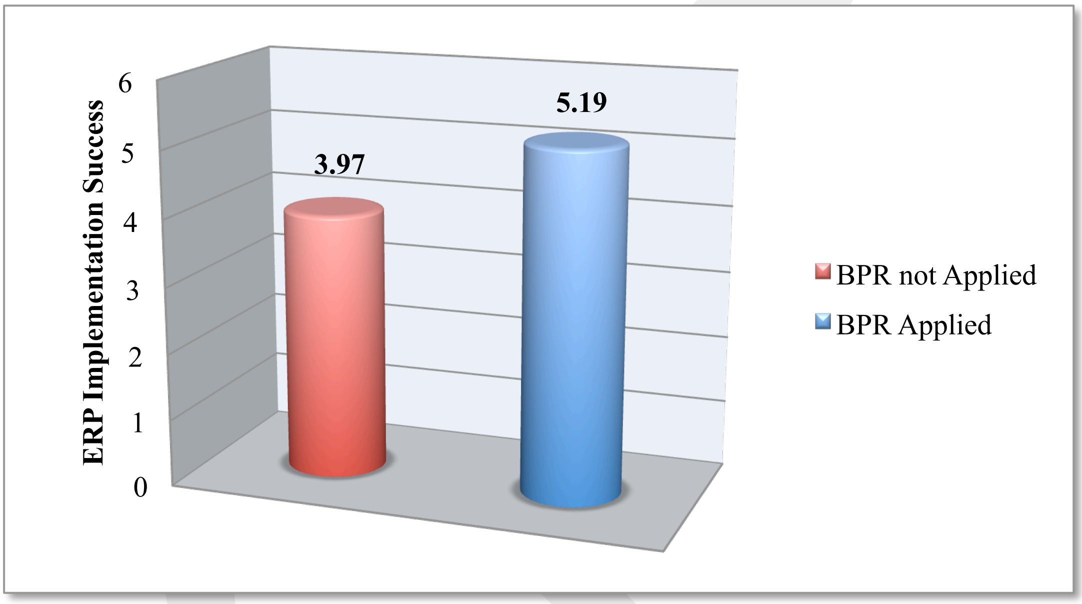


Figure 38: Amount of difference that BPR's existence creates on ERP implementation success score

In means of emphasizing the relation between the BPR and the ERP an additional regression model have been built. ERP implementation success as a function of BPR application success has been defined according to following equation:

$$ERPsuc = f\left(BPRsuc\right) + \varepsilon \qquad (73)$$

This regression model has been used to investigate the effect of changes in the BPR's success on the success of ERP. Related SLR model has been solved and some of the results have been given in Appendix 31. According to output given in Appendix 31, Pearson correlations table shows a significant ($p < 0.01$) correlation higher than 80% between the BPR and ERP successes in the 90% confidence interval. ANOVA table shows that the model is significant (with a p value of 0.000) with a high F score. Rest of the results of the model has been given in Tables 50 and 51.

Table 50: SLR model summary to determine the effects of BPR application success on the ERP implementation success

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.846[a]	.715	.711	.739	.715	165.541	1	66	.000

[a]. Predictors: (Constant), *BPRsuc*

According to R^2 value model significantly ($p < 0.01$) predicts the 71.5% of changes in the ERP success score value that has been caused by the changes in BPR's success. Adjusted R^2 value also confirms the result with a similar value of 73.9% which indicates a strong prediction capability. Both values are significant in 99% confidence interval.

Table 51: BPR success factor coefficient for its effect on ERP implementation success

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.962	.266		7.363	.000
	BPRsuc	.686	.053	.846	12.866	.000

According to Table 51, success of BPR application has been found to have an effect on the success of ERP implementation with a very high statistical significance ($p < 0.01$) in the 99% confidence interval. By using the standardized coefficient (since both ERP and BPR successes have been rated by using 7-point Likert scale) it can be said that the BPR success score has an important effect (with an amount of 0.846) on ERP success. According to unstandardized coefficient SLR model of ERP implementation success can be formulated as:

$$ER\hat{P}suc = 1.962 + 0.686 \times BPRsuc \qquad (74)$$

As the independent samples t-test's results, SLR model results also confirmed the positive relation between the ERP and BPR successes. In addition, SLR model shows that the ERP success increases as the BPR success increases, which means, the more success achieved in the BPR application prior to ERP implementation, more the chance of successful implementation chance of the ERP.

Up until here all the interrelations have been proved with the necessary statistical analysis between the BPR, ERP and SC flexibility (main factors considered in the thesis that affect SC overall performance). According to analyses carried put, basis needed to achieve flexibility reaches along to BPR. So the last question to be answered is: "*What is needed for a successful BPR implementation?*". Analysis carried out in the next section intends to answer this question.

5.3.3 Determining the Factors Affecting BPR Success by Multiple Linear Regression Model

Similar to ERP implementation process, also BPR application phase requires some factors to be considered to increase the chances of application success and increase the efficiency of the application. It is not guaranteed that each BPR application will succeed. So, during the application some vital factors have to be understood clearly and specific steps have to be followed carefully.

As a result of literature survey 15 factors have been gathered together to determine the success of BPR applications. List of these factors have been given in Appendix 3. Purpose of the analysis carried out here is to determine the factors that have statistically significant direct effect on the BPR application success in the Turkish companies. "ERP implementation and BPR application successes" questionnaire has been used to gather the necessary data for the analysis. Then this data has been used in MLR model to specify the important factors that affects BPR success. Functional form of the regression model for this specification purpose has been given below:

$$BPRsuc = f\begin{pmatrix} BPRV1, BPRV2, BPRV3, BPRV4, BPRV5, BPRV6, \\ BPRV7, BPRV8, BPRV9, BPRV10, BPRV11, \\ BPRV12, BPRV13, BPRV14, BPRV15 \end{pmatrix} + \varepsilon \qquad (75)$$

As some of the previous models *stepwise* algorithm, for the selection of the most important factors, has been used in the solution of this MLR model. Related model summaries of all the models *stepwise* algorithm built and the coefficients related with these models; Pearson correlations, and ANOVA analyses, histogram and normal P-P plot of regression standardized residuals, and partial regression plots of each independent variable, can be seen in Appendix 33. Figures provided, have been used to check the normal distribution and linearity conditions and no problems found. A few correlation values that exceed 0.8 in the correlation matrix have been found that may indicate some multicollinearity problems. Because of this reason *VIF* values and tolerance related with this values have been checked in the coefficients table. As a result, all variables seem clear from any multicollinearity problem. ANOVA table shows that the model is significant with $p < 0.01$ in the 99% confidence interval, which is the natural result of *stepwise* algorithm, with a high F score (also checked with *enter* algorithm).

Model summaries of *stepwise* MLR model and information related with the coefficients have been given in Tables 52 and 53 respectively.

Table 52: MLR model summaries of factors effecting BPR application success

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.859[a]	.737	.733	.874	.737	185.375	1	66	.000	
2	.934[b]	.873	.869	.612	.136	69.562	1	65	.000	
3	.967[c]	.934	.931	.444	.061	59.613	1	64	.000	
4	.977[d]	.954	.951	.374	.020	27.321	1	63	.000	
5	.982[e]	.964	.961	.333	.010	17.168	1	62	.000	
6	.984[f]	.969	.966	.315	.004	8.662	1	61	.005	
7	.986[g]	.972	.968	.302	.003	6.336	1	60	.015	
8	.987[h]	.974	.970	.293	.002	4.582	1	59	.036	
9	.988[i]	.975	.972	.285	.002	4.212	1	58	.045	1.859

[a]. Predictors: (Constant), *BPRV9*
[b]. Predictors: (Constant), *BPRV9, BPRV2*
[c]. Predictors: (Constant), *BPRV9, BPRV2, BPRV10*
[d]. Predictors: (Constant), *BPRV9, BPRV2, BPRV10, BPRV3*
[e]. Predictors: (Constant), *BPRV9, BPRV2, BPRV10, BPRV3, BPRV12*
[f]. Predictors: (Constant), *BPRV9, BPRV2, BPRV10, BPRV3, BPRV12, BPRV4*
[g]. Predictors: (Constant), *BPRV9, BPRV2, BPRV10, BPRV3, BPRV12, BPRV4, BPRV5*
[h]. Predictors: (Constant), *BPRV9, BPRV2, BPRV10, BPRV3, BPRV12, BPRV4, BPRV5, BPRV15*
[i]. Predictors: (Constant), *BPRV9, BPRV2, BPRV10, BPRV3, BPRV12, BPRV4, BPRV5, BPRV15, BPRV11*

According to Table 52, *stepwise* algorithm built 9 models. With the addition of each independent variable into the model, prediction ability of the model increased according to R^2 (from 73.2% to 97.5%) and adjusted R^2 (from 73.3% to 97.2%) values. Final model (9[th] model) predicts the 97.5% of the change in the BPR application success score that was caused by the changes in the factors according to R^2 value. As mentioned before, adjusted R^2 gives more accurate results in MLR models. So, the final model correctly predicts 97.2% of the variance in the success of BPR application according to adjusted R^2 value. This value is significant in 99% confidence interval with a p value less than 0.01 as mentioned in the ANOVA interpretations. Such a prediction rate is so strong so the unpredicted portion of the change can be neglected. Model also shows no signs of autocorrelation with a Durbin-Watson value of $d = 1.859$ which is in the range of 1.5 to 2.

Table 53: ERP application success factor coefficients

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.	Collinearity Statistics VIF
9	(Constant)	-.527	.132		-4.004	.000	
	BPRV9	.297	.029	.330	10.402	.000	2.374
	BPRV2	.226	.028	.291	8.071	.000	3.074
	BPRV10	.072	.033	.074	2.193	.032	2.670
	BPRV3	.123	.034	.127	3.624	.001	2.906
	BPRV12	.085	.026	.092	3.303	.002	1.850
	BPRV4	.108	.030	.108	3.547	.001	2.176
	BPRV5	.073	.033	.069	2.249	.028	2.252
	BPRV15	.059	.024	.070	2.495	.015	1.834
	BPRV11	.079	.038	.085	2.052	.045	4.094

9 of 15 independent variables have entered the final model. These variables are *BPRV2, BPRV3, BPRV4, BPRV5, BPRV9, BPRV10, BPRV11, BPRV12,* and *BPRV15*. Among these factors; *BPRV5, BPRV10, BPRV11,* and *BPRV15* proved to have a significance effect ($p < 0.05$) on the success of BPR in the 95% confidence interval. Rest of the factors proved to be significant with a p value less than 0.01 in the 99% confidence interval.

Factors *BPRV1:"Extensive user involvement in design", BPRV6:*"*Growth-oriented goal instead of cost-cutting*", *BPRV7:*"*Full-time participation of key members of the project*", *BPRV8:*"*Adequate budget for the project*", *BPRV13:*"*Pilot application prior to full implementation*", and *BPRV14:"Following a detailed methodology"* have been found insignificant and excluded from the MLR model. Champy's (Hammer and Champy, 1993) Top-down approach is valid for the Turkish business organization's structure. For this reason involvement of users is so rare in the design phase, an expected result. Even the optimal strategy for the BPR application is to be growth-oriented, unfortunately most companies' main goal is to survive and for this purpose cutting-costs outmatches the seizing the growing opportunities. Even mentioned rarely in the literature full-time participants in the projects is also seems as a not vital element of ERP success in Turkey. Main reason of this is the hiring of consultants in the application projects. Budget amount of the project is flexible when BPR application is supported by the top-management. CEO commitment brings undertake of the budget by the executives and since no financial problems left for the application budget spared could be shifted to another projects. A pilot application is not preferred most of the times in the project implementation methods because of cultural reasons in Turkey. Impatience to see the results causes this and direct implementation and testing the results during the process is preferred in most of the times. The experts who filled the questionnaires may misunderstand “Following a detailed methodology” factor and interpreted it as the long and detailed reporting of each step to the top-management. This is not a common procedure in Turkish companies for not to take too much time of the executives.

According to significance values calculated in Table 53, factors that effect ERP implementation success in the Turkish enterprises are:

- *BPRV2:“Strong support, commitment and sponsorship from senior management”,*
- *BPRV3:“Realistic project expectations”,*
- *BPRV4:“Extensive cross-functional memberships between project teams”,*
- *BPRV5:“Clear vision of project goals”,*
- *BPRV9:“Adequate education and training conducted”,*
- *BPRV10:“Communications with employees during the project”,*
- *BPRV11:“Significant portion of CEO's time committed to project”,*
- *BPRV12:“Senior executive responsible for the project”,* and
- *BPRV15:“Performance Measurement before, during, and after the project”*.

Among these factors most important one seems the factor related with the BPR application. This consequence was an expected result. For that reason further analyses has been carried out to strength this finding.

Negative sign of the constant means that the BPR success score remains to be zero since total sum of other variables’ score exceed the limit of 0.527. This result is understandable, because achieving success in the BPR application requires a considerable effort and commitment, until enough amount of this factors have been satisfied the BPR progress can not be initiated.

Possibility of a multicollinearity problem related with the independent variables in MLR model have to be investigated since some significantly high correlations have been found in the correlation table. According to information gathered from the literature in section *3.2.3.3*; *VIF* value of each coefficient should be smaller than $\frac{1}{1-R^2} = \frac{1}{1-0.975} = 40$. Since all *VIF* values are smaller than 4.094, no problem has been found related with multicollinearity. Since both the R^2 and adjusted R^2 values are way over 90%, multicollinearity doesn't pose a problem for this MLR model.

Since all the data used in the model have been standardized (pointed over 7-point Likert Scale), comparison of importances of the BPR success factors can be carried out according to standardized coefficients (β_i) in Table 53. Distribution of the factors affecting the success of BPR according to their importance has been schematized in Figure 39.

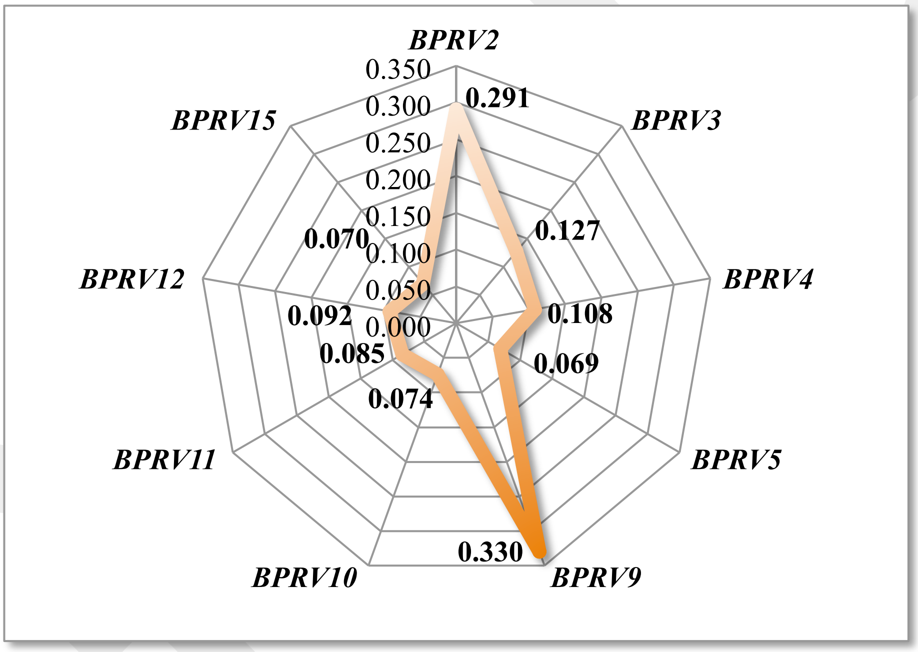


Figure 39: Distribution of BPR application success estimation factors according to their importance

Regression equation, related with the BPR application success MLR model, can be written as given below by using the unstandardized coefficients (B):

$$BP\hat{R}suc = \begin{matrix} -0.527 + 0.291BPRV2 + 0.127BPRV3 + 0.108BPRV4 + \\ 0.069BPRV5 + 0.330BPRV9 + 0.074BPRV10 + \\ 0.085BPRV11 + 0.092BPRV12 + 0.070BPRV15 \end{matrix} \quad (76)$$

BPR application success score can be computed by using the factor evaluation scores and the equation given above.

By finalizing the last regression model, second and third goals of the thesis have been completed by specifying all the relations between BPR, ERP, flexibility, and performance and by specifying all the factors related with each one of them.

As a result of all the analysis carried out in this chapter, relations between BPR, ERP, flexibility, and performance has been statistically proved. These interrelationships can be summarized as explained below:

- For an improved SC performance, flexible SC structure has to be obtained,
- To acquire SC flexibility, a successful ERP implementation is needed,
- For a successful ERP implementation, a successful BPR application is necessary together with some other prerequisites already specified,
- To successfully apply BPR to the company some factors have to be considered during the application phase,
- Successful ERP implementation and BPR application also have a direct effect on the SC performance.

Only one more goal left to be completed to reach the main objective of creating a road map for overall SC performance and flexibility measurement and improvement tracking. Last goal of the thesis is to determine the weights of BPR, ERP, and flexibility related with their effect on the SC performance.

CHAPTER 6

EVALUATING STRATEGIES TO INCREASE OVERALL SUPPLY CHAIN PERFORMANCE

Factors affecting SC performance have been specified in the previous chapter. Necessary models and analyses have been demonstrated to prove these effects. Strategies, which effect performance of the SC, are applying BPR, implementing ERP and improving SC flexibility. Calculation of each factors' success rate have been demonstrated in the related sections of the thesis. To reach the ultimate goal, which is creating a road map to evaluate and benchmark the overall SC performance, of the thesis one more analysis is required to specify the weights related with each factor according to their relation with overall SC performance, which is measured with SCOPS metric. This determination will be made with an ANP model. Previous ANP model used in the thesis has been used to determine the weights of KPIs for calculating SCOPS. In this chapter, by considering the effects of each factor's on each KPI and on each other, weights of the BPR, ERP and flexibility have been specified.

6.1 Brief Model of Factors Affecting Supply Chain Overall Performance

SCOPS is being measured by 11 KPIs as mentioned before according to equation (49). The list of these KPIs has been given in Appendix 1. Each KPI's weight has been determined with an ANP model. This model will be modified to compare the factors (BPR, ERP and flexibility) according to their effect on the SCOPS.

SC performance evaluation structure used in the thesis has been given in Figure 11. On this figure, each factor's effect on the SCOPS has been proved by statistical methods before, but their contribution amounts to the performance have not been determined. It was not possible to built a MLR model and define each factor as an independent variable because of their interrelationship, which will result in high correlation between the factors. This MLR model wouldn't give significant results. Purpose of the ANP model used here is to compare these factors together. As a result of this ANP model weights of each factor will be determined related with their effect on the SCOPS. These weights are necessary to calculate SCOPS for benchmark and/or strategic planning related comparisons needed to evaluate the performance gains acquired by BPR, ERP and flexibility.

ANP method has been selected because of its capability to consider the interdependencies between each factor in the criteria cluster and alternative cluster. Since proposed model's structure (which has interrelationships in both criteria and alternative clusters, so it is a network structure indeed) has such relationships, ANP was the best choice to evaluate the model.

6.2 ANP Model to Weight the Factors According to Their Contribution on the Supply Chain Performance

As mentioned before this model is the expanded form of the first ANP model used. So the criteria evaluation phase is the same with the first model. Steps related with the ANP model to evaluate strategies according to their effect on the SCOPS have been defined as below:

Step-1: Construction of the model.

Since this model is the expansion of the first ANP model (SCOPS development model), one more cluster has been added to the first structure. So the model consists of three clusters: goal, criteria and alternatives.

Goal is specified as calculating the SCOPS according to gains achieved by the investment strategy selected. So selection of the alternative with the highest importance from the aspect of performance is the main goal. Each pair-wise comparison has been made with this in mind.

Criteria cluster consists of KPIs same as the first model. Their evaluations have already been made according to their effects on the performance. After the addition of alternative new pair-wise comparisons are needed to evaluate each alternative under each criterion according to their effects on the KPI. Interdependencies of criteria cluster are also the same as the first model.

Last cluster is the alternative. As strategic alternatives that affect performance BPR, ERP, and flexibility are defined as the nodes of this cluster. Flexibility has been measured with SCOFS so flexibility will be regarded as SCOFS. Interdependencies in the alternative cluster have been determined by the statistical analysis carried out in the previous chapter.

Structure of the ANP model to evaluate BPR, ERP and SCOFS has been given in Figure 40.

As it can be seen from the network structure interdependencies of criteria are same as the first ANP model. Objective has been updated to selection of the best alternative and alternatives have been defined. As mentioned before interrelations between each alternative has been proved by the statistical analyses carried out. According to the results of these analyses;

- ERP affects the amount of flexibility achieved in the SC. So, ERP has an effect on SCOFS,
- BPR application affects the success of ERP implementation. So the efficiency and effectiveness of ERP system depends upon BPR application success.

Since all the relations have been defined by the statistical analyses explained in details in the previous chapter, as the results of real-life data used, no expert evaluations have been used to define these relations.

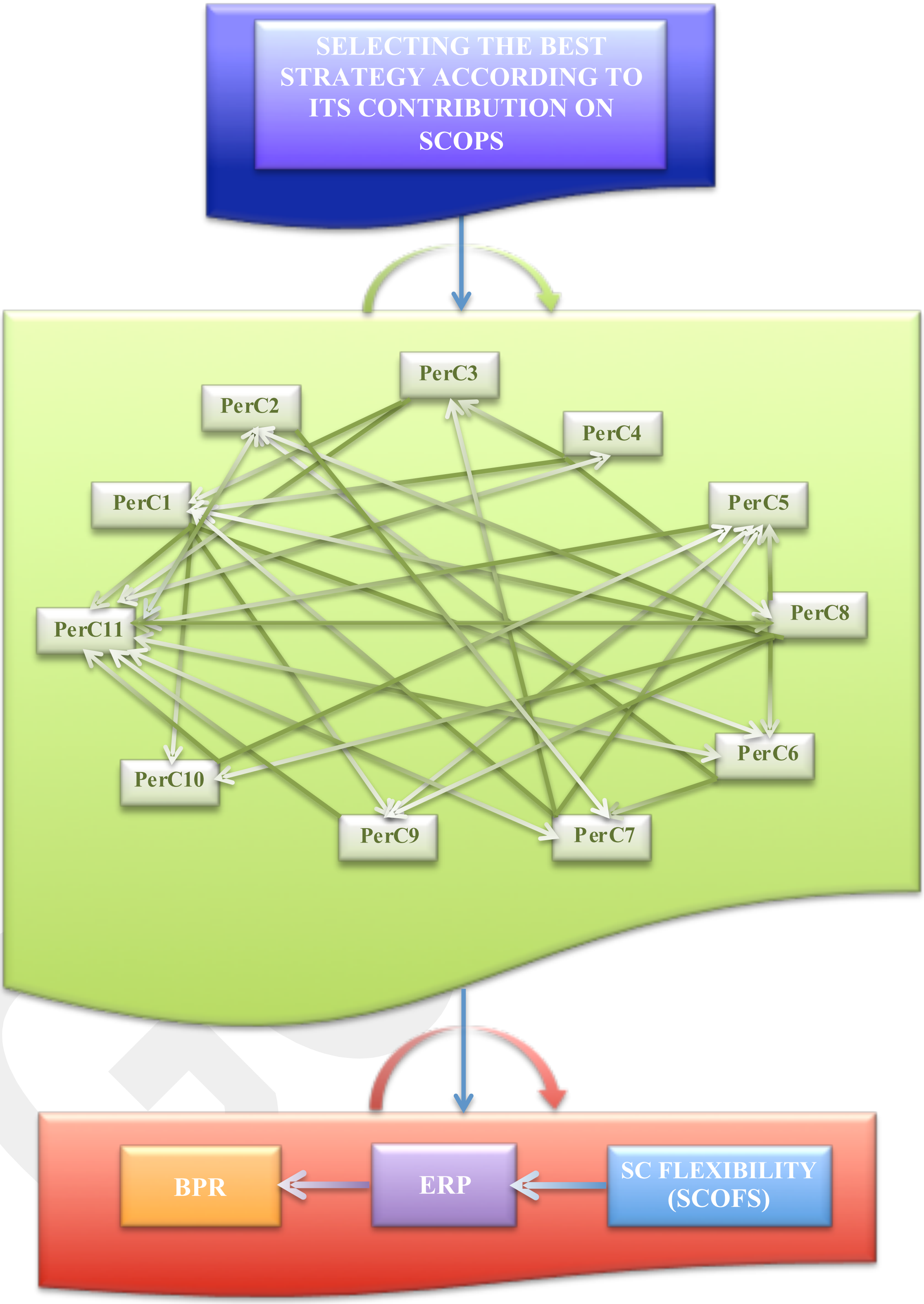


Figure 40: ANP network model structure to evaluate strategies according to their contribution on SCOPS

Step-2: Gathering of pair-wise comparisons from experts.

Pair-wise comparisons are necessary for the member nodes of each cluster in the model. Criteria related comparisons have been already made by the experts and the aggregated pair-wise comparison matrix has been given in Table 19.

Since this model also includes alternatives cluster, each alternative have to be compared against each other under each criteria. Same experts with manufacturing, service and academic backgrounds have made pair-wise comparisons of alternatives. Questionnaire used to gather these comparisons from DMs have been given in Appendix 14. Each comparison has been made according to Saaty's (1980) 9-point comparison scale given in Table 15 in section *3.2.2.1*. Results of gathered questionnaires formed a pair-wise comparison matrix in form of:

$$A_c^k = \left[{}_c a_{ij}^k \right] = \begin{bmatrix} 1 & {}_c a_{12}^k & \cdots & {}_c a_{1n}^k \\ 1/{}_c a_{12}^k & 1 & \cdots & {}_c a_{2n}^k \\ \vdots & \vdots & \ddots & \vdots \\ 1/{}_c a_{1n}^k & 1/{}_c a_{2n}^k & \cdots & 1 \end{bmatrix} \tag{77}$$

for a total of K DMs, n alternatives and C criteria; where ${}_c a_{ij}^k$ represents the importance of i^{th} alternative over j^{th} alternative under the c^{th} criteria for k^{th} DM.

As mentioned before, to determine the interdependencies between the nodes of alternative cluster, statistical methods have been used. Interdependency matrix for the alternatives used in the ANP model has been given in Table 54. Criteria interdependencies are same as the ones given in Appendix 15.

Table 54: Alternatives cluster strategy nodes interdependency matrix

	BPR	**ERP**	**SCOFS**
BPR	0	1	0
ERP	0	0	1
SCOFS	0	0	0

Step-3: Checking consistency ratios (CR) for each pair-wise comparison matrix created according to questionnaires filled by DMs.

After gathering the experts' evaluation questionnaires of alternatives, a consistency check is necessary. For this purpose, Equations (7), (8), and (9) have been used. RI value related with the consistency calculations was selected as 0.58 from Table 16; λ_{max}, CR and CI values have been calculated for each A_c^k $\left(k = 1,2,3;\ c = 1,2,...,11\right)$ where A_c^k is the pair-wise comparison matrix of alternatives according to the c^{th} criterion made by k^{th} DM. Manufacturing, service, and academic experts made first, second, and third group of comparisons respectively. Results of consistency ratio calculations can be summarized as in Table 18.

Table 55: Consistency results for ANP alternatives pair-wise comparison matrices

		PerC1	***PerC2***	***PerC3***	***PerC4***	***PerC5***	***PerC6***	***PerC7***	***PerC8***	***PerC9***	***PerC10***	***PerC11***
DM1	***λmax***	3.0092	3.0539	3.0000	3.0000	3.0183	3.0292	3.0183	3.0000	3.0000	3.0000	3.0000
	CI	0.0046	0.0270	0.0000	0.0000	0.0092	0.0146	0.0092	0.0000	0.0000	0.0000	0.0000
	CR	*0.0079*	*0.0465*	*0.0000*	*0.0000*	*0.0158*	*0.0252*	*0.0158*	*0.0000*	*0.0000*	*0.0000*	*0.0000*
DM2	***λmax***	3.0387	3.0539	3.0000	3.0387	3.0387	3.0055	3.0247	3.0387	3.0387	3.0387	3.0183
	CI	0.0194	0.0270	0.0000	0.0194	0.0194	0.0028	0.0123	0.0194	0.0194	0.0194	0.0092
	CR	*0.0334*	*0.0465*	*0.0000*	*0.0334*	*0.0334*	*0.0048*	*0.0213*	*0.0334*	*0.0334*	*0.0334*	*0.0158*
DM3	***λmax***	3.0183	3.0539	3.0000	3.0037	3.0000	3.0037	3.0539	3.0387	3.0092	3.0092	3.0142
	CI	0.0092	0.0270	0.0000	0.0018	0.0000	0.0018	0.0270	0.0194	0.0046	0.0046	0.0071
	CR	*0.0158*	*0.0465*	*0.0000*	*0.0032*	*0.0000*	*0.0032*	*0.0465*	*0.0334*	*0.0079*	*0.0079*	*0.0122*

Since all the CR values are smaller than 0.1; according to Saaty (1998) all pair-wise comparisons made by DMs are consistent.

Step-4: Form the aggregated pair-wise comparison matrix.

According to group MCDM logic, all DM judgments have to be combined before the ANP analysis to form an aggregated pair-wise comparison matrix (Pandey et.al., 2012). Geometric mean method has been used to acquire the aggregated comparison matrix (Guzzo et.al., 1995; Schrage. 1995). Geometric means of each DM for each A_c^k has been calculated for each KPI according to Equation (48).

Aggregated pair-wise comparison values for each KPI (A_c^G) of the alternatives cluster of ANP model has been given in Table 56.

Table 56: Aggregated pair-wise node comparisons matrix of alternatives cluster in ANP model

Alternatives		BPR	ERP	SCOFS
PerC1	**BPR**	1.00000	1.21644	1.38672
	ERP	0.82207	1.00000	1.44225
	SCOFS	0.72112	0.69336	1.00000
PerC2	**BPR**	1.00000	0.33333	2.00000
	ERP	3.00000	1.00000	3.00000
	SCOFS	0.50000	0.33333	1.00000
PerC3	**BPR**	1.00000	0.55032	1.25992
	ERP	1.81712	1.00000	2.28943
	SCOFS	0.79370	0.43679	1.00000
PerC4	**BPR**	1.00000	0.28114	0.87358
	ERP	3.55689	1.00000	3.55689
	SCOFS	1.14471	0.28114	1.00000
PerC5	**BPR**	1.00000	0.58480	1.10064
	ERP	1.70998	1.00000	2.62074
	SCOFS	0.90856	0.38157	1.00000
PerC6	**BPR**	1.00000	0.28114	1.25992
	ERP	3.55689	1.00000	4.64159
	SCOFS	0.79370	0.21544	1.00000
PerC7	**BPR**	1.00000	0.28114	1.00000
	ERP	3.55689	1.00000	2.88450
	SCOFS	1.00000	0.34668	1.00000
PerC8	**BPR**	1.00000	0.32183	1.00000
	ERP	3.10723	1.00000	3.10723
	SCOFS	1.00000	0.32183	1.00000
PerC9	**BPR**	1.00000	0.73681	1.25992
	ERP	1.35721	1.00000	2.28943
	SCOFS	0.79370	0.43679	1.00000
PerC10	**BPR**	1.00000	0.73681	1.25992
	ERP	1.35721	1.00000	2.28943
	SCOFS	0.79370	0.43679	1.00000
PerC11	**BPR**	1.00000	0.28114	1.25992
	ERP	3.55689	1.00000	3.47603
	SCOFS	0.79370	0.28768	1.00000

Consistency checks have also been made for the alternatives cluster's aggregated pair-wise comparison matrix (A_c^G). λ_{max}, *CI*, and *CR* values for (A_c^G) has been given in Table 57.

Table 57: Consistency results for aggregated ANP alternatives' pair-wise comparison matrix

	PerC1	*PerC2*	*PerC3*	*PerC4*	*PerC5*	*PerC6*	*PerC7*	*PerC8*	*PerC9*	*PerC10*	*PerC11*
λ_{max}	3.0061	3.0539	3.0000	3.0020	3.0122	3.0001	3.0049	3.0000	3.0095	3.0095	3.0072
CI	0.0031	0.0270	0.0000	0.0010	0.0061	0.0001	0.0024	0.0000	0.0047	0.0047	0.0036
CR	*0.0053*	*0.0465*	*0.0000*	*0.0018*	*0.0105*	*0.0001*	*0.0042*	*0.0000*	*0.0082*	*0.0082*	*0.0062*

As expected pair-wise comparison matrices of each alternative for each criterion have been found consistent.

After acquiring the aggregated pair-wise comparison matrix of alternatives cluster an AHP model have been solved to calculate the weights of each strategic alternative. This analysis has been carried out to compare its results with the findings of ANP model to see the effect of interdependencies between the KPIs and most importantly to emphasize the importance of interdependencies between the BPR, ERP and flexibility. According to results acquired from AHP model; weights have been calculated as given in Table 58:

Table 58: AHP weights and rankings of BPR, ERP and flexibility

Alternative	Weight	Rank
BPR	0.263636	2
ERP	0.525140	1
SCOFS	0.211224	3

Step-5: Solve the ANP model and establish supermatrix and limit matrix.

For the solution of the ANP model Super Decisions software version 2.2.3 has been used. Structure of the ANP model built in the Super Decisions has been given in Appendix 33.

Interdependencies in the alternatives node indicate a sink node in the cluster (a node without a connection emanating from it). BPR is a sink node in the ANP model as it can be seen in Figure 32. Problem with the sink nodes is that the large powers of the scaled supermatrix tend toward zero in the limit matrix calculation phase except of the values of the sink node. There are various algorithms for the calculation of the limit matrix to overcome this problem (Adams, 2011). Straight normalization algorithm has been chosen to calculate the limit matrix in the thesis among mentioned algorithms. Adams (2011) summarizes the sink formula (straight normalize) as given below:

- Group the nodes in two by deciding if they are sink nodes or not. So the scaled supermatrix will be divided in two pieces and it will be in the form given below (B: matrix that includes non sink nodes, A: matrix that connects the sink nodes to non sink nods):

$$\begin{bmatrix} B & 0 \\ A & 0 \end{bmatrix} \tag{78}$$

- Renormalize the columns of B,
- So the limit matrix will be calculated as given below:

$$\begin{bmatrix} limitB & 0 \\ A \times limitB & 0 \end{bmatrix} \tag{79}$$

Unweighted supermatrix, weighted supermatrix, and limit matrix related with the solution of the ANP model have been given in Appendix 34. Unweighted supermatrix includes all the values of pair-wise comparisons and the interdependencies acquired from the DMs related with the criteria and alternatives clusters. By the normalization of the unweighted supermatrix, weighted supermatrix has been computed. Calculated weighted supermatrix with stochastic columns has been raised to sufficient large power until it converges and attains unique weights. So the global weights can be acquired from the final limit matrix. Priorities associated with the solution have been given in Appendix 35.

Weights calculated for the strategies to improve SCOPS by solving the ANP model by using the Super Decisions software have been given in Table 59.

Table 59: ANP weights and rankings of SCOPS improvement strategies

Alternatives	Ideals	Normals	Raw	Ranking
BPR	1.000000	*0.482617*	0.328402	1
ERP	0.888163	*0.428643*	0.291675	2
SCOFS	0.183871	*0.088740*	0.060384	3

'Normals' column of the Table 59 shows the normalized weights of strategic performance alternatives acquired by the ANP model. Distribution of these weights has been given in Figure 41.

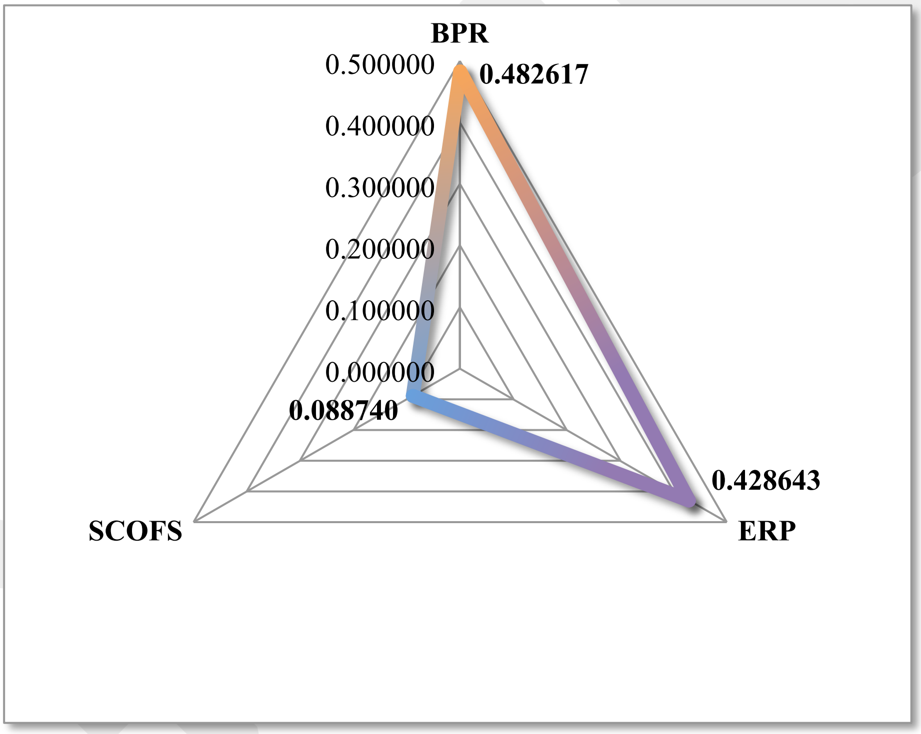


Figure 41: Distribution of the weights of BPR, ERP, and SCOFS

By using the weights calculated by ANP analysis, actual SCOPS metric, which considers the effects of BPR, ERP and flexibility, can be calculated as given below:

$$SCOPS = 0.482617 \times BPRsuc + 0.428643 \times ERPsuc + 0.088740 \times SCOFS \quad (80)$$

This equation can be used to evaluate the effects of the strategic performance improvement factors' effects on the overall performance. A road map to measure and benchmark SC performance has been given in the next final chapter of the thesis.

Results found by the solution of the ANP model emphasize the importance of interdependencies between BPR, ERP and flexibility. Ranking of these alternatives has been changed when compared to the AHP results. This comparison confirms the right choice of ANP method for the solution of the model.

According to findings, weight of the BPR has been increased drastically while the weight of flexibility decreased when compared with the AHP results. ERP's weight also decreased. Logically, even flexibility seems the best choice to improve performance; it shall be reminded that a satisfactory level of flexibility can only be achieved if it is supported by a successful implementation of ERP. And the success of ERP implementation is strongly depends upon the application success of BPR.

By the completion of the final analysis of the theses, all necessary proofs have been made related with the relations between performance, flexibility, ERP, and BPR. Also relations in the flexibility hierarchy, factors affecting each flexibility hierarchy, KPIs related with the performance measurement, factors affecting ERP implementation success, and factors affecting BPR application success have been determined one by one. Most importantly to new metrics have been developed to measure overall SC performance and overall SC flexibility; named as SCOPS and SCOFS respectively. By the use of SCOFS, question of "*How flexible is my Supply Chain?*" can be answered with quantitative calculations. By using the SCOPS measurement of the SC performance can be made which also makes a consistent benchmarking possible. ERP implementation success and BPR application success can be evaluated by using the corresponding factors and their weights. As a result of these measurements planning of the improvements in the current system can be made in addition to the pre-implementation/pre-application planning and organizing. Most importantly by using all the findings in the thesis together managers of the Supply Chains can evaluate their companies' current performance and evaluate different scenarios, consisting different combinations of improving flexibility, implementing an ERP system, and applying BPR, to plan their investments for the strategic performance improvement decisions. As it can be understood that the findings can be summed up to form a road map for the evaluation of SC performance and flexibility which may be used as a guide for the strategic planning efforts that aims the improvement of performance. Last chapter of the thesis combines the findings of all models used to form the mentioned road map with the necessary calculations.

CHAPTER 7

ROAD MAP TO EVALUATE SUPPLY CHAIN PERFORMANCE UNDER THE EFFECTS OF FLEXIBILITY, ERP AND BPR WITH SCOPS AND SCOFS METRICS

Main findings of the thesis can be used for many purposes such as:

- Evaluation of the base performance score of the SC,
- Evaluation of the flexibility score of the SC,
- Evaluation of the implementation success of ERP,
- Evaluation of the application success of BPR,
- Analysis of strategic investment options (ERP, BPR, and flexibility) according to improvements they cause on the SC performance.

Even though the first four purposes given above can be achieved independently; to achieve the last purpose, all previous purposes have to be achieved one by one. Because the last one is actually the ultimate purpose of attaining a road map to evaluate Supply Chain performance under the effects of flexibility, ERP and BPR with SCOPS and SCOFS metrics, which is the ultimate goal of the thesis.

Proposed steps to be followed can be schematized by modifying the framework scheme of the thesis, previously given in Figure 17, by excluding the analysis carried out only for proving the related relations between factors, has been given in Figure 42.

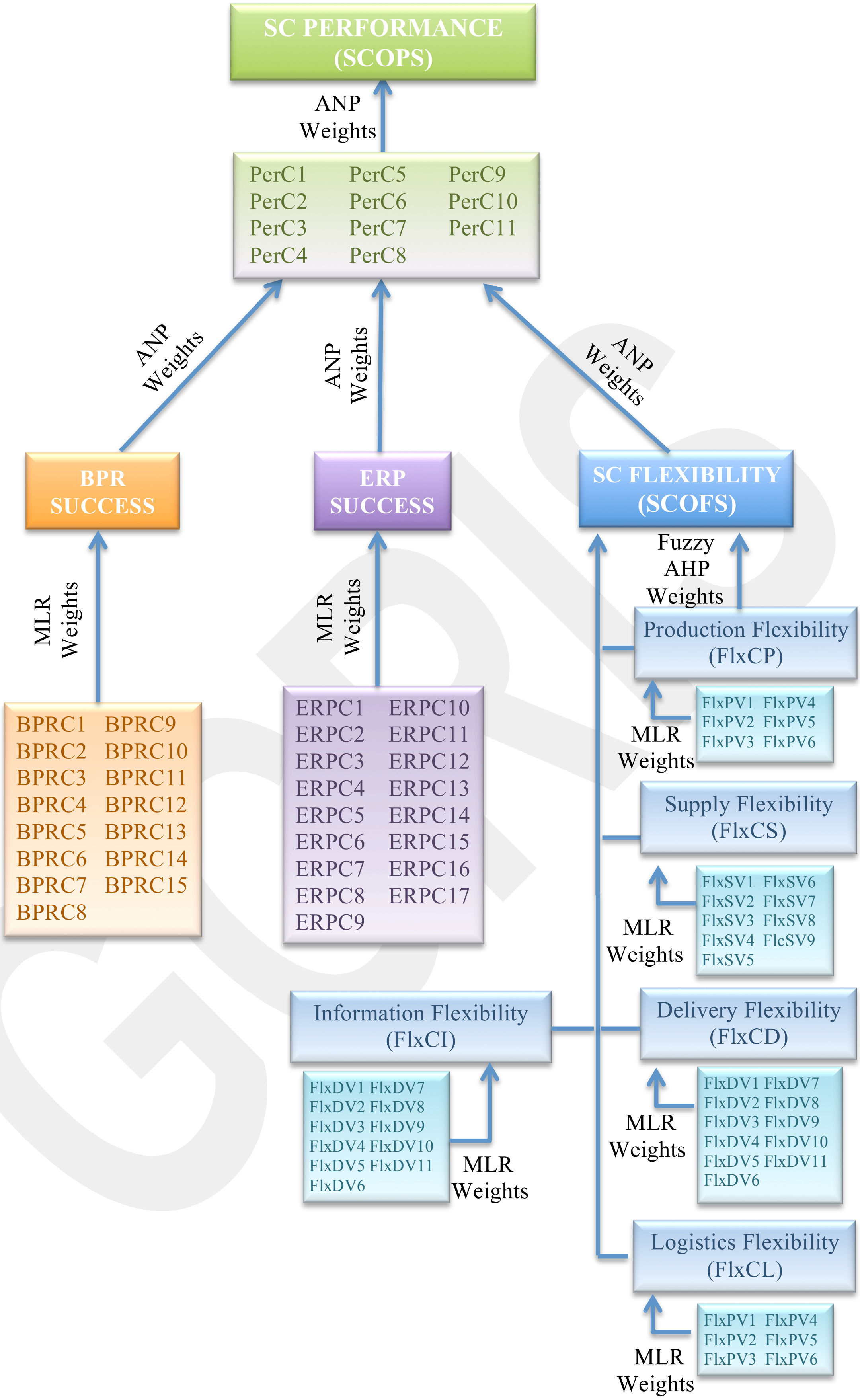


Figure 42: Algorithm proposed for the road map to evaluate performance improvement strategies

Road map designed here will render the detailed evaluation of SC performance evaluation possible by considering the effects of ERP, BPR and flexibility. Each step of the proposed road map can also be used for individual evaluations of the BPR success, ERP success or SC overall flexibility. Road map proposed in the thesis can be achieved by following four steps. These steps have been explained in details below.

Step-1: Evaluation of the base performance score of the SC (Calculate base SCOPS):

For the companies where there is no ERP system or BPR application exists and the flexibility is omitted, calculation of the SCOPS alone is enough to measure the SC performance, which is one of the contributions of the thesis. This can be achieved by the use of Equation (49). Each KPI, given in Appendix 1, has to be evaluated one by one and the value attained has to be multiplied by the given weights. Total will give the SCOPS of the company.

However, SCOPS calculation has been used in the proposed algorithm for determining the base performance score before making any improvements or before making any investments on either of the performance improvement strategies. This base score will be used for the comparisons of the effectiveness of the actions took place to improve the performance and evaluate the success of investments and efforts made for this purpose. So the base SCOPS is necessary for evaluation.

Step-2: Evaluation of the flexibility score of the SC (Calculate SCOFS):

This step can be used to evaluate the flexibility of the SC. For this evaluation SCOFS have to be calculated. SCOFS consists of two parts: factors affecting each level of flexibility hierarchy and the weights related with each level of flexibility hierarchy. So the equations related with each part have to be gathered together for the evaluation of SCOFS.

First of all, SC flexibility have to be evaluated by using the stated significant factors (specified in section *4.2.2*) that affects each level of flexibility hierarchy given in Appendices 5-10.

By using the MLR results, value of the dependent variable can be calculated (Schwarz and Hinz, 2001). Production flexibility have to be calculated by using Equation (51), supply flexibility have to be calculated by using Equation (53), delivery flexibility have to be calculated by using Equation (55), logistics flexibility have to be calculated by using Equation (57), and information flexibility have to be calculated by using Equation (59). After these calculations each score associated with the related flexibility level have to be multiplied by the weights associated with them determined by fuzzy AHP method to calculate the SCOFS, as given in Equation (62). All of these calculations have been gathered together to formulate the SCOFS equation as given below:

$$SCOFS = \begin{bmatrix} 0.2630 \times \begin{pmatrix} 0.302 + 0.214 \times FlxPV1 + 0.346 \times FlxPV3 + \\ 0.143 \times FlxPV4 + 0.160 \times FlxPV5 + \\ 0.142 \times FlxPV6 \end{pmatrix} + \\ 0.2764 \times \begin{pmatrix} 0.220 + 0.179 \times FlxSV1 + 0.250 \times FlxSV3 + \\ 0.126 \times FlxSV4 + 0.145 \times FlxSV5 + \\ 0.156 \times FlxSV6 + 0.152 \times FlxSV7 \end{pmatrix} + \\ 0.2334 \times \begin{pmatrix} 0.225 + 0.176 \times FlxDV1 + 0.176 \times FlxDV2 + \\ 0.179 \times FlxDV3 + 0.124 \times FlxDV4 + \\ 0.149 \times FlxDV5 + 0.239 \times FlxDV7 + \\ 0.174 \times FlxDV9 - 0.185 \times FlxDV10 \end{pmatrix} + \\ 0.1464 \times \begin{pmatrix} 0.409 + 0.176 \times FlxLV1 + 0.230 \times FlxLV2 + \\ 0.206 \times FlxLV3 + 0.164 \times FlxLV4 + \\ 0.194 \times FlxLV5 \end{pmatrix} + \\ 0.0808 \times \begin{pmatrix} 0.059 + 0.234 \times FlxIV1 + 0.240 \times FlxIV2 + \\ 0.135 \times FlxIV4 + 0.161 \times FlxIV5 + \\ 0.152 \times FlxIV6 + 0.169 \times FlxIV7 + 0.179 \times FlxIV11 \end{pmatrix} \end{bmatrix} \quad (81)$$

which has been calculated as:

$$
SCOFS=\left[\begin{array}{l}
\left(\begin{array}{l}0.07943+0.05628\times FlxPV1+0.09100\times FlxPV3+\\0.03761\times FlxPV4+0.04208\times FlxPV5+\\0.03735\times FlxPV6\end{array}\right)+\\
\left(\begin{array}{l}0.06081+0.04948\times FlxSV1+0.06910\times FlxSV3+\\0.03483\times FlxSV4+0.04008\times FlxSV5+\\0.04312\times FlxSV6+0.04201\times FlxSV7\end{array}\right)+\\
\left(\begin{array}{l}0.05252+0.04108\times FlxDV1+0.04108\times FlxDV2+\\0.04178\times FlxDV3+0.02894\times FlxDV4+\\0.03478\times FlxDV5+0.05578\times FlxDV7+\\0.04061\times FlxDV9-0.04318\times FlxDV10\end{array}\right)+\\
\left(\begin{array}{l}0.05988+0.02577\times FlxLV1+0.03367\times FlxLV2+\\0.03016\times FlxLV3+0.02401\times FlxLV4+\\0.02840\times FlxLV5\end{array}\right)+\\
\left(\begin{array}{l}0.00477+0.01891\times FlxIV1+0.01939\times FlxIV2+\\0.01091\times FlxIV4+0.01301\times FlxIV5+\\0.01228\times FlxIV6+0.01366\times FlxIV7+0.01446\times FlxIV11\end{array}\right)
\end{array}\right] \quad (82)
$$

Equation given above is the detailed calculation method of SCOFS metric. This metric can also be used individually to evaluate the flexibility of any SC. This was one of the main contributions of the thesis.

SCOFS calculated in this step will be used in the last step while calculating the SCOPS metric.

Step-3: Evaluation of the implementation success of ERP:

Managers of SCs may want to evaluate the implementation planning of ERP or they may need to evaluate the current implementation success of their ERP systems. For these purposes, significant (stated in section *5.2.3*) ERP implementation steps (given in Appendix 2) have to be evaluated by using Equation (70). As mentioned before, by using this equation ERP implementation success can be measured by calculating $ERPsuc$. This score will be used in the final step to calculate SCOPS.

Step-4: Evaluation of the application success of BPR:

Similar to previous step, BPR application success can be evaluated, either in planning phase to evaluate the BPR plans or after achieving the application phase, by the managers of companies. To do this, significant (stated in section *5.3.2*) factors that affect the BPR implementation (given in Appendix 3) have to be evaluated first according to Equation (76). Calculated BPR success score ($BPRsuc$) will be used in the final step in this algorithm for the creation of a road map to evaluate SC performance according to strategic performance improvement options.

Step-5: Calculation of SCOPS:

Since all the necessary elements have been gathered together, measurements and some pre calculations have been completed; overall SC performance score can be calculated. Calculation of SCOPS will be made by expanding the Equation (80) by combining it with Equations (70), (76), and (82).

There is another SCOPS formula to calculate the base performance score that has been developed in section *4.1.2*. This SCOPS metric has been used during the questionnaires to evaluate companies' performances and this evaluation values has been used in the statistical analysis. In the road map to evaluate strategic investment alternatives and for benchmarking purposes mentioned SCOPS calculation metric has been used to determine the base performance score of SC. Base score calculation formula doesn't include the effects of BPR, ERP and flexibility. It measures merely the performance according to given KPIs.

SCOPS formula that has been given in this step evaluates the SCOPS metric according to performance improvements (or decrements) caused by the BPR, ERP and flexibility. Development of this metric was one of the main goals of the thesis as mentioned before. Values calculated with any of the formula can be compared to measure the improvement in the SC performance or to plan the investments on the performance improvement factors.

SCOPS metric that has been developed as a result of the thesis can be calculated by the given equations:

$$SCOPS = \left[\begin{array}{l} 0.482617 \times \left(\begin{array}{l} -0.527 + 0.226 \times BPRV2 + 0.123 \times BPRV3 + \\ 0.108 \times BPRV4 + 0.073 \times BPRV5 + \\ 0.297 \times BPRV9 + 0.072 \times BPRV10 + \\ 0.079 \times BPRV11 + 0.085 \times BPRV12 + \\ 0.059 \times BPRV15 + \end{array} \right) + \\ 0.428643 \times \left(\begin{array}{l} -0.436 + 0.069 \times ERPV1 + 0.070 \times ERPV2 + \\ 0.109 \times ERPV3 + 0.133 \times ERPV4 + \\ 0.080 \times ERPV5 + 0.079 \times ERPV7 + \\ 0.084 \times ERPV9 + 0.072 \times ERPV10 + \\ 0.102 \times ERPV11 + 0.043 \times ERPV12 + \\ 0.075 \times ERPV13 + 0.029 \times ERPV14 + \\ 0.034 \times ERPV15 + 0.065 \times ERPV16 + \\ 0.104 \times ERPV17 \end{array} \right) + \\ 0.08874 \times \left(\begin{array}{l} 0.07943 + 0.05628 \times FlxPV1 + 0.09100 \times FlxPV3 + \\ 0.03761 \times FlxPV4 + 0.04208 \times FlxPV5 + \\ 0.03735 \times FlxPV6 \end{array} \right) + \\ 0.08874 \times \left(\begin{array}{l} 0.06081 + 0.04948 \times FlxSV1 + 0.06910 \times FlxSV3 + \\ 0.03483 \times FlxSV4 + 0.04008 \times FlxSV5 + \\ 0.04312 \times FlxSV6 + 0.04201 \times FlxSV7 \end{array} \right) + \\ 0.08874 \times \left(\begin{array}{l} 0.05252 + 0.04108 \times FlxDV1 + 0.04108 \times FlxDV2 + \\ 0.04178 \times FlxDV3 + 0.02894 \times FlxDV4 + \\ 0.03478 \times FlxDV5 + 0.05578 \times FlxDV7 + \\ 0.04061 \times FlxDV9 - 0.04318 \times FlxDV10 \end{array} \right) + \\ 0.08874 \times \left(\begin{array}{l} 0.05988 + 0.02577 \times FlxLV1 + 0.03367 \times FlxLV2 + \\ 0.03016 \times FlxLV3 + 0.02401 \times FlxLV4 + \\ 0.02840 \times FlxLV5 \end{array} \right) + \\ 0.08874 \times \left(\begin{array}{l} 0.00477 + 0.01891 \times FlxIV1 + 0.01939 \times FlxIV2 + \\ 0.01091 \times FlxIV4 + 0.01301 \times FlxIV5 + \\ 0.01228 \times FlxIV6 + 0.01366 \times FlxIV7 \\ +0.01446 \times FlxIV11 \end{array} \right) \end{array} \right] \quad (83)$$

By calculating the multiplications, SCOPS formula has been attained as given below:

$$SCOPS = \left[\begin{array}{l} \left(\begin{array}{l} -0.25434 + 0.10907 \times BPRV2 + 0.05936 \times BPRV3 + \\ 0.05212 \times BPRV4 + 0.03523 \times BPRV5 + \\ 0.14334 \times BPRV9 + 0.03475 \times BPRV10 + \\ 0.03813 \times BPRV11 + 0.04102 \times BPRV12 + \\ 0.02847 \times BPRV15 + \end{array} \right) + \\ \left(\begin{array}{l} -0.18689 + 0.02958 \times ERPV1 + 0.03001 \times ERPV2 + \\ 0.04672 \times ERPV3 + 0.05701 \times ERPV4 + \\ 0.03429 \times ERPV5 + 0.3386 \times ERPV7 + \\ 0.03601 \times ERPV9 + 0.03086 \times ERPV10 + \\ 0.04372 \times ERPV11 + 0.01843 \times ERPV12 + \\ 0.03215 \times ERPV13 + 0.01243 \times ERPV14 + \\ 0.01457 \times ERPV15 + 0.02786 \times ERPV16 + \\ 0.04458 \times ERPV17 \end{array} \right) + \\ \left(\begin{array}{l} 0.00705 + 0.00499 \times FlxPV1 + 0.00808 \times FlxPV3 + \\ 0.00334 \times FlxPV4 + 0.00373 \times FlxPV5 + \\ 0.00331 \times FlxPV6 \end{array} \right) + \\ \left(\begin{array}{l} 0.00540 + 0.00439 \times FlxSV1 + 0.00613 \times FlxSV3 + \\ 0.00309 \times FlxSV4 + 0.00356 \times FlxSV5 + \\ 0.00383 \times FlxSV6 + 0.00373 \times FlxSV7 \end{array} \right) + \\ \left(\begin{array}{l} 0.00466 + 0.00365 \times FlxDV1 + 0.00365 \times FlxDV2 + \\ 0.00371 \times FlxDV3 + 0.00257 \times FlxDV4 + \\ 0.00309 \times FlxDV5 + 0.00495 \times FlxDV7 + \\ 0.00360 \times FlxDV9 - 0.00383 \times FlxDV10 \end{array} \right) + \\ \left(\begin{array}{l} 0.00531 + 0.00229 \times FlxLV1 + 0.00299 \times FlxLV2 + \\ 0.00268 \times FlxLV3 + 0.00213 \times FlxLV4 + \\ 0.00252 \times FlxLV5 \end{array} \right) + \\ \left(\begin{array}{l} 0.00042 + 0.00168 \times FlxIV1 + 0.00172 \times FlxIV2 + \\ 0.00097 \times FlxIV4 + 0.00115 \times FlxIV5 + \\ 0.00109 \times FlxIV6 + 0.00121 \times FlxIV7 \\ + 0.00128 \times FlxIV11 \end{array} \right) \end{array} \right] \quad (84)$$

Step-6: Analysis of strategic investment options (ERP, BPR, and flexibility) according to improvements they cause on the SC performance:

After using the Equation (84) and calculating the SCOPS of the company it can be compared with the base score calculated in Step-1. Difference between the base score and the final SCOPS will give information about the improvement in the performance that can be achieved by the implementation of planned strategic investments.

By finalizing the demonstration of the developed metrics and the steps of the algorithm to calculate SCOPS and SCOFS together with the evaluation road map for investment strategies, studies carried out had been summarized.

This method can be used by the managers of companies who

- plans to invest on any (or any combination) of the strategic performance improvement alternatives (BPR, ERP, and flexibility) and wants to analyze the gains that will be achieved from the aspect of performance or
- already have any (or any combination) of the strategic performance improvement alternatives in their companies and wants to evaluate the current performance of the company.

Use of the proposed evaluation metrics could also create an opportunity for academic studies that focus on the measurement, improvement, and evaluation of SC performance and/or flexibility by providing a consistent metrics, which will facilitate the comparison, evaluation, and testing of the proposed methodology phases.

CONCLUSION

Continuously improving technology and changing customer needs forces the managers of enterprises to achieve satisfactory degrees of flexibility in the Supply Chain levels. Lack of flexibility results in loss of customers, which probably leads the companies' collapse. So, customer's growing expectations and their increasing standards, result in an increase in competition in both domestic and global markets. Managers of companies focus on the performance of their Supply Chain to keep their competitive advantage. As a result, Supply Chain Management gained a considerable amount of interest in the academic studies.

To keep the competitive advantage continuous improvements in the performance have to be achieved in the Supply Chain. But from another perspective flexibility have to be one of these performance-increasing strategies. Because performance can be increased in a various ways, but the lack of flexibility will obstruct the managers to receive the expected results in terms of performance improvement and its effects on the competitive advantage gains.

As there are many performance improvement strategies, there are also many performance indicators to evaluate Supply Chain performance. Most significant property of these indicators is their specialization on a very specific part of the Supply Chain to measure performance. To capture the big picture, several metrics have to be used together to evaluate overall Supply Chain performance. Yet this also is not enough. As stated before, performance improvement efforts have to include flexibility improvement studies along. Lack of continuous improvement in the flexibility would result in dissatisfaction from the performance achieved and creates a challenging situation for the company to compete their rivals in the challenging market environment.

Flexibility have to be considered during performance improvement investments to adapt changes in the market, technology, and customer needs. But this will result in a need of evaluation of flexibility. Improvements have to be benchmarked in terms of both flexibility and performance. Traditional performance indicators are not enough to evaluate the performance by considering the achievements acquired in flexibility. This results in a requirement of some evaluation metrics that can measure the overall Supply Chain performance and flexibility, which can be merged into a new scoring system that can evaluate flexibility and performance together by considering the necessary interdependencies. Development of mentioned metrics and their integration is the main focus of the thesis.

To measure Supply Chain's overall performance score and Supply Chain's overall flexibility score, two new metrics have been developed in the thesis, SCOPS and SCOFS respectively, as a result of series of hybrid MCDM and statistical methods used with the utilization of over 200 real-life data sets acquired with different questionnaire studies. First part of SCOPS metric evaluates the base Supply Chain performance by combining various performance indicators and findings of this score acts as a benchmarking base for the comparison and evaluation purposes. More detailed SCOPS calculation results in a Supply Chain performance measurement, which includes the effects of BPR application, ERP implementation, flexibility evaluations and includes both of their interrelated effects and their effects on the performance. SCOFS metric enables the managers of Supply Chains to evaluate the flexibility of the Supply Chain in all hierarchical levels. Score obtained by the use of SCOFS can be used for both evaluation of flexibility studies and benchmarking of flexibility as a result of improvement efforts. When SCOFS used together with SCOPS, ultimate Supply Chain performance evaluation can be achieved by considering the effects of flexibility, which is perfectly convenient for the present-day's competitive market conditions.

Studies carried out in the thesis are not limited with the development of overall performance and flexibility measurement metrics. This development effort was the beginning and prerequisite for the performance and flexibility improvement research. Before suggesting any strategies for better performing Supply Chain structures with higher levels of flexibility, first of all some scoring system was needed to prove the effects of the suggested strategies. SCOPS and SCOFS metrics have been used in the evaluation of the improvement strategies throughout the thesis. After enabling the necessary evaluations different investment strategies has been researched, in addition to flexibility, which can contribute to the flexibility and performance scores.

Enterprise Resource Planning is one of the strategic investment options, which has direct effect on the Supply Chain flexibility and performance. To attain flexibility, options provided by ERP systems are precious. ERP system changes the way Supply Chain works and brings automation procedures to increase the companies' agility. When successfully implemented, ERP systems increases the efficiency of time spent on many activities, reduces the mistake rates in the order and sales processes, coordinates the production effectively, improves the reaction times required by changes that occurs in the Supply Chain, directly effects the flexibility, and offers many more advantages. But implementing an ERP system is a risky investment alternative because of the possibility of implementation failure, which will result in loss of invested capital and maybe possibility of worsening of the operation of Supply Chain.

Main focus in the thesis related with the ERP systems is the achievement of implementation success. Before determining the factors needed for the implementation success some statistical analysis has been carried out to prove the effects of ERP systems existence has on the Supply Chain flexibility and performance. In all of these studies real-life data collected from Turkish enterprises have been used. After proving the improvements that an ERP system assures on the flexibility and performance, factors that affect the implementation success have been investigated. As a result of these studies main focus areas that needs an exhaustive consideration during the implementation phase have been determined as a result of analyses carried out in different Turkish enterprises with different sizes and from different sectors. Findings of these studies act both as a road map for increasing the success of implementation of an ERP system, and an evaluation tool of the implementation success of an existing ERP system.

During the literature surveys and the field studies carried out, Business Process Re-engineering came forward as a prerequisite of ERP implementation in addition to the factors that affect the implementation success. BPR changes the way of operations carried out in the companies and this feature makes it a perfect tool for adapting the recent conditions in the market for accommodating the continuous changes in the environment. It requires the companies to evade from traditional applications and outdated management strategies. By doing so, after BPR application, companies face with an avant-garde management and Supply Chain structure that is ready to adapt the requirements of up-to-date market conditions and customer expectations. BPR also has an effect on Supply Chain performance. So as the final performance improvement strategy BPR has been selected.

As similar to ERP implementation phase, BPR application is also a time consuming and dedication requiring phase. So it is an important decision to decide if BPR is really needed. Because of this, the promises of the BPR have to be proved. First studies aim to prove the effects of BPR have on the Supply Chain performance followed by studies for proving its effect on the ERP implementation success. Both of these studies have been carried out in Turkish enterprises to determine the real-life conditions in Turkey. Findings points out that BPR has statistically significant effects on both Supply Chain performance and ERP implementation success. These results emphasizes the importance of BPR more clearly since successful ERP implementation assures improvement of Supply Chain flexibility, which has a direct effect on the performance, the fact that BPR's impact on the Supply Chain performance is more than it seems. These interrelations covers the base of selection of the methodologies (such as ANP) used to solve the necessary models built in the thesis for development of the proposed metrics.

After proving the necessary relations between BPR, ERP, and performance next studies consist of investigating the factors necessary for a successful BPR application. Since BPR has been found in the center of all improvements, an extensive literature survey has been carried out to determine these factors. Turkish companies, which applied BPR has been used to collect data to test the factors that affects the success of BPR application in real-life. As a result of the analysis completed by the use of data collected, steps required for a successful BPR application have been determined and offered as a road map for the application phase.

As a result of studies carried out until here, necessity of a flexible Supply Chain for an improved performance and competitive advantage, a successful ERP implementation for achieving flexibility, and a successful BPR application for the implementation success of ERP have been revealed by the statistical analysis. Also as a result of different hybrid fuzzy AHP, ANP, and statistical approaches used, SCOPS and SCOFS metrics have been developed and used in the mentioned analyses. After achieving the main goals of the thesis, everything had been set to achieve the ultimate goal of proposing a road map to evaluate Supply Chain performance under the effects of flexibility, ERP and BPR by using the SCOPS and SCOFS metrics.

Following the completion of all the required analyses, findings of the MCDM models and statistical analyses results have been combined with an ANP model to create an evaluation and strategic decision making road map to measure the Supply Chain performance under some key performance indicators and the effects of flexibility, ERP, and BPR by considering all the interrelationships in the proposed model. By the use of the outputs acquired from this final model; BPR application success, ERP implementation success, overall Supply Chain flexibility, and overall Supply Chain performance can be measured and evaluated. The proposed road map can be used to evaluate performance improvement investments being planned and benchmark improvements achieved in the performance as a result of the strategic decisions made. Basically, this road map and the stated metrics are the main contribution of the thesis to the literature.

Novelty behind the contribution of the thesis is its methodology that utilizes a hybrid approach to develop the metrics, which brings performance and flexibility together. Both of the proposed metrics also include the factors necessary to evaluate each components success. Brief road maps for ERP implementation and BPR application successes has been integrated into the system. As a result of these combinations, a comprehensive measurement and evaluation system has been originated.

With the concern of real-life applicability in mind, the ease of evaluation in the companies and validity of real-life measurements' results have been determined as the main criteria to increase practicality. Each metric that forms the SCOPS and SCOFS has been tested for its real-life effects on the performance and flexibility with statistical methods with the data sets over 200. Overall performance and flexibility measurement metrics are consisting of factors that only have statistically significant effects. Same concern lies behind the proposed evaluation methods of the

BPR application and ERP implementation successes. So these success score measurement factors have been also tested with over 200 data acquired from Turkish companies before being used in the metrics proposed. In means of generalizability, all data have been acquired form different sized companies from different sectors and expert decisions have been acquired from people with different backgrounds.

When compared to the literature, instead of proposing overwhelmingly long list of metrics; practical, easy to evaluate and easy to measure metrics used in the proposed scoring system in the thesis. Advantage of this kind of framework is the increase in chances of getting ahead of its theoretical importance and finding an opportunity to be applied in real-life. Also the easily applicable and measurable structure of the proposed system hopefully will make it a preferable performance and flexibility evaluation tool in the literature for the academic studies in the future.

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APPENDIX 1: FULL LIST OF OVERALL PERFORMANCE MEASUREMENT CRITERIA

Performance KPIs have been defined as criteria according to formula $PerCi$ where $i = 1, 2, ..., 11$. List of these variables are as follows:

$PerC1$: Increased efficiency.

$PerC2$: Improved communication.

$PerC3$: Lower operating costs.

$PerC4$: Increased revenue.

$PerC5$: Reduced cycle times.

$PerC6$: Better collaboration.

$PerC7$: Higher profit margins.

$PerC8$: Higher customer satisfaction.

$PerC9$: Inbound logistics performance.

$PerC10$: Outbound logistics performance.

$PerC11$: Human Resource Management performance.

APPENDIX 2: FULL LIST OF ERP SUCCESS MEASUREMENT VARIABLES

Prerequisite of ERP success have been defined as variables according to formula $ERPVi$ where $i = 1,2,...,17$. List of these variables are as follows:

$ERPV1$: There is a fitment between the company's ERP strategy and the overall business strategy.

$ERPV2$: ERP implementation related key milestones have been well identified.

$ERPV3$: Management of the SC has been significantly involved in the ERP implementation phase.

$ERPV4$: The company has followed a clear and detailed BPR plan.

$ERPV5$: Business requirements such as competition can be named as the motive of the ERP implementation.

$ERPV6$: Software suppliers have provided satisfactory support and assistance.

$ERPV7$: Project team's efforts were satisfactory to implement the project.

$ERPV8$: The benefits of the ERP system have been clearly identified and communicated.

$ERPV9$: The company has required amount of financial resources for the implementation and long-term utilization of the ERP system.

$ERPV10$: The company has explicit and well-articulated procedures for system implementation, performance evaluation and utilization.

*ERPV*11 : Management of SC is ready for the chances that came with the ERP and BPR.

*ERPV*12 : Responsibility and job definitions of workers before and after BPR have been defined clearly.

*ERPV*13 : There was a partnership between the company and the ERP software provider for technologic cooperation and education.

*ERPV*14 : For the required education of the end-users necessary support has been given by external experts.

*ERPV*15 : The company has the sufficient experience to determine the required ERP implementation strategies.

*ERPV*16 : Majority of users have the sufficient skills to use the ERP software.

*ERPV*17 : ERP software has a user-friendly interface.

APPENDIX 3: FULL LIST OF BPR SUCCESS MEASUREMENT VARIABLES

Prerequisite of BPR success have been defined as variables according to formula $BPRVi$ where $i = 1,2,...,15$. List of these variables are as follows:

$BPRV1$: Extensive user involvement in design.

$BPRV2$: Strong support, commitment and sponsorship from senior management.

$BPRV3$: Realistic project expectations.

$BPRV4$: Extensive cross-functional memberships between project teams.

$BPRV5$: Clear vision of project goals.

$BPRV6$: Growth-oriented goal instead of cost-cutting.

$BPRV7$: Full-time participation of key members of the project.

$BPRV8$: Adequate budget for the project.

$BPRV9$: Adequate education and training conducted.

$BPRV10$: Communications with employees during the project.

$BPRV11$: Significant portion of CEO's time committed to project.

$BPRV12$: Senior executive responsible for the project.

$BPRV13$: Pilot application prior to full implementation.

*BPRV*14 : Following a detailed methodology.

*BPRV*15 : Performance Measurement before, during, and after the project.

APPENDIX 4: "BPR APPLICATION AND ERP IMPLEMENTATION SUCCESSES" QUESTIONNAIRE

T.C. ATILIM ÜNİVERSİTESİ, ENDÜSTRİ MÜHENDİSLİĞİ BÖLÜMÜ, MODES ERP, BPR DEĞERLENDİRME ANKETİ

Üniversitemiz doktora programı kapsamında yürütülmekte olan tez çalışması kapsamında hazırlanan bu anket ile gelişmiş bir tedarik zincirine sahip firmalarda ERP ve BPR uygulamalarının sistem performansı üzerindeki etkileri ve bu uygulamaların başarılarını etkileyen faktörler araştırılmaktadır. Ankete verilecek tüm cevaplar gizli tutulacaktır.

Bölüm-1: Genel Bilgiler
Bu bölümde şirketiniz ile ilgili genel bilgilere ilişkin sorular yer almaktadır.

S.1) Şirketinizin türü:
- [ ] Üretici
- [ ] Taşıma şirketi
- [ ] Depo/dağıtıcı firma
- [ ] Servis şirketi
- [ ] Diğer: ………………

S.2) Çalışan sayınız:
- [ ] 50'den az
- [ ] 50 – 100
- [ ] 101 – 250
- [ ] 251 – 500
- [ ] 501 – 1000
- [ ] 1000'den fazla

S.3) Faaliyet gösterdiğiniz alan:
- [ ] Otomotiv
- [ ] Bilgisayar/Elektronik
- [ ] Beyaz Eşya
- [ ] İnşaat
- [ ] İlaç
- [ ] Kimyasal
- [ ] Mobilya
- [ ] Tekstil
- [ ] Gıda
- [ ] Diğer: ………………

S.4) Son finansal yıldaki geliriniz:
- [ ] 10.000 TL'den az
- [ ] 10.000 – 50.000 TL
- [ ] 50.000 – 100.000 TL
- [ ] 100.000 – 250.000 TL
- [ ] 250.000 – 500.000 TL
- [ ] 500.000 – 1.000.000 TL
- [ ] 1.000.000 TL'den fazla

S.5) Firmanızda yüksek düzeyde bilgisayar entegrasyonu mevcuttur:

Kesinlikle Katılmıyorum *Kesinlikle Katılıyorum*

1…..2…..3…..4…..5…..6…..7

S.6) Firmanızda yeniden yapılanma çalışmalarına başvurdunuz mu?

[ ] Evet[ ] Hayır

S.7) Soru-6'ya cevabınız "evet" ise, bu uygulama sizce başarıyla sonuçlandı mı?

Kesinlikle Katılmıyorum *Kesinlikle Katılıyorum*

1…..2…..3…..4…..5…..6…..7

S.8) Firmanızda herhangi bir ERP yazılımı kullanmakta mısınız?

[ ] Evet (Belirtiniz: ....) [ ] Hayır

S.9) Soru-8'e cevabınız "evet" ise, bu yazılımı şirketinize başarıyla uyarlayabildiniz mi?

Kesinlikle Katılmıyorum *Kesinlikle Katılıyorum*

1…..2…..3…..4…..5…..6…..7

S.10) Soru-8'e cevabınız evet ise, lütfen firmanızın üzerinde son yıllarda çalışmış olduğu ERP projeleri ile ilgili aşağıdaki tabloyu doldurunuz:

				Proje sonucu		
Proje Tanımı	Tarihi	Maliyeti	Yazılım Firması	Zamanında gerçekleşti	Tahmin edilen bütçeye uydu	Proje beklentileri karşıladı
				[ ] Evet [ ] Hayır	[ ] Evet [ ] Hayır	[ ] Evet [ ] Hayır
				[ ] Evet [ ] Hayır	[ ] Evet [ ] Hayır	[ ] Evet [ ] Hayır

Bölüm-2: BPR Uygulama Bilgileri

S.11) Lütfen aşağıdaki tabloda yer alan, başarılı bir BPR uygulaması için gerekli olan firma karakteristiklerini değerlendiriniz (1:Geçersiz, ….. , 7:Tamamen geçerli).

Başarı Ön Koşulu	**Geçerlilik**
Tasarım aşamasında kapsamlı kullanıcı katılımı	
Güçlü üst yönetim desteği	
Proje beklentilerinin gerçekçiliği	
Proje takımları arasında kapsamlı fonksiyonlar arası işbirliği	
Projenin hedefi konusunda firmanın vizyonunu açıklığı	
Projenin maliyetleri azaltmak yerine büyümeyi amaçlaması	
Projede yer alan çalışanların tam zamanlı olması	

Proje bütçesinin yeterliliği	
Yeterli eğitimin verilmesi	
İşçiler ile proje sırasında iletişim	
Üst yöneticilerin kayda değer miktarda zaman ayırması	
Yönetimin proje başarısından sorumluluğu	
Projenin hayata geçirilmesi öncesinde pilot uygulama yapılması	
Detaylı bir yöntem izlenmesi	
Proje öncesinde ve sonrasında performans değerlendirmesi	
Diğer faktörler: ……………………………………………………………………… ……………………………………………………………………… ………………………………………………………………………	

Bölüm-3: ERP Yazılımı Uygulama Bilgileri

(Soru 8'e cevabınız "hayır" ise lütfen bu bölümü geçiniz)

Bu bölüm altında firmanızın uygulamaya çalıştığı ERP yazılımı/yazılımları ile ilgili tecrübelerine dair sorular yer almaktadır. Sorular, ERP yazılımlarının firmanız üzerindeki etkilerini ve başarısını araştırmaya yöneliktir.

S.12) Lütfen ERP sistemleri ile ilgili olarak firmanızın aşağıdaki tabloda verilen karakteristiklerini değerlendiriniz (1:Katılmıyorum, ….. , 7:Tamamen katılıyorum):

ERP Stratejileri, Entegrasyonu, Performans ve Örgütsel Öğrenme	**Görüşünüz**
Firmamızın ERP stratejisi genel stratejilerimizle uyuşmaktadır	
ERP uygulama çalışmaların kilometre taşları açıkça tanımlanmış ve planlanmıştır	
Üst yönetim ERP uygulama çalışmalarına belirgin bir biçimde katılım göstermiştir	
Firma açık bir değişim yönetimi planı hazırlamıştır	
ERP sistemi uygulamasının nedeni olarak rekabet gibi ticari gereklilikler gösterilebilir	
ERP yazılım firmaları yeterli destek ve katkıda bulunmuştur	
Projenin hayata geçirilmesi için çalışan takım gerekli gayreti göstermiştir	
ERP'nin faydaları açıkça konuşulmuş ve belirlenmiştir	
Firma sistemin kurulumu ve uzun vadede kullanımı için yeterli finansal kaynağa sahiptir	
Firma, sistem kurulumu, performans değerlendirmesi ve kullanımı için açık ve iyi planlanmış prosedürlere sahiptir	
Üst yönetim ERP ile gelen sistem yeniliğine ve BPR uygulamalarına açıktır	
Değişim öncesinde ve sonrasında çalışanların üstlendikleri roller açıkça tanımlanmıştır	

Firma ERP yazılım firmaları ile teknolojik birliktelik ve eğitim için ortaklığa gitmiştir	
Son kullanıcıların eğitimi için dışarıdan yardım alınmıştır	
Firmanın ERP stratejilerini belirlemek için yeterli tecrübesi bulunmaktadır	
Kullanıcıların büyük bir bölümü ERP yazılımını kullanmakta yeterli ustalıktadır	
Kullandığınız ERP yazılımı kullanıcı dostu bir ara yüze sahiptir	
ERP sisteminin başarıyla adapte edilebilmesi için BPR uygulamasına gidilmiştir	

S.13) Lütfen uyguladığınız ERP yazılımının firmanızın performansına sağladığı / sağlayacağı performans avantajlarını aşağıdaki tablo aracılığı ile değerlendiriniz (1:Çok Zayıf, ….. , 7:Çok Güçlü):

Performans Kriteri	**Görüşünüz**
Esneklikte artış	
Verimlilikte (etkenlikte) artış	
Sağlıklı iletişim	
Düşük işletme maliyetleri	
Gelir artışı	
Kısa çevrim zamanları	
Verimli işbirliği	
Yüksek kar marjı	
Müşteri memnuniyeti	
Tedarik lojistiği	
Dağıtım lojistiği	
İnsan kaynakları yönetimi	

Q.14)
Firmanızda başka yönetim yaklaşımları / modelleri / araçları kullanılmakta mı? Lütfen kullandıklarınızı işaretleyiniz:

[ ] Kurumsal Karne (Balanced Scorecard)
[ ] Süreç Yönetimi (Process Management)
[ ] Toplam Kalite Yönetimi (Total Quality Management)
[ ] Bilgi Yönetimi (Knowledge Management)
[ ] Entellektüel Sermaye Yönetimi (Intellectual Capital Management)
[ ] Diğer (lütfen belirtiniz): ___________________________

APPENDIX 5: FULL LIST OF OVERALL FLEXIBILITY MEASUREMENT VARIABLES

Flexibility hierarchy levels have been defined as criteria according to formula *FlxCX* where *X* : initial of flexibility level. List of these variables are as follows:

FlxCP : Production Flexibility.

FlxCS : Supply Flexibility.

FlxCD : Delivery Flexibility.

FlxCL : Logistics Flexibility.

FlxCI : Information Flexibility.

APPENDIX 6: FULL LIST OF PRODUCTION FLEXIBILITY MEASUREMENT VARIABLES

Questions to measure production level of flexibility hierarchy have been defined as variables according to formula $FlxPVi$ where $i = 1, 2, ..., 6$. List of these variables are as follows:

$FlxPV1$: We can quickly change our production volume.

$FlxPV2$: We can change our production volume with low cost.

$FlxPV3$: We can operate efficiently under different production volumes.

$FlxPV4$: We can produce extensive variety of products in our facility.

$FlxPV5$: Our production workers are capable of handling many types of duties.

$FlxPV6$: When needed, outsourcing demands can be satisfied under reasonable costs and time.

APPENDIX 7: FULL LIST OF SUPPLY FLEXIBILITY MEASUREMENT VARIABLES

Questions to measure supply level of flexibility hierarchy have been defined as variables according to formula $FlxSVi$ where $i = 1,2,...,9$. List of these variables are as follows:

$FlxSV1$: We have more than one supplier for our most purchased products.

$FlxSV2$: We can change one supplier with another with low cost.

$FlxSV3$: We can change one supplier with another within short time.

$FlxSV4$: We can change one supplier with another without an important compromise on the qualities of raw materials, spare parts and design.

$FlxSV5$: Our suppliers are ready to accommodate the changes we requested on the product variety, supply volume, etc.

$FlxSV6$: Our production efficiency and profitability won't be affected by the changes in production volume because of the supply problems.

$FlxSV7$: Our suppliers can adapt to different order quantities and delivery frequencies.

$FlxSV8$: Changes in the supply delivery schedules can be managed with cost and time effective manners.

$FlxSV9$: Changes in the delivery times of suppliers can be handled with low cost.

APPENDIX 8: FULL LIST OF DELIVERY FLEXIBILITY MEASUREMENT VARIABLES

Questions to measure delivery level of flexibility hierarchy have been defined as variables according to formula $FlxDVi$ where $i = 1,2,...,11$. List of these variables are as follows:

$FlxDV1$: We can adapt to the changes in the delivery times that are requested by the customers.

$FlxDV2$: We can adapt to the changes in the delivery locations that are requested by the customers.

$FlxDV3$: We can adapt to the changes in the delivery amounts that are requested by the customers.

$FlxDV4$: We can satisfy low volume orders from our customers.

$FlxDV5$: We can satisfy frequent delivery orders from our customers.

$FlxDV6$: We can satisfy variety of special requests of our customers about the deliveries.

$FlxDV7$: We can handle different delivery plans without any difficulty for different kinds of products.

$FlxDV8$: We can deliver one or more of our customer's order(s) by variety of channels.

$FlxDV9$: Changes in the order delivery schedules can be managed with cost and time effective manners.

$FlxDV10$: If there had been a delay in the order delivery, we can manage costs, which were caused because of the delay, effectively.

$FlxDV11$: Changes in the order volume and type can be managed with cost and time effective manners.

APPENDIX 9: FULL LIST OF LOGISTICS FLEXIBILITY MEASUREMENT VARIABLES

Questions to measure logistics level of flexibility hierarchy have been defined as variables according to formula $FlxLVi$ where $i = 1,2,...,5$. List of these variables are as follows:

$FlxLV1$: We have more than one distribution channel for different kind of products and services.

$FlxLV2$: If required by he competition we can change our physical distribution channels easily.

$FlxLV3$: We can change our distribution channels with the minimum amount of effect on logistics performance.

$FlxLV4$: Changes in logistics channels can be made with low cost.

$FlxLV5$: Changes in logistics channels can be made in a short time and agilely.

APPENDIX 10: FULL LIST OF INFORMATION FLEXIBILITY MEASUREMENT VARIABLES

Questions to measure information level of flexibility hierarchy have been defined as variables according to formula $FlxIVi$ where $i = 1,2,...,11$. List of these variables are as follows:

$FlxIV1$: We can share information with our major suppliers very quickly.

$FlxIV2$: By the use of Information Technologies (IT), automatic information sharing with the major suppliers is possible.

$FlxIV3$: Real-time information sharing is possible with our major suppliers.

$FlxIV4$: Our major suppliers are ready to share information with us to adapt the changes caused by our demands.

$FlxIV5$: To support the changing requirements, commonality and prevalence of Information Systems (IS) is adequate.

$FlxIV6$: Flow rate/speed of information throughout our Supply Chain is satisfactorily high.

$FlxIV7$: Required hardware and software changes by the IT systems can be done easily.

$FlxIV8$: Integration of third party applications to existing IS can be done with a high efficiency ratio.

$FlxIV9$: Managing the information requested can be done with low cost and short time.

*FlxIV*10 : IT application installations and maintenances can be done with low cost and in short time.

*FlxIV*11 : Under the need of changing environmental requirements, updates and upgrades of existing IT applications can be done with low cost and in short time.

APPENDIX 11: “SUPPLY CHAIN FLEXIBILITY” QUESTIONNAIRE

T.C. ATILIM ÜNİVERSİTESİ, ENDÜSTRİ MÜHENDİSLİĞİ BÖLÜMÜ, MODES TEDARİK ZİNCİRİ ESNEKLİK DEĞERLENDİRME ANKETİ

Üniversitemiz doktora programı kapsamında yürütülmekte olan tez çalışması kapsamında hazırlanan bu anket ile gelişmiş bir tedarik zincirine sahip firmalarda Esnekliğin sistem performansı üzerindeki etkileri ve bu uygulamaların başarılarını etkileyen faktörler araştırılmaktadır. Ankete verilecek tüm cevaplar gizli tutulacaktır.

Bölüm-1: Genel Bilgiler
Bu bölümde şirketiniz ile ilgili genel bilgilere ilişkin sorular yer almaktadır.

S.1) Şirketinizin türü:
- [ ] Üretici
- [ ] Taşıma şirketi
- [ ] Depo/dağıtıcı firma
- [ ] Servis şirketi
- [ ] Diğer: ………………

S.2) Çalışan sayınız:
- [ ] 50’den az
- [ ] 50 – 100
- [ ] 101 – 250
- [ ] 251 – 500
- [ ] 501 – 1000
- [ ] 1000’den fazla

S.3) Faaliyet gösterdiğiniz alan:
- [ ] Otomotiv
- [ ] Bilgisayar/Elektronik
- [ ] Beyaz Eşya
- [ ] İnşaat
- [ ] İlaç
- [ ] Kimyasal
- [ ] Mobilya
- [ ] Tekstil
- [ ] Gıda
- [ ] Diğer: ………………

S.4) Firmanızda yüksek düzeyde bilgisayar entegrasyonu mevcuttur:

Kesinlikle *Kesinlikle*
Katılmıyorum *Katılıyorum*
1…..2…..3…..4…..5…..6…..7

S.5) Firmanızda yeniden yapılanma çalışmalarına başvurdunuz mu?
[ ] Evet[ ] Hayır

S.6) Soru-'e cevabınız "evet" ise, bu uygulama sizce başarıyla sonuçlandı mı?

Kesinlikle *Kesinlikle*
Katılmıyorum *Katılıyorum*
1…..2…..3…..4…..5…..6…..7

S.7) Firmanızda herhangi bir ERP yazılımı kullanmakta mısınız?
[ ] Evet (Belirtiniz: ....) [ ] Hayır

S.8) Soru-7'ye cevabınız "evet" ise, bu yazılımı şirketinize başarıyla uyarlayabildiniz mi?

Kesinlikle *Kesinlikle*
Katılmıyorum *Katılıyorum*
1…..2…..3…..4…..5…..6…..7

Bölüm-2: Üretim Esnekliği

Lütfen aşağıdaki tabloda yer alan, esneklik kriterlerini firmanıza uygunluğu açısından değerlendiriniz (1:Geçersiz, ….. , 7:Tamamen geçerli).

Esneklik Kriteri	**Geçerlilik**
Üretim hacmini kısa süre içerisinde değiştirebiliriz	
Üretim hacmini düşük maliyetlerle değiştirebiliriz	
Değişik üretim miktarlarında verimli olarak çalışmamızı sürdürebiliriz	
Tesisimizde değişik çeşitlerde ürünler üretebiliriz	
Üretimde yer alan çalışanlar farklı türlerde işleri yapabilmeye hazırdırlar	
Gerekli olduğu durumlarda fason üretim uygun maliyet ve zamanda sağlanabilir	
Diğer faktörler:	

Bölüm-3: Tedarik Esnekliği

Lütfen aşağıdaki tabloda yer alan, esneklik kriterlerini firmanıza uygunluğu açısından değerlendiriniz (1:Geçersiz, ….. , 7:Tamamen geçerli).

Esneklik Kriteri	Geçerlilik
En çok satılan ürünlerimiz için birden fazla tedarikçimiz vardır	
Bir tedarikçiyi başkasıyla düşük maliyetlerle değiştirebiliriz	
Bir tedarikçiyi başkasıyla kısa sürede değiştirebiliriz	
Ürün hammadde/yedek parça ve tasarım kalitesinde önemli bir değişim olmadan tedarikçilerde değişim yapabiliriz	
Temel tedarikçilerimiz bizim isteklerimiz doğrultusundaki değişimlere (hacim, ürün çeşitliliği) açıktırlar	
Değişik üretim miktarlarında verimli ve karlı olarak üretimimizi sürdürebiliriz	
Tedarikçilerimiz değişik sipariş miktarlarını ve dağıtım sıklıklarına ayak uydurabilirler	
Dağıtım çizelgesindeki değişimler maliyet ve zaman etkin bir biçimde gerçekleştirilebilir	
Tedarikçilerin teslim zamanlarında yapılan değişikliler düşük maliyetle sağlanabilir	
Diğer faktörler:	

Bölüm-4: Dağıtım Esnekliği

Lütfen aşağıdaki tabloda yer alan, esneklik kriterlerini firmanıza uygunluğu açısından değerlendiriniz (1:Geçersiz, ….. , 7:Tamamen geçerli).

Esneklik Kriteri	Geçerlilik
Belli kullanıcı gereksinimleri altında değişen dağıtım zamanlarına uyum sağlayabiliriz	
Belli kullanıcı gereksinimleri altında değişen dağıtım lokasyonlarına uyum sağlayabiliriz	
Belli kullanıcı gereksinimleri altında değişen dağıtım miktarlarına uyum sağlayabiliriz	
Müşterilerden gelen düşük hacimli talepleri karşılayabiliriz	
Sık gelen müşteri taleplerini karşılayabiliriz	
Dağıtım için müşterilerden özel olarak gelen çeşitli talepleri karşılayabiliriz	
Değişik ürünler için değişik dağıtım planlarını sorunsuz yürütebiliriz	
Bir müşterinin bir ya da daha fazla siparişini değişik kanallardan karşılayabiliriz	
Teslim tarihlerindeki değişimleri maliyeti ve zamanı etkin kullanarak gerçekleştirebiliriz	
Taleplerinin geç karşılanması durumunda maliyetleri etkin bir biçimde yönetebiliriz	
Talep edilen ürün miktarı ve türündeki değişimleri maliyeti ve zamanı etkin kullanarak gerçekleştirebiliriz	

Diğer faktörler:	

Bölüm-5: Lojistik Esnekliği

Lütfen aşağıdaki tabloda yer alan, esneklik kriterlerini firmanıza uygunluğu açısından değerlendiriniz (1:Geçersiz, ….. , 7:Tamamen geçerli).

Esneklik Kriteri	Geçerlilik
Değişik ürün ve hizmetler için birden fazla dağıtım kanalımız bulunmaktadır	
Rekabetin gerektirdiği durumlarda kolayca fiziksel dağıtım kanallarımızı değiştirebiliriz	
Dağıtım kanallarımızı lojistik performansı üzerinde çok düşük negatif etkilerle değiştirebiliriz	
Lojistik kanallarındaki değişimler düşük maliyetle gerçekleştirilebilir	
Lojistik kanallarındaki değişimleri çok kısa sürede ve çevik bir biçimde gerçekleştirebiliriz	
Diğer faktörler:	

Bölüm-6: Bilgi (SPANNING/Information) Esnekliği

Lütfen aşağıdaki tabloda yer alan, esneklik kriterlerini firmanıza uygunluğu açısından değerlendiriniz (1:Geçersiz, ….. , 7:Tamamen geçerli).

Esneklik Kriteri	Geçerlilik
Temel tedarikçilerimizle çok kısa sürede bilgi alışverişi sağlayabiliriz	
Bilgi Teknolojileri (IT) kullanılarak temel tedarikçilerimizle otomatik paylaşım sağlanabilir	
Temel tedarikçilerimizle gerçek zamanlı bilgi paylaşımı sağlanabilmektedir	
Temel tedarikçilerimiz taleplerimiz nedeni ile ortaya çıkan değişimlere ayak uydurmak için bizimle bilgi paylaşmaya açıktırlar	
Değişen gereksinimleri desteklemek için Bilgi Sistemlerinin ortaklık ve yaygınlık derecesi yüksektir	
Tedarik zincirimizde bilginin akış hızı oldukça yüksektir	
Bilgi Teknolojileri (IT) sistemlerinin gerektirdiği donanım ve yazılım değişiklikleri kolayca gerçekleştirilebilir	
Mevcut Bilgi Sistemlerinin üçüncü parti (diğer) yazılımlar ile entegrasyonu yüksek verimlilikte sağlanabilmektedir	
Gerekli bilgilerin yönetimi düşük maliyet ve zamanlarda sağlanabilir	
Bilgi Teknolojileri (IT) uygulamalarının kurulumu ve bakımı düşük maliyet ve zamanlarda sağlanabilir	
Mevcut Bilgi Teknolojileri (IT) uygulamalarının değişen gereklilikler	

doğrultusunda güncellemeleri düşük maliyetlerle ve uygun zamanlarda sağlanabilir	
Diğer faktörler:	

Bölüm-7: Performans Değerlendirme

Lütfen temel rakiplerinizle firmanızı aşağıdaki performans metriklerine göre değerlendiriniz: (1:Çok Zayıf, ….. , 7:Çok Güçlü).

Performans Kriteri	**Geçerlilik**
Ortalama net karlılık	
Ortalama satış hacmi büyüme oranı	
Sipariş teslim süreleri (order lead-time)	
Müşterilerin sorularına geri dönüş zamanı	
Ürünlerin müşteri tarafından algılanan değeri	
Müşterilerin belli ihtiyaçlarını karşılamaya yönelik servis sistemlerinin seviyesi	

S.57) Firmanızın esnekliğini genel olarak (üretim, tedarik, dağıtım, lojistik, bilgi) değerlendiriniz:

Düşük *Yüksek*

1…..2…..3…..4…..5…..6…..7

S.58) Firmanızın üretim esnekliğini genel olarak değerlendiriniz:

Düşük *Yüksek*

1…..2…..3…..4…..5…..6…..7

S.59) Firmanızın tedarik esnekliğini genel olarak değerlendiriniz:

Düşük *Yüksek*

1…..2…..3…..4…..5…..6…..7

S.60) Firmanızın dağıtım esnekliğini genel olarak değerlendiriniz:

Düşük *Yüksek*

1…..2…..3…..4…..5…..6…..7

S.61) Firmanızın lojistik esnekliğini genel olarak değerlendiriniz:

Düşük *Yüksek*

1…..2…..3…..4…..5…..6…..7

S.62) Firmanızın bilgi esnekliğini genel olarak değerlendiriniz:

Düşük *Yüksek*

1…..2…..3…..4…..5…..6…..7

S.63) Firmanızın Tedarik Zincirinin performansını genel olarak değerlendiriniz:

Düşük *Yüksek*

1…..2…..3…..4…..5…..6…..7

Bölüm-8: Performans Avantajları

Esnek bir tedarik zinciri yapısı oluşturmanın firmanızın performansına sağladığı/sağlayacağı performans avantajları aşağıdaki tablo aracılığı ile değerlendiriniz (1:Çok Zayıf, ….. , 7:Çok Güçlü):

Performans Kriteri	Görüşünüz
Verimlilikte (etkenlikte) artış	
Sağlıklı iletişim	
Düşük işletme maliyetleri	
Gelir artışı	
Kısa çevrim zamanları	
Verimli işbirliği	
Yüksek kar marjı	
Müşteri memnuniyeti	
Tedarik lojistiği	
Dağıtım lojistiği	
İnsan kaynakları yönetimi	

S.75) Firmanızda herhangi bir yönetim yaklaşımı / modeli / aracı kullanılmakta mı? Lütfen kullandıklarınızı işaretleyiniz:

[ ] Kurumsal Karne (Balanced Scorecard)
[ ] Süreç Yönetimi (Process Management)
[ ] Toplam Kalite Yönetimi (Total Quality Management)
[ ] Bilgi Yönetimi (Knowledge Management)
[ ] Entellektüel Sermaye Yönetimi (Intellectual Capital Management)
[ ] Diğer (lütfen belirtiniz): ___________________________

APPENDIX 12: EXPERT EVALUATION QUESTIONNAIRES FOR SCOPS CALCULATION

According to their effects on *Overall Supply Chain Performance*, please compare two criteria according to their importance																		
Increased Efficiency	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Improved Communication**
Increased Efficiency	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Lower Operating Costs**
Increased Efficiency	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Increased Revenue**
Increased Efficiency	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Reduced Cycle Times**
Increased Efficiency	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Better Collaboration**
Increased Efficiency	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Higher Profit Margins**
Increased Efficiency	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Higher Customer Satisfaction**
Increased Efficiency	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Inbound Logistics Performance**

Increased Efficiency	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Outbound Logistics Performance**
Increased Efficiency	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Human Resource Management Performance**
Improved Communication	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Lower Operating Costs**
Improved Communication	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Increased Revenue**
Improved Communication	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Reduced Cycle Times**
Improved Communication	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Better Collaboration**
Improved Communication	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Higher Profit Margins**
Improved Communication	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Higher Customer Satisfaction**
Improved Communication	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Inbound Logistics Performance**
Improved Communication	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Outbound Logistics Performance**
Improved Communication	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Human Resource Management Performance**
Lower Operating Costs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Increased Revenue**

Lower Operating Costs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Reduced Cycle Times
Lower Operating Costs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Better Collaboration
Lower Operating Costs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Higher Profit Margins
Lower Operating Costs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Higher Customer Satisfaction
Lower Operating Costs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Inbound Logistics Performance
Lower Operating Costs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Outbound Logistics Performance
Lower Operating Costs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Human Resource Management Performance
Increased Revenue	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Reduced Cycle Times
Increased Revenue	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Better Collaboration
Increased Revenue	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Higher Profit Margins
Increased Revenue	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Higher Customer Satisfaction
Increased Revenue	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Inbound Logistics Performance
Increased Revenue	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Outbound Logistics Performance

Increased Revenue	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Human Resource Management Performance**
Reduced Cycle Times	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Better Collaboration**
Reduced Cycle Times	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Higher Profit Margins**
Reduced Cycle Times	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Higher Customer Satisfaction**
Reduced Cycle Times	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Inbound Logistics Performance**
Reduced Cycle Times	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Outbound Logistics Performance**
Reduced Cycle Times	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Human Resource Management Performance**
Better Collaboration	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Higher Profit Margins**
Better Collaboration	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Higher Customer Satisfaction**
Better Collaboration	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Inbound Logistics Performance**
Better Collaboration	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Outbound Logistics Performance**
Better Collaboration	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Human Resource Management Performance**

Higher Profit Margins	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Higher Customer Satisfaction**
Higher Profit Margins	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Inbound Logistics Performance**
Higher Profit Margins	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Outbound Logistics Performance**
Higher Profit Margins	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Human Resource Management Performance**
Higher Customer Satisfaction	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Inbound Logistics Performance**
Higher Customer Satisfaction	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Outbound Logistics Performance**
Higher Customer Satisfaction	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Human Resource Management Performance**
Inbound Logistics Performance	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Outbound Logistics Performance**
Inbound Logistics Performance	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Human Resource Management Performance**
Outbound Logistics Performance	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Human Resource Management Performance**

Please state that, if exists, the degree of effect that the criteria on the left-hand-side has on the criteria on the right-hand-side. Don't mark any values if there isn't any interrelationship exists.										
Increased Efficiency	1	2	3	4	5	6	7	8	9	**Improved Communication**
Increased Efficiency	1	2	3	4	5	6	7	8	9	**Lower Operating Costs**
Increased Efficiency	1	2	3	4	5	6	7	8	9	**Increased Revenue**
Increased Efficiency	1	2	3	4	5	6	7	8	9	**Reduced Cycle Times**
Increased Efficiency	1	2	3	4	5	6	7	8	9	**Better Collaboration**
Increased Efficiency	1	2	3	4	5	6	7	8	9	**Higher Profit Margins**
Increased Efficiency	1	2	3	4	5	6	7	8	9	**Higher Customer Satisfaction**
Increased Efficiency	1	2	3	4	5	6	7	8	9	**Inbound Logistics Performance**
Increased Efficiency	1	2	3	4	5	6	7	8	9	**Outbound Logistics Performance**
Increased Efficiency	1	2	3	4	5	6	7	8	9	**Human Resource Management Performance**
Improved Communication	1	2	3	4	5	6	7	8	9	**Increased Efficiency**
Improved Communication	1	2	3	4	5	6	7	8	9	**Lower Operating Costs**
Improved Communication	1	2	3	4	5	6	7	8	9	**Increased Revenue**
Improved Communication	1	2	3	4	5	6	7	8	9	**Reduced Cycle Times**
Improved Communication	1	2	3	4	5	6	7	8	9	**Better Collaboration**

Improved Communication	1	2	3	4	5	6	7	8	9	**Higher Profit Margins**
Improved Communication	1	2	3	4	5	6	7	8	9	**Higher Customer Satisfaction**
Improved Communication	1	2	3	4	5	6	7	8	9	**Inbound Logistics Performance**
Improved Communication	1	2	3	4	5	6	7	8	9	**Outbound Logistics Performance**
Improved Communication	1	2	3	4	5	6	7	8	9	**Human Resource Management Performance**
Lower Operating Costs	1	2	3	4	5	6	7	8	9	**Increased Efficiency**
Lower Operating Costs	1	2	3	4	5	6	7	8	9	**Improved Communication**
Lower Operating Costs	1	2	3	4	5	6	7	8	9	**Increased Revenue**
Lower Operating Costs	1	2	3	4	5	6	7	8	9	**Reduced Cycle Times**
Lower Operating Costs	1	2	3	4	5	6	7	8	9	**Better Collaboration**
Lower Operating Costs	1	2	3	4	5	6	7	8	9	**Higher Profit Margins**
Lower Operating Costs	1	2	3	4	5	6	7	8	9	**Higher Customer Satisfaction**
Lower Operating Costs	1	2	3	4	5	6	7	8	9	**Inbound Logistics Performance**
Lower Operating Costs	1	2	3	4	5	6	7	8	9	**Outbound Logistics Performance**
Lower Operating Costs	1	2	3	4	5	6	7	8	9	**Human Resource Management Performance**
Increased Revenue	1	2	3	4	5	6	7	8	9	**Increased Efficiency**

Increased Revenue	1	2	3	4	5	6	7	8	9	**Improved Communication**
Increased Revenue	1	2	3	4	5	6	7	8	9	**Lower Operating Costs**
Increased Revenue	1	2	3	4	5	6	7	8	9	**Reduced Cycle Times**
Increased Revenue	1	2	3	4	5	6	7	8	9	**Better Collaboration**
Increased Revenue	1	2	3	4	5	6	7	8	9	**Higher Profit Margins**
Increased Revenue	1	2	3	4	5	6	7	8	9	**Higher Customer Satisfaction**
Increased Revenue	1	2	3	4	5	6	7	8	9	**Inbound Logistics Performance**
Increased Revenue	1	2	3	4	5	6	7	8	9	**Outbound Logistics Performance**
Increased Revenue	1	2	3	4	5	6	7	8	9	**Human Resource Management Performance**
Reduced Cycle Times	1	2	3	4	5	6	7	8	9	**Increased Efficiency**
Reduced Cycle Times	1	2	3	4	5	6	7	8	9	**Improved Communication**
Reduced Cycle Times	1	2	3	4	5	6	7	8	9	**Lower Operating Costs**
Reduced Cycle Times	1	2	3	4	5	6	7	8	9	**Increased Revenue**
Reduced Cycle Times	1	2	3	4	5	6	7	8	9	**Better Collaboration**
Reduced Cycle Times	1	2	3	4	5	6	7	8	9	**Higher Profit Margins**
Reduced Cycle Times	1	2	3	4	5	6	7	8	9	**Higher Customer Satisfaction**

Reduced Cycle Times	1	2	3	4	5	6	7	8	9	Inbound Logistics Performance
Reduced Cycle Times	1	2	3	4	5	6	7	8	9	Outbound Logistics Performance
Reduced Cycle Times	1	2	3	4	5	6	7	8	9	Human Resource Management Performance
Better Collaboration	1	2	3	4	5	6	7	8	9	Increased Efficiency
Better Collaboration	1	2	3	4	5	6	7	8	9	Improved Communication
Better Collaboration	1	2	3	4	5	6	7	8	9	Lower Operating Costs
Better Collaboration	1	2	3	4	5	6	7	8	9	Increased Revenue
Better Collaboration	1	2	3	4	5	6	7	8	9	Reduced Cycle Times
Better Collaboration	1	2	3	4	5	6	7	8	9	Higher Profit Margins
Better Collaboration	1	2	3	4	5	6	7	8	9	Higher Customer Satisfaction
Better Collaboration	1	2	3	4	5	6	7	8	9	Inbound Logistics Performance
Better Collaboration	1	2	3	4	5	6	7	8	9	Outbound Logistics Performance
Better Collaboration	1	2	3	4	5	6	7	8	9	Human Resource Management Performance
Higher Profit Margins	1	2	3	4	5	6	7	8	9	Increased Efficiency
Higher Profit Margins	1	2	3	4	5	6	7	8	9	Improved Communication
Higher Profit Margins	1	2	3	4	5	6	7	8	9	Lower Operating Costs

Higher Profit Margins	1	2	3	4	5	6	7	8	9	**Increased Revenue**
Higher Profit Margins	1	2	3	4	5	6	7	8	9	**Reduced Cycle Times**
Higher Profit Margins	1	2	3	4	5	6	7	8	9	**Better Collaboration**
Higher Profit Margins	1	2	3	4	5	6	7	8	9	**Higher Customer Satisfaction**
Higher Profit Margins	1	2	3	4	5	6	7	8	9	**Inbound Logistics Performance**
Higher Profit Margins	1	2	3	4	5	6	7	8	9	**Outbound Logistics Performance**
Higher Profit Margins	1	2	3	4	5	6	7	8	9	**Human Resource Management Performance**
Higher Customer Satisfaction	1	2	3	4	5	6	7	8	9	**Increased Efficiency**
Higher Customer Satisfaction	1	2	3	4	5	6	7	8	9	**Improved Communication**
Higher Customer Satisfaction	1	2	3	4	5	6	7	8	9	**Lower Operating Costs**
Higher Customer Satisfaction	1	2	3	4	5	6	7	8	9	**Increased Revenue**
Higher Customer Satisfaction	1	2	3	4	5	6	7	8	9	**Reduced Cycle Times**
Higher Customer Satisfaction	1	2	3	4	5	6	7	8	9	**Better Collaboration**
Higher Customer Satisfaction	1	2	3	4	5	6	7	8	9	**Higher Profit Margins**
Higher Customer Satisfaction	1	2	3	4	5	6	7	8	9	**Inbound Logistics Performance**
Higher Customer Satisfaction	1	2	3	4	5	6	7	8	9	**Outbound Logistics Performance**

Higher Customer Satisfaction	1	2	3	4	5	6	7	8	9	**Human Resource Management Performance**
Inbound Logistics Performance	1	2	3	4	5	6	7	8	9	**Increased Efficiency**
Inbound Logistics Performance	1	2	3	4	5	6	7	8	9	**Improved Communication**
Inbound Logistics Performance	1	2	3	4	5	6	7	8	9	**Lower Operating Costs**
Inbound Logistics Performance	1	2	3	4	5	6	7	8	9	**Increased Revenue**
Inbound Logistics Performance	1	2	3	4	5	6	7	8	9	**Reduced Cycle Times**
Inbound Logistics Performance	1	2	3	4	5	6	7	8	9	**Better Collaboration**
Inbound Logistics Performance	1	2	3	4	5	6	7	8	9	**Higher Profit Margins**
Inbound Logistics Performance	1	2	3	4	5	6	7	8	9	**Higher Customer Satisfaction**
Inbound Logistics Performance	1	2	3	4	5	6	7	8	9	**Outbound Logistics Performance**
Inbound Logistics Performance	1	2	3	4	5	6	7	8	9	**Human Resource Management Performance**
Outbound Logistics Performance	1	2	3	4	5	6	7	8	9	**Increased Efficiency**
Outbound Logistics Performance	1	2	3	4	5	6	7	8	9	**Improved Communication**
Outbound Logistics Performance	1	2	3	4	5	6	7	8	9	**Lower Operating Costs**
Outbound Logistics Performance	1	2	3	4	5	6	7	8	9	**Increased Revenue**
Outbound Logistics Performance	1	2	3	4	5	6	7	8	9	**Reduced Cycle Times**

Outbound Logistics Performance	1	2	3	4	5	6	7	8	9	**Better Collaboration**
Outbound Logistics Performance	1	2	3	4	5	6	7	8	9	**Higher Profit Margins**
Outbound Logistics Performance	1	2	3	4	5	6	7	8	9	**Higher Customer Satisfaction**
Outbound Logistics Performance	1	2	3	4	5	6	7	8	9	**Inbound Logistics Performance**
Outbound Logistics Performance	1	2	3	4	5	6	7	8	9	**Human Resource Management Performance**
Human Resource Management Performance	1	2	3	4	5	6	7	8	9	**Increased Efficiency**
Human Resource Management Performance	1	2	3	4	5	6	7	8	9	**Improved Communication**
Human Resource Management Performance	1	2	3	4	5	6	7	8	9	**Lower Operating Costs**
Human Resource Management Performance	1	2	3	4	5	6	7	8	9	**Increased Revenue**
Human Resource Management Performance	1	2	3	4	5	6	7	8	9	**Reduced Cycle Times**
Human Resource Management Performance	1	2	3	4	5	6	7	8	9	**Better Collaboration**
Human Resource Management Performance	1	2	3	4	5	6	7	8	9	**Higher Profit Margins**
Human Resource Management Performance	1	2	3	4	5	6	7	8	9	**Higher Customer Satisfaction**
Human Resource Management Performance	1	2	3	4	5	6	7	8	9	**Inbound Logistics Performance**
Human Resource Management Performance	1	2	3	4	5	6	7	8	9	**Outbound Logistics Performance**

APPENDIX 13: EXPERT EVALUATION QUESTIONNAIRE FOR SCOFS CALCULATION

According to their effects on Overall Supply Chain Flexibility, please compare two criteria according to their importance.
(**EqP:** Equally Preferred, **Eq-MP:** Equally to Moderately Preferred, **MP:** Moderately Preferred, **M-SP:** Moderately to Strongly Preferred, **SP:** Strongly Preferred, **S-VSP:** Strongly to Very Strongly Preferred, **VSP:** Very Strongly Preferred, **VS-ExP:** Very Strongly to Extremely Preferred, **ExP:** Extremely Preferred)

Production Flexibility	**ExP**	**VS-ExP**	**VSP**	**S-VSP**	**SP**	**M-SP**	**MP**	**Eq-MP**	**EqP**	**Eq-MP**	**MP**	**M-SP**	**SP**	**S-VSP**	**VSP**	**VS-ExP**	**ExP**	**Supply Flexibility**
Production Flexibility	**ExP**	**VS-ExP**	**VSP**	**S-VSP**	**SP**	**M-SP**	**MP**	**Eq-MP**	**EqP**	**Eq-MP**	**MP**	**M-SP**	**SP**	**S-VSP**	**VSP**	**VS-ExP**	**ExP**	**Delivery Flexibility**
Production Flexibility	**ExP**	**VS-ExP**	**VSP**	**S-VSP**	**SP**	**M-SP**	**MP**	**Eq-MP**	**EqP**	**Eq-MP**	**MP**	**M-SP**	**SP**	**S-VSP**	**VSP**	**VS-ExP**	**ExP**	**Logistics Flexibility**
Production Flexibility	**ExP**	**VS-ExP**	**VSP**	**S-VSP**	**SP**	**M-SP**	**MP**	**Eq-MP**	**EqP**	**Eq-MP**	**MP**	**M-SP**	**SP**	**S-VSP**	**VSP**	**VS-ExP**	**ExP**	**Information Flexibility**
Supply Flexibility	**ExP**	**VS-ExP**	**VSP**	**S-VSP**	**SP**	**M-SP**	**MP**	**Eq-MP**	**EqP**	**Eq-MP**	**MP**	**M-SP**	**SP**	**S-VSP**	**VSP**	**VS-ExP**	**ExP**	**Delivery Flexibility**
Supply Flexibility	**ExP**	**VS-ExP**	**VSP**	**S-VSP**	**SP**	**M-SP**	**MP**	**Eq-MP**	**EqP**	**Eq-MP**	**MP**	**M-SP**	**SP**	**S-VSP**	**VSP**	**VS-ExP**	**ExP**	**Logistics Flexibility**
Supply Flexibility	**ExP**	**VS-ExP**	**VSP**	**S-VSP**	**SP**	**M-SP**	**MP**	**Eq-MP**	**EqP**	**Eq-MP**	**MP**	**M-SP**	**SP**	**S-VSP**	**VSP**	**VS-ExP**	**ExP**	**Information Flexibility**

Delivery Flexibility	**ExP**	**VS-ExP**	**VSP**	**S-VSP**	**SP**	**M-SP**	**MP**	**Eq-MP**	**EqP**	**Eq-MP**	**MP**	**M-SP**	**SP**	**S-VSP**	**VSP**	**VS-ExP**	**ExP**	**Logistics Flexibility**
Delivery Flexibility	**ExP**	**VS-ExP**	**VSP**	**S-VSP**	**SP**	**M-SP**	**MP**	**Eq-MP**	**EqP**	**Eq-MP**	**MP**	**M-SP**	**SP**	**S-VSP**	**VSP**	**VS-ExP**	**ExP**	**Information Flexibility**
Logistics Flexibility	**ExP**	**VS-ExP**	**VSP**	**S-VSP**	**SP**	**M-SP**	**MP**	**Eq-MP**	**EqP**	**Eq-MP**	**MP**	**M-SP**	**SP**	**S-VSP**	**VSP**	**VS-ExP**	**ExP**	**Information Flexibility**

APPENDIX 14: EXPERT EVALUATION QUESTIONNAIRE FOR SELECTING PERFORMANCE STRATEGY

According to their effects on "*Increased Efficiency*" performance metric, please compare two alternatives according to their importance																		
BPR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ERP
BPR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Flexibility (SCOFS)
ERP	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Flexibility (SCOFS)

According to their effects on "*Improved Communication*" performance metric, please compare two alternatives according to their importance																		
BPR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ERP
BPR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Flexibility (SCOFS)
ERP	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Flexibility (SCOFS)

According to their effects on "*Lower Operating Costs*" performance metric, please compare two alternatives according to their importance																		
BPR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**ERP**
BPR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Flexibility (SCOFS)**
ERP	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Flexibility (SCOFS)**

According to their effects on "*Increased Revenue*" performance metric, please compare two alternatives according to their importance																		
BPR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**ERP**
BPR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Flexibility (SCOFS)**
ERP	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Flexibility (SCOFS)**

According to their effects on "*Reduced Cycle Times*" performance metric, please compare two alternatives according to their importance																		
BPR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**ERP**
BPR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Flexibility (SCOFS)**
ERP	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Flexibility (SCOFS)**

According to their effects on "*Better Collaboration*" performance metric, please compare two alternatives according to their importance																		
BPR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**ERP**
BPR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Flexibility (SCOFS)**
ERP	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Flexibility (SCOFS)**

According to their effects on "*Higher Profit Margins*" performance metric, please compare two alternatives according to their importance																		
BPR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**ERP**
BPR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Flexibility (SCOFS)**
ERP	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Flexibility (SCOFS)**

According to their effects on "*Higher Customer Satisfaction*" performance metric, please compare two alternatives according to their importance																		
BPR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**ERP**
BPR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Flexibility (SCOFS)**
ERP	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Flexibility (SCOFS)**

According to their effects on "*Inbound Logistics Performance*" performance metric, please compare two alternatives according to their importance																		
BPR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**ERP**
BPR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Flexibility (SCOFS)**
ERP	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Flexibility (SCOFS)**

According to their effects on "*Outbound Logistics Performance*" performance metric, please compare two alternatives according to their importance																		
BPR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**ERP**
BPR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Flexibility (SCOFS)**
ERP	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Flexibility (SCOFS)**

According to their effects on "*Human Resource Management Performance*" performance metric, please compare two alternatives according to their importance																		
BPR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**ERP**
BPR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Flexibility (SCOFS)**
ERP	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Flexibility (SCOFS)**

APPENDIX 15: CRITERIA CLUSTER PERFORMANCE NODES INTERDEPENDENCY MATRIX

Table 60: Performance criteria's interdependencies

	PerC1	***PerC2***	***PerC3***	***PerC4***	***PerC5***	***PerC6***	***PerC7***	***PerC8***	***PerC9***	***PerC10***	***PerC11***
PerC1	0	0	2	3	0	0	3	2	0	0	0
PerC2	0	0	0	0	0	2	0	2	0	0	2
PerC3	0	0	0	2	0	0	2	0	0	0	0
PerC4	0	0	0	0	0	0	0	0	0	0	2
PerC5	0	0	0	0	0	0	2	3	0	0	0
PerC6	2	0	0	0	0	0	0	3	5	5	3
PerC7	0	2	0	0	0	2	0	0	0	0	3
PerC8	0	0	0	6	0	0	0	0	0	0	2
PerC9	2	0	0	0	4	0	0	4	0	0	0
PerC10	2	0	0	0	0	0	0	6	0	0	0
PerC11	2	3	2	2	2	2	2	5	3	3	0

APPENDIX 16: UNWEIGHTED/WEIGHTED SUPERMATRICES AND LIMIT MATRIX OF SCOPS ANP MODEL

Table 61: SCOPS ANP model unweighted and weighted supermatrix

		CRITERIA											GOAL
		PerC1	***PerC2***	***PerC3***	***PerC4***	***PerC5***	***PerC6***	***PerC7***	***PerC8***	***PerC9***	***PerC10***	***PerC11***	**SCOPS**
CRITERIA	***PerC1***	0.00000	0.00000	0.50000	0.23077	0.00000	0.00000	0.33333	0.08000	0.00000	0.00000	0.00000	0.15973
	PerC2	0.00000	0.00000	0.00000	0.00000	0.00000	0.33333	0.00000	0.08000	0.00000	0.00000	0.16667	0.04573
	PerC3	0.00000	0.00000	0.00000	0.15385	0.00000	0.00000	0.22222	0.00000	0.00000	0.00000	0.00000	0.18646
	PerC4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.16667	0.10618
	PerC5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.22222	0.12000	0.00000	0.00000	0.00000	0.14480
	PerC6	0.25000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.12000	0.62500	0.62500	0.25000	0.05678
	PerC7	0.00000	0.40000	0.00000	0.00000	0.00000	0.33333	0.00000	0.00000	0.00000	0.00000	0.25000	0.06920
	PerC8	0.00000	0.00000	0.00000	0.46154	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.16667	0.09842
	PerC9	0.25000	0.00000	0.00000	0.00000	0.66667	0.00000	0.00000	0.16000	0.00000	0.00000	0.00000	0.05266
	PerC10	0.25000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.24000	0.00000	0.00000	0.00000	0.05266
	PerC11	0.25000	0.60000	0.50000	0.15385	0.33333	0.33333	0.22222	0.20000	0.37500	0.37500	0.00000	0.02737
GOAL	**SCOPS**	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

Table 62: SCOPS ANP model limit matrix

		CRITERIA											GOAL
		PerC1	***PerC2***	***PerC3***	***PerC4***	***PerC5***	***PerC6***	***PerC7***	***PerC8***	***PerC9***	***PerC10***	***PerC11***	**SCOPS**
CRITERIA	***PerC1***	0.08401	0.08401	0.08401	0.08401	0.08401	0.08401	0.08401	0.08401	0.08401	0.08401	0.08401	0.08401
	PerC2	0.09556	0.09556	0.09556	0.09556	0.09556	0.09556	0.09556	0.09556	0.09556	0.09556	0.09556	0.09556
	PerC3	0.03959	0.03959	0.03959	0.03959	0.03959	0.03959	0.03959	0.03959	0.03959	0.03959	0.03959	0.03959
	PerC4	0.04128	0.04128	0.04128	0.04128	0.04128	0.04128	0.04128	0.04128	0.04128	0.04128	0.04128	0.04128
	PerC5	0.04048	0.04048	0.04048	0.04048	0.04048	0.04048	0.04048	0.04048	0.04048	0.04048	0.04048	0.04048
	PerC6	0.14836	0.14836	0.14836	0.14836	0.14836	0.14836	0.14836	0.14836	0.14836	0.14836	0.14836	0.14836
	PerC7	0.14959	0.14959	0.14959	0.14959	0.14959	0.14959	0.14959	0.14959	0.14959	0.14959	0.14959	0.14959
	PerC8	0.06033	0.06033	0.06033	0.06033	0.06033	0.06033	0.06033	0.06033	0.06033	0.06033	0.06033	0.06033
	PerC9	0.05764	0.05764	0.05764	0.05764	0.05764	0.05764	0.05764	0.05764	0.05764	0.05764	0.05764	0.05764
	PerC10	0.03548	0.03548	0.03548	0.03548	0.03548	0.03548	0.03548	0.03548	0.03548	0.03548	0.03548	0.03548
	PerC11	0.24767	0.24767	0.24767	0.24767	0.24767	0.24767	0.24767	0.24767	0.24767	0.24767	0.24767	0.24767
GOAL	**SCOPS**	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

APPENDIX 17: SPSS OUTPUTS FOR PRODUCTION FLEXIBILITY MLR MODEL

Table 63: Production flexibility regression model's variable correlations

		FlxCP	*FlxPV1*	*FlxPV2*	*FlxPV3*	*FlxPV4*	*FlxPV5*	*FlxPV6*
Pearson Correlation	*FlxCP*	1.000	.731	.635	.748	.645	.472	.651
	FlxPV1	.731	1.000	.727	.769	.567	.372	.578
	FlxPV2	.635	.727	1.000	.712	.536	.219	.501
	FlxPV3	.748	.769	.712	1.000	.553	.284	.575
	FlxPV4	.645	.567	.536	.553	1.000	.492	.587
	FlxPV5	.472	.372	.219	.284	.492	1.000	.453
	FlxPV6	.651	.578	.501	.575	.587	.453	1.000
Sig. (1-tailed)	*FlxCP*	.	.000	.000	.000	.000	.000	.000
	FlxPV1	.000	.	.000	.000	.000	.000	.000
	FlxPV2	.000	.000	.	.000	.000	.015	.000
	FlxPV3	.000	.000	.000	.	.000	.002	.000
	FlxPV4	.000	.000	.000	.000	.	.000	.000
	FlxPV5	.000	.000	.015	.002	.000	.	.000
	FlxPV6	.000	.000	.000	.000	.000	.000	.

Table 64: Production flexibility regression model's ANOVA results

Model[f]		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	175.054	1	175.054	122.268	.000[a]
	Residual	137.446	96	1.432		
	Total	312.500	97			
2	Regression	199.149	2	99.574	83.454	.000[b]
	Residual	113.351	95	1.193		
	Total	312.500	97			
3	Regression	208.880	3	69.627	63.162	.000[c]
	Residual	103.620	94	1.102		
	Total	312.500	97			
4	Regression	215.547	4	53.887	51.690	.000[d]
	Residual	96.953	93	1.043		
	Total	312.500	97			
5	Regression	219.579	5	43.916	43.481	.000[e]
	Residual	92.921	92	1.010		
	Total	312.500	97			

[a]. Predictors: (Constant), *FlxPV3*
[b]. Predictors: (Constant), *FlxPV3, FlxPV4*
[c]. Predictors: (Constant), *FlxPV3, FlxPV4, FlxPV1*
[d]. Predictors: (Constant), *FlxPV3, FlxPV4, FlxPV1, FlxPV6*
[e]. Predictors: (Constant), *FlxPV3, FlxPV4, FlxPV1, FlxPV6, FlxPV5*
[f]. Dependent Variable: *FlxCP*

Table 65: Production flexibility regression model's variable coefficients

Model[a]		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics
		B	Std. Error	Beta			VIF
1	(Constant)	1.359	.285		4.764	.000	
	FlxPV3	.723	.065	.748	11.057	.000	1.000
2	(Constant)	.741	.294		2.517	.014	
	FlxPV3	.545	.072	.564	7.612	.000	1.440
	FlxPV4	.297	.066	.333	4.494	.000	1.440
3	(Constant)	.681	.284		2.401	.018	
	FlxPV3	.364	.092	.377	3.956	.000	2.570
	FlxPV4	.245	.066	.275	3.713	.000	1.550
	FlxPV1	.277	.093	.286	2.971	.004	2.632
4	(Constant)	.615	.277		2.221	.029	
	FlxPV3	.322	.091	.333	3.535	.001	2.660
	FlxPV4	.185	.069	.207	2.694	.008	1.765
	FlxPV1	.236	.092	.244	2.568	.012	2.714
	FlxPV6	.172	.068	.197	2.529	.013	1.824
5	(Constant)	.302	.315		.961	.339	
	FlxPV3	.346	.090	.358	3.829	.000	2.709
	FlxPV4	.143	.071	.160	2.019	.046	1.937
	FlxPV1	.214	.091	.221	2.346	.021	2.755
	FlxPV6	.142	.069	.162	2.060	.042	1.919
	FlxPV5	.160	.080	.136	1.998	.049	1.424

[a]. Dependent Variable: *FlxCP*

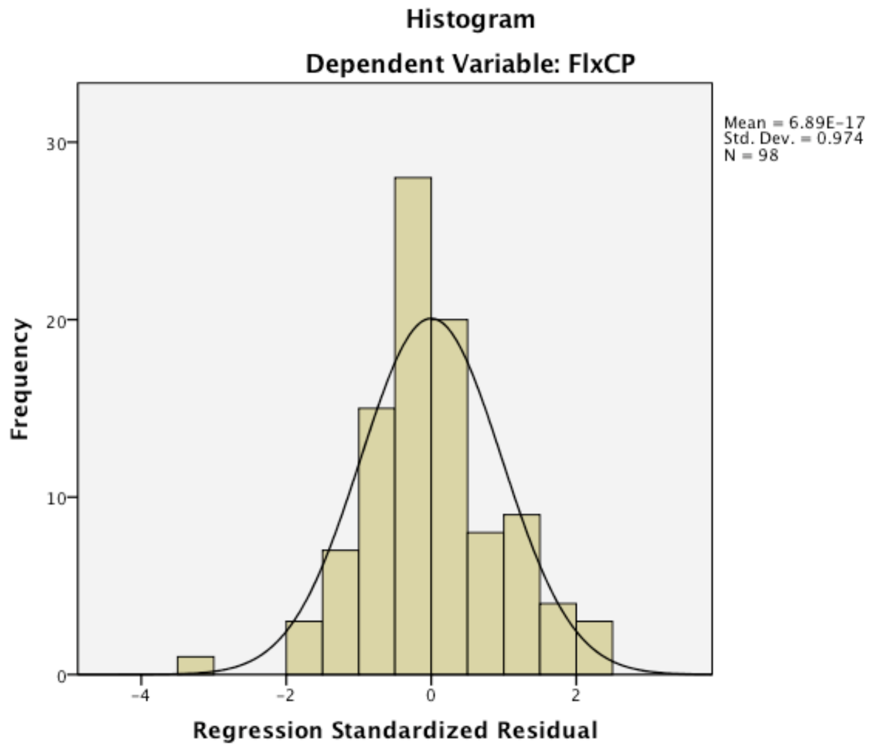

Figure 43: Production flexibility regression model's standardized residual histogram

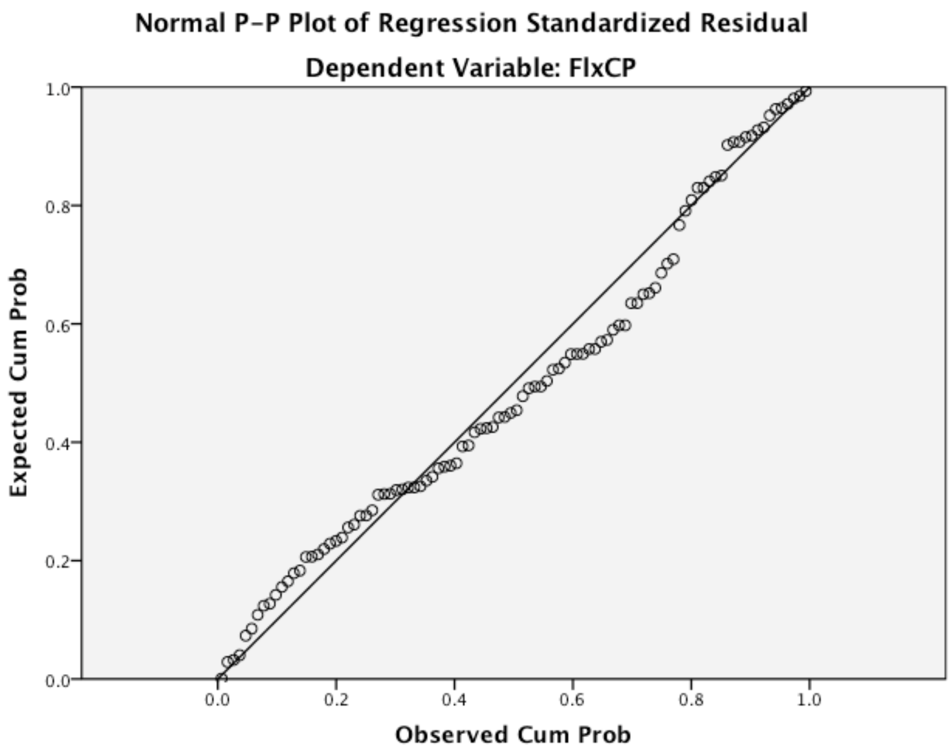

Figure 44: Production flexibility regression model's standardized residual normal p-p plot

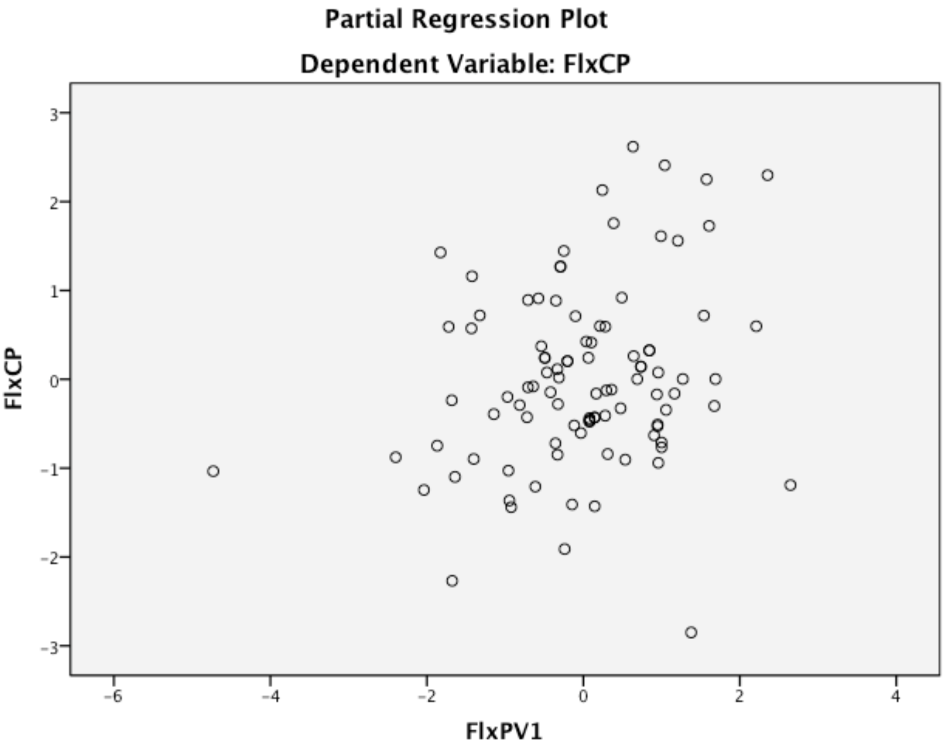

Figure 45: Partial plot of *FlxCP* and *FlxPV1*

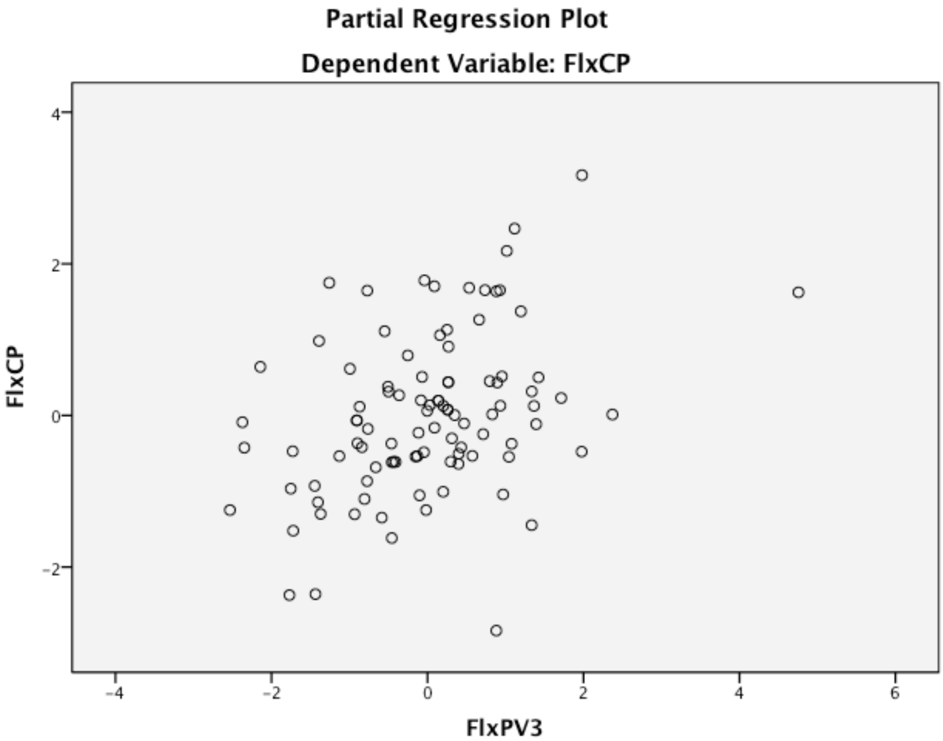

Figure 46: Partial plot of *FlxCP* and *FlxPV3*

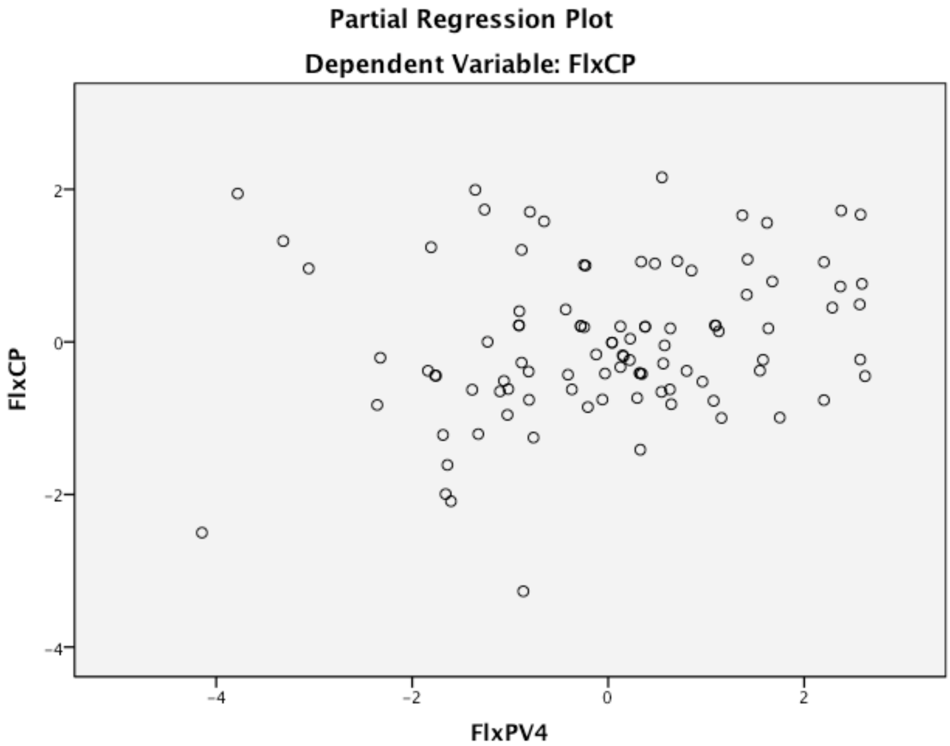

Figure 47: Partial plot of *FlxCP* and *FlxPV4*

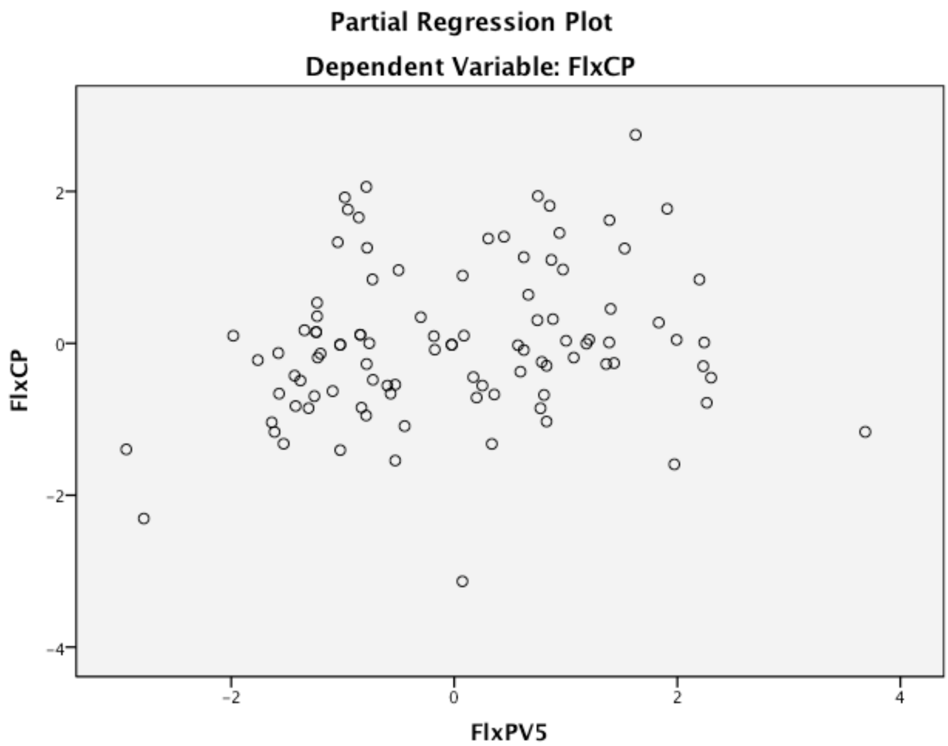

Figure 48: Partial plot of *FlxCP* and *FlxPV5*

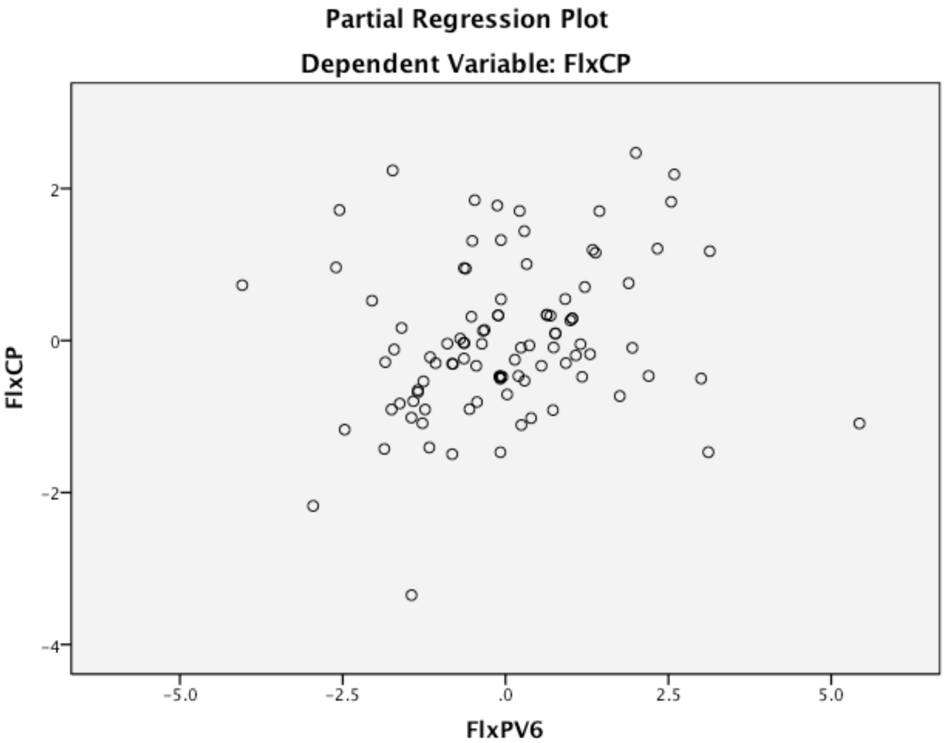

Figure 49: Partial plot of *FlxCP* and *FlxPV6*

APPENDIX 18: SPSS OUTPUTS FOR SUPPLY FLEXIBILITY MLR MODEL

Table 66: Supply flexibility regression model's variable correlations

		FlxCS	*FlxSV1*	*FlxSV2*	*FlxSV3*	*FlxSV4*	*FlxSV5*	*FlxSV6*	*FlxSV7*	*FlxSV8*	*FlxSV9*
Pearson Correlation	*FlxCS*	1.000	.807	.640	.802	.637	.769	.718	.790	.644	.500
	FlxSV1	.807	1.000	.693	.730	.584	.708	.701	.760	.625	.491
	FlxSV2	.640	.693	1.000	.588	.588	.684	.579	.731	.514	.478
	FlxSV3	.802	.730	.588	1.000	.493	.712	.595	.706	.543	.531
	FlxSV4	.637	.584	.588	.493	1.000	.497	.551	.567	.530	.397
	FlxSV5	.769	.708	.684	.712	.497	1.000	.602	.753	.608	.546
	FlxSV6	.718	.701	.579	.595	.551	.602	1.000	.623	.864	.609
	FlxSV7	.790	.760	.731	.706	.567	.753	.623	1.000	.542	.457
	FlxSV8	.644	.625	.514	.543	.530	.608	.864	.542	1.000	.689
	FlxSV9	.500	.491	.478	.531	.397	.546	.609	.457	.689	1.000
Sig. (1-tailed)	*FlxCS*	.	.000	.000	.000	.000	.000	.000	.000	.000	.000
	FlxSV1	.000	.	.000	.000	.000	.000	.000	.000	.000	.000
	FlxSV2	.000	.000	.	.000	.000	.000	.000	.000	.000	.000
	FlxSV3	.000	.000	.000	.	.000	.000	.000	.000	.000	.000
	FlxSV4	.000	.000	.000	.000	.	.000	.000	.000	.000	.000
	FlxSV5	.000	.000	.000	.000	.000	.	.000	.000	.000	.000
	FlxSV6	.000	.000	.000	.000	.000	.000	.	.000	.000	.000
	FlxSV7	.000	.000	.000	.000	.000	.000	.000	.	.000	.000
	FlxSV8	.000	.000	.000	.000	.000	.000	.000	.000	.	.000
	FlxSV9	.000	.000	.000	.000	.000	.000	.000	.000	.000	.

Table 67: Supply flexibility regression model's ANOVA results

Model[g]		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	196.406	1	196.406	179.812	.000[a]
	Residual	104.859	96	1.092		
	Total	301.265	97			
2	Regression	225.560	2	112.780	141.523	.000[b]
	Residual	75.705	95	.797		
	Total	301.265	97			
3	Regression	234.960	3	78.320	111.033	.000[c]
	Residual	66.305	94	.705		
	Total	301.265	97			
4	Regression	240.726	4	60.181	92.450	.000[d]
	Residual	60.540	93	.651		
	Total	301.265	97			
5	Regression	244.248	5	48.850	78.822	.000[e]
	Residual	57.017	92	.620		
	Total	301.265	97			
6	Regression	246.834	6	41.139	68.777	.000[f]
	Residual	54.432	91	.598		
	Total	301.265	97			

[a]. Predictors: (Constant), *FlxSV1*
[b]. Predictors: (Constant), *FlxSV1, FlxSV3*
[c]. Predictors: (Constant), *FlxSV1, FlxSV3, FlxSV7*
[d]. Predictors: (Constant), *FlxSV1, FlxSV3, FlxSV7, FlxSV6*
[e]. Predictors: (Constant), *FlxSV1, FlxSV3, FlxSV7, FlxSV6, FlxSV4*
[f]. Predictors: (Constant), *FlxSV1, FlxSV3, FlxSV7, FlxSV6, FlxSV4, FlxSV5*
[g]. Dependent Variable: *FlxCS*

Table 68: Supply flexibility regression model's variable coefficients

Model[a]		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics
		B	Std. Error	Beta			VIF
1	(Constant)	1.156	.263		4.394	.000	
	FlxSV1	.836	.062	.807	13.409	.000	1.000
2	(Constant)	.790	.233		3.394	.001	
	FlxSV1	.491	.078	.475	6.306	.000	2.143
	FlxSV3	.391	.065	.455	6.048	.000	2.143
3	(Constant)	.602	.225		2.675	.009	
	FlxSV1	.335	.085	.324	3.947	.000	2.874
	FlxSV3	.311	.065	.362	4.801	.000	2.424
	FlxSV7	.271	.074	.289	3.651	.000	2.675
4	(Constant)	.380	.229		1.665	.099	
	FlxSV1	.235	.088	.227	2.669	.009	3.360
	FlxSV3	.290	.063	.337	4.632	.000	2.455
	FlxSV7	.239	.072	.255	3.322	.001	2.734
	FlxSV6	.204	.069	.199	2.976	.004	2.071
5	(Constant)	.282	.227		1.243	.217	
	FlxSV1	.203	.087	.196	2.326	.022	3.445
	FlxSV3	.287	.061	.334	4.699	.000	2.456
	FlxSV7	.209	.072	.223	2.919	.004	2.826
	FlxSV6	.171	.068	.166	2.495	.014	2.162
	FlxSV4	.127	.053	.140	2.384	.019	1.681
6	(Constant)	.220	.225		.981	.329	
	FlxSV1	.179	.086	.173	2.079	.040	3.503
	FlxSV3	.250	.063	.291	4.003	.000	2.668
	FlxSV7	.152	.075	.162	2.009	.048	3.259
	FlxSV6	.156	.068	.152	2.303	.024	2.187
	FlxSV4	.126	.052	.139	2.410	.018	1.681
	FlxSV5	.145	.070	.156	2.079	.040	2.848

[a]. Dependent Variable: *FlxCS*

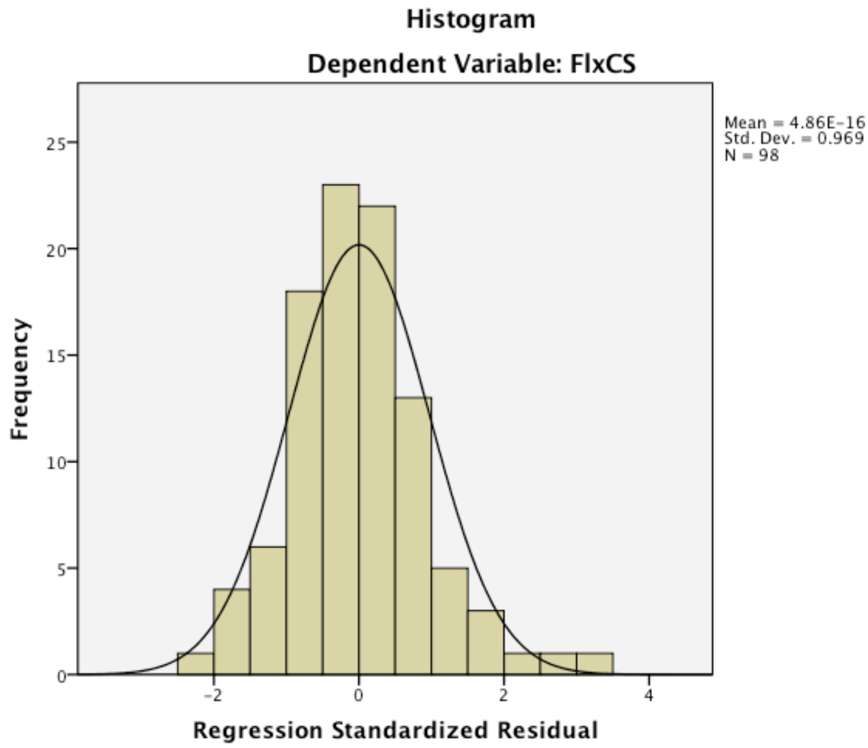

Figure 50: Supply flexibility regression model's standardized residual histogram

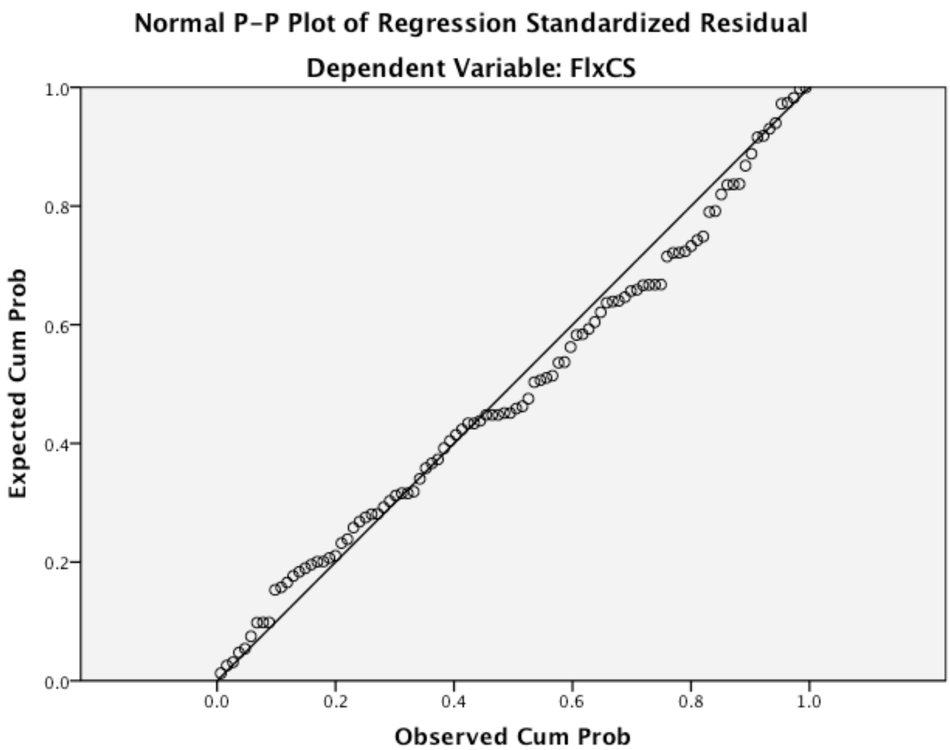

Figure 51: Supply flexibility regression model's standardized residual normal p-p plot

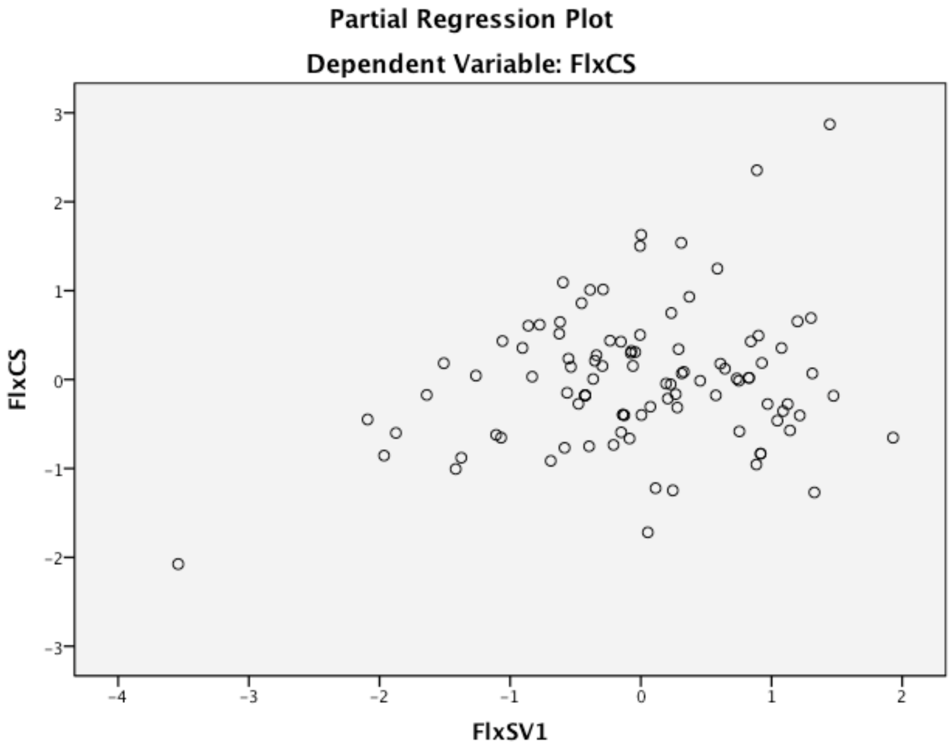

Figure 52: Partial plot of *FlxCS* and *FlxSV1*

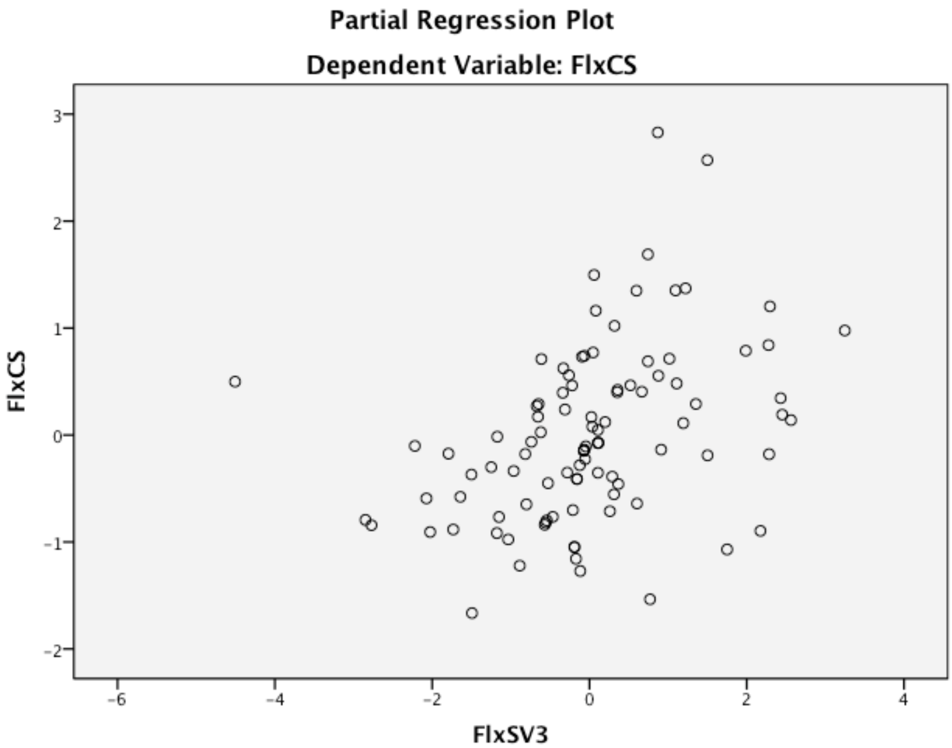

Figure 53: Partial plot of *FlxCS* and *FlxSV3*

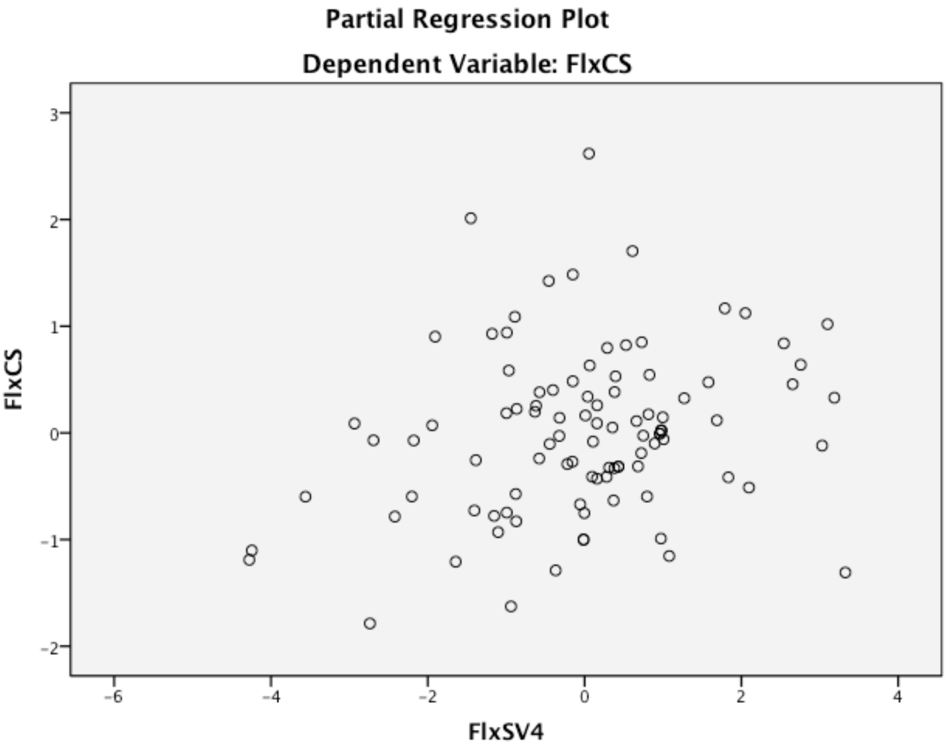

Figure 54: Partial plot of *FlxCS* and *FlxSV4*

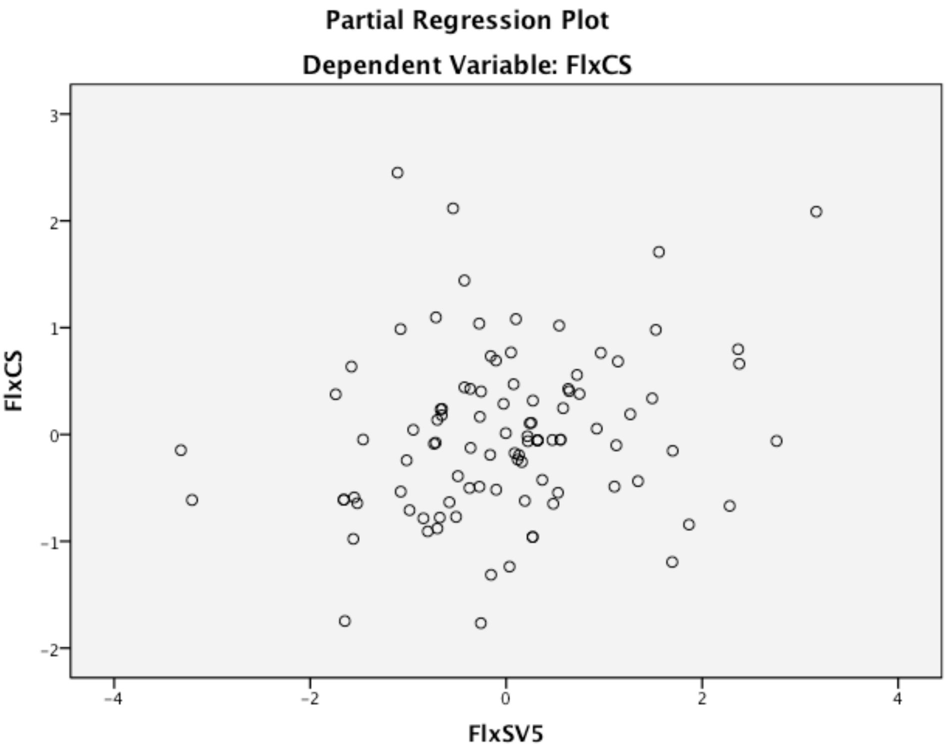

Figure 55: Partial plot of *FlxCS* and *FlxSV5*

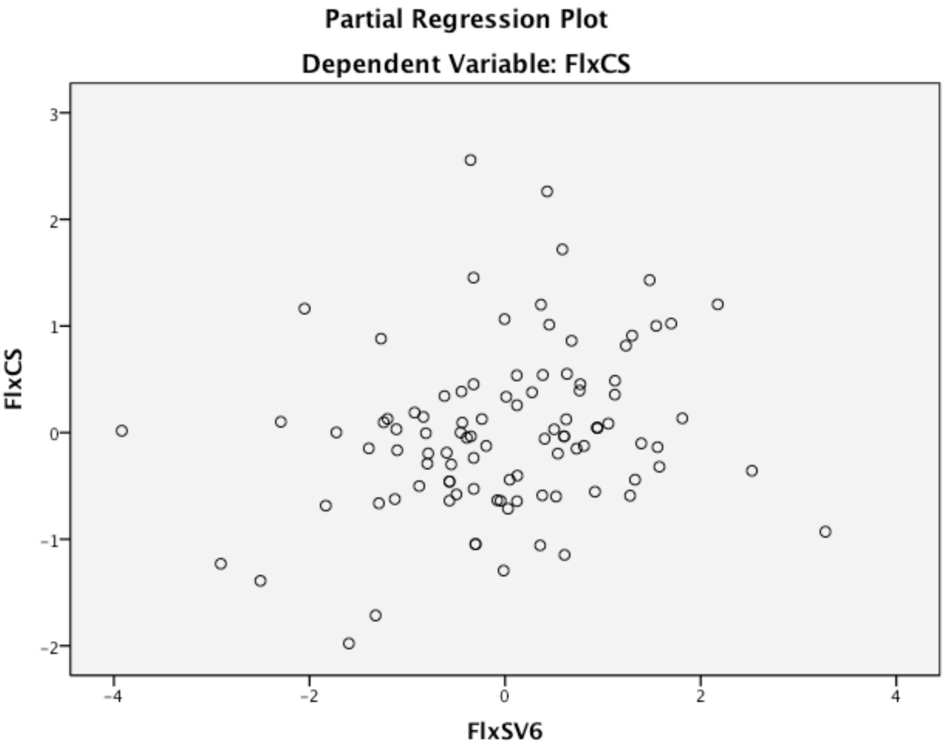

Figure 56: Partial plot of *FlxCS* and *FlxSV6*

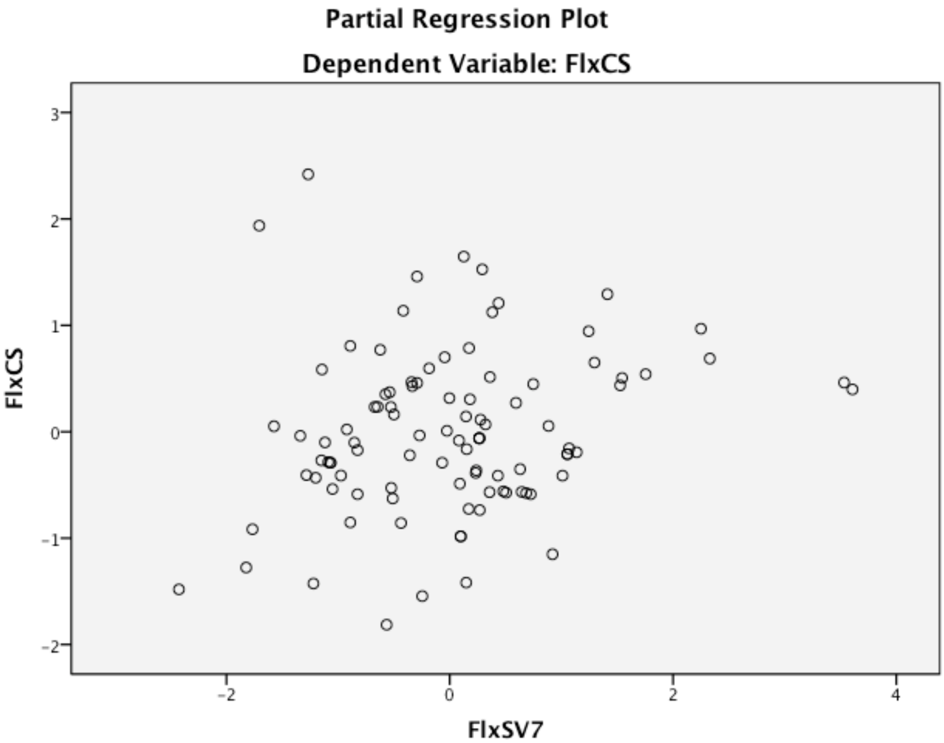

Figure 57: Partial plot of *FlxCS* and *FlxSV7*

APPENDIX 19: SPSS OUTPUTS FOR DELIVERY FLEXIBILITY MLR MODEL

Table 69: Delivery flexibility regression model's variable correlations

		FlxCD	*FlxD V1*	*FlxD V2*	*FlxD V3*	*FlxD V4*	*FlxD V5*	*FlxD V6*	*FlxD V7*	*FlxD V8*	*FlxD V9*	*FlxD V10*	*FlxD V11*
Pearson Correlation	*FlxCD*	1.000	.858	.842	.804	.752	.775	.714	.833	.694	.832	.716	.765
	FlxDV1	.858	1.000	.830	.843	.680	.732	.709	.807	.693	.781	.795	.810
	FlxDV2	.842	.830	1.000	.775	.679	.777	.725	.765	.694	.775	.773	.733
	FlxDV3	.804	.843	.775	1.000	.611	.697	.660	.742	.638	.713	.799	.732
	FlxDV4	.752	.680	.679	.611	1.000	.633	.525	.679	.582	.670	.576	.672
	FlxDV5	.775	.732	.777	.697	.633	1.000	.635	.661	.608	.699	.684	.684
	FlxDV6	.714	.709	.725	.660	.525	.635	1.000	.772	.587	.737	.607	.592
	FlxDV7	.833	.807	.765	.742	.679	.661	.772	1.000	.699	.814	.775	.742
	FlxDV8	.694	.693	.694	.638	.582	.608	.587	.699	1.000	.707	.631	.582
	FlxDV9	.832	.781	.775	.713	.670	.699	.737	.814	.707	1.000	.695	.746
	FlxDV10	.716	.795	.773	.799	.576	.684	.607	.775	.631	.695	1.000	.776
	FlxDV11	.765	.810	.733	.732	.672	.684	.592	.742	.582	.746	.776	1.000
Sig. (1-tailed)	*FlxCD*	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	FlxDV1	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	FlxDV2	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000
	FlxDV3	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000
	FlxDV4	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000
	FlxDV5	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000
	FlxDV6	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000
	FlxDV7	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000
	FlxDV8	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000
	FlxDV9	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000
	FlxDV10	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000
	FlxDV11	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.

Table 70: Delivery flexibility regression model's ANOVA results

Model[b]		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	257.430	11	23.403	53.526	.000[a]
	Residual	37.601	86	.437		
	Total	295.031	97			

[a]. Predictors: (Constant), *FlxDV11, FlxDV8, FlxDV6, FlxDV4, FlxDV5, FlxDV3, FlxDV10, FlxDV9, FlxDV2, FlxDV7, FlxDV1*
[b]. Dependent Variable: *FlxCD*

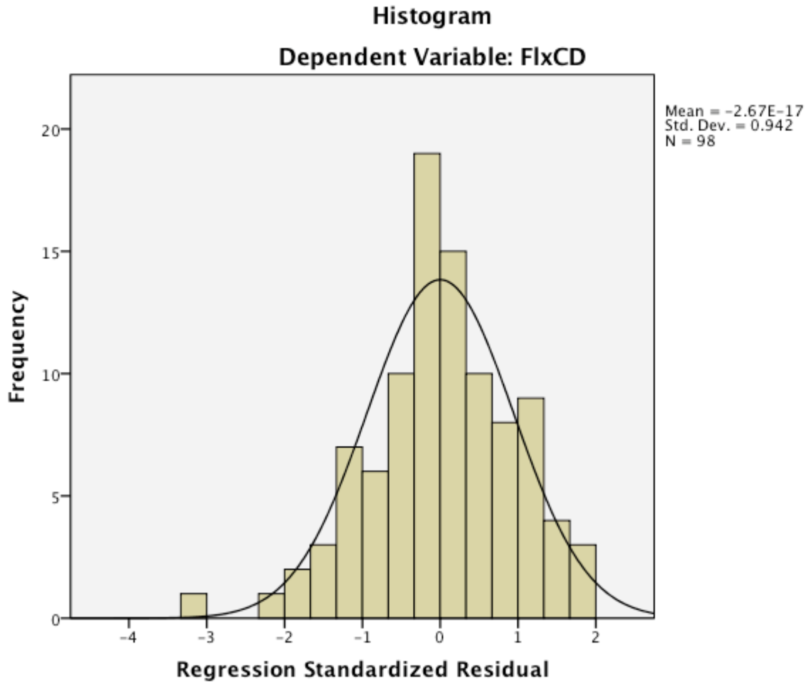

Figure 58: Delivery flexibility regression model's standardized residual histogram

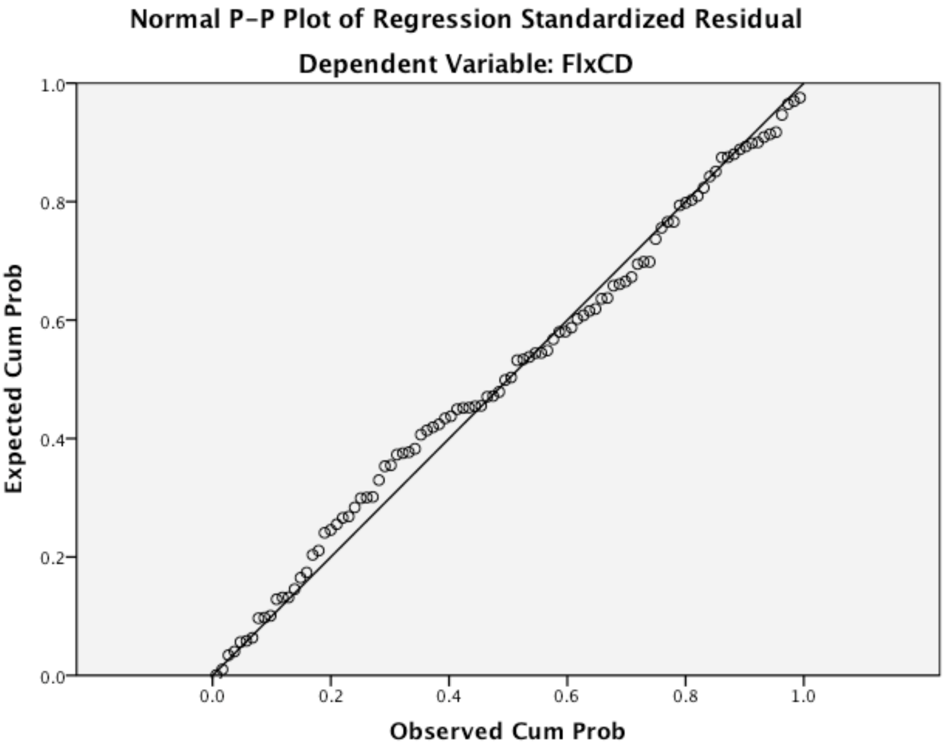

Figure 59: Supply flexibility regression model's standardized residual normal p-p plot

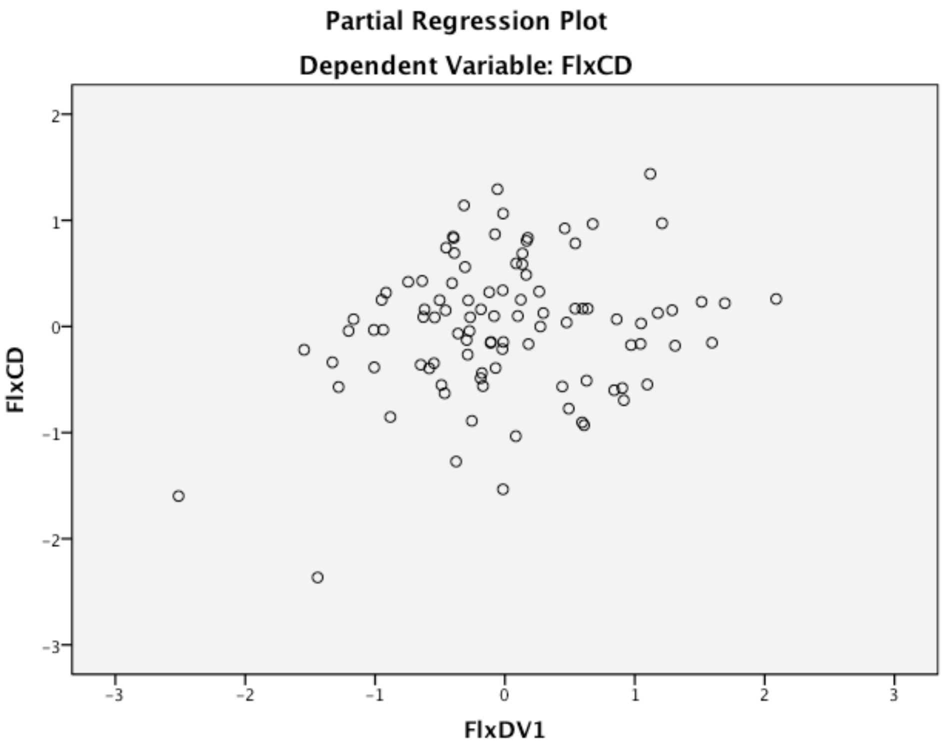

Figure 60: Partial plot of *FlxCD* and *FlxDV1*

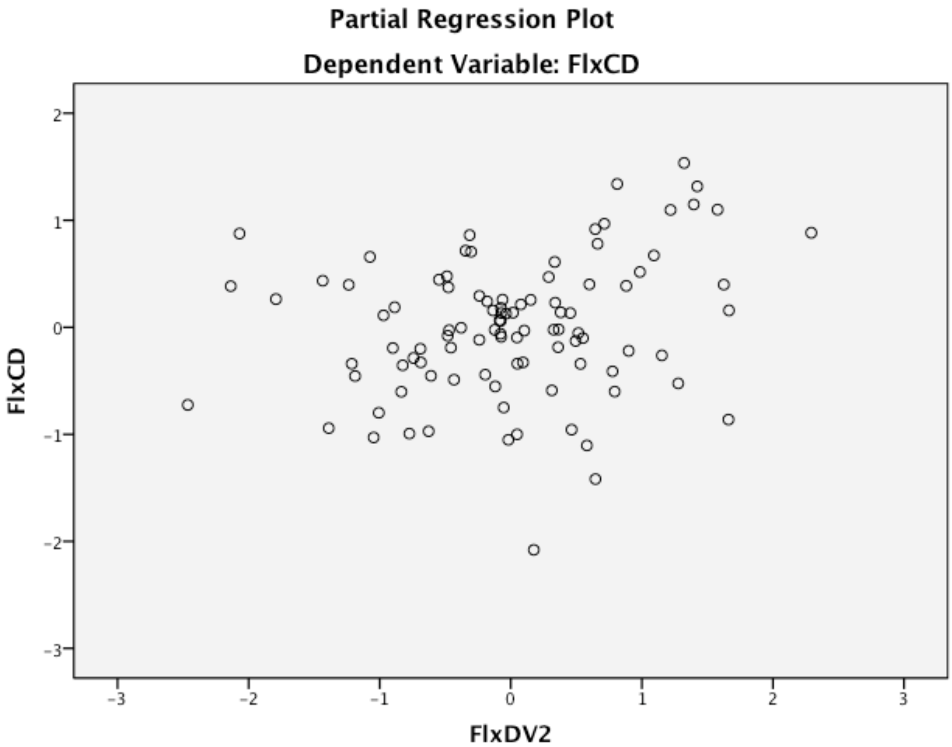

Figure 61: Partial plot of *FlxCD* and *FlxDV2*

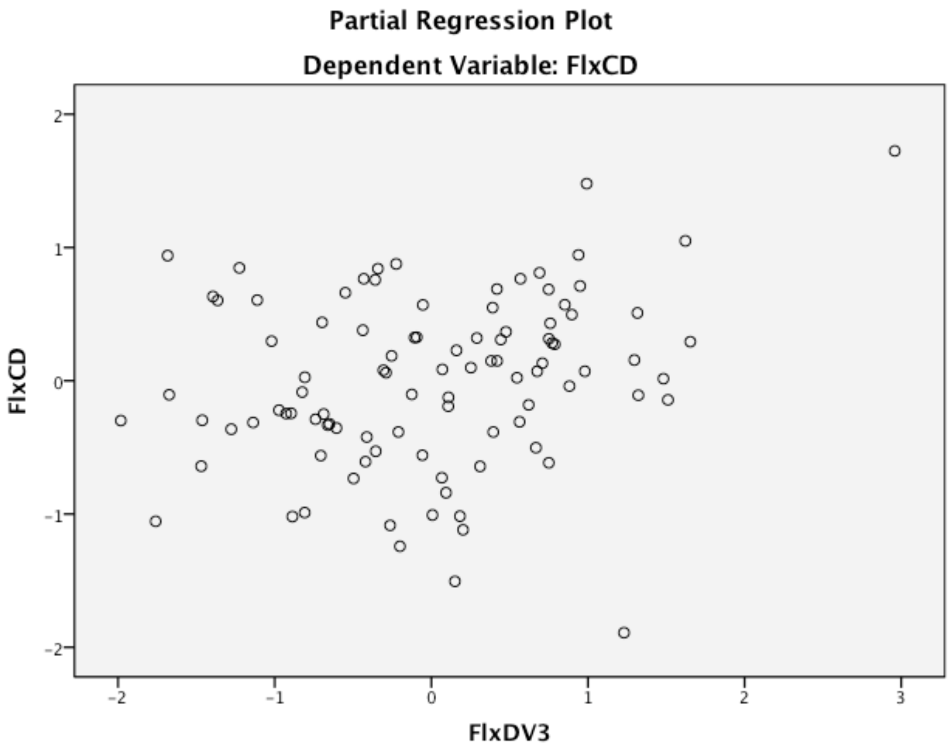

Figure 62: Partial plot of *FlxCD* and *FlxDV3*

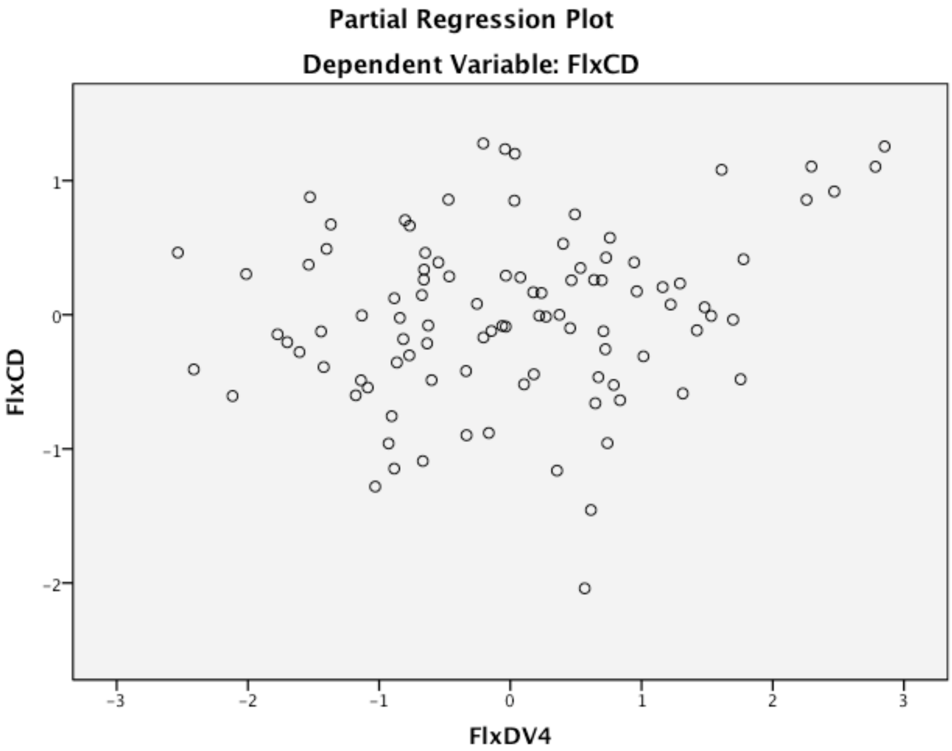

Figure 63: Partial plot of *FlxCD* and *FlxDV4*

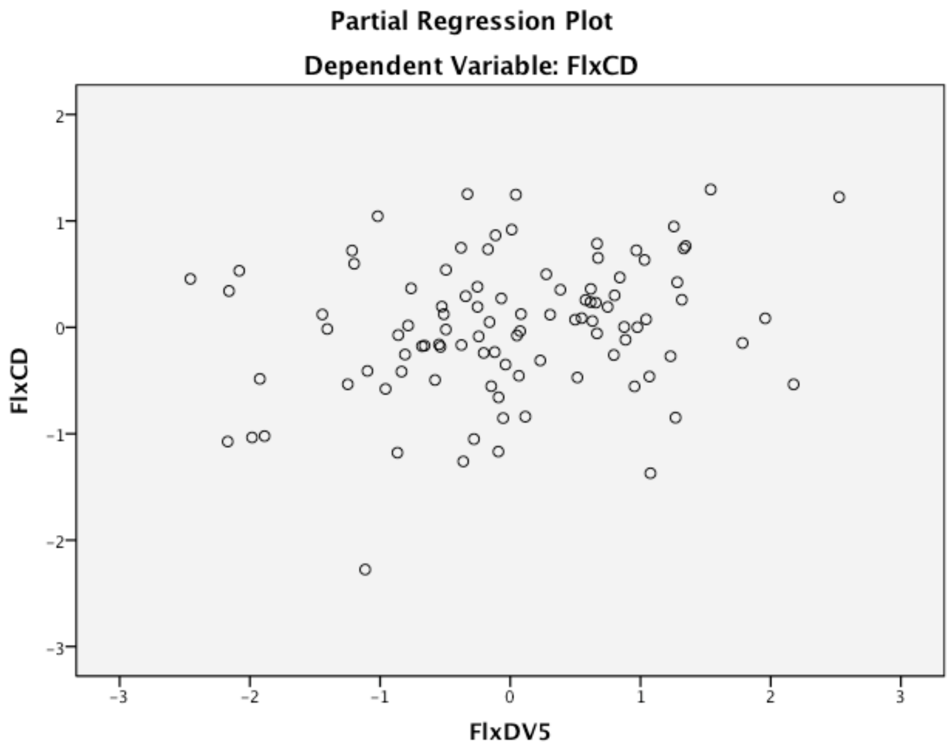

Figure 64: Partial plot of *FlxCD* and *FlxDV5*

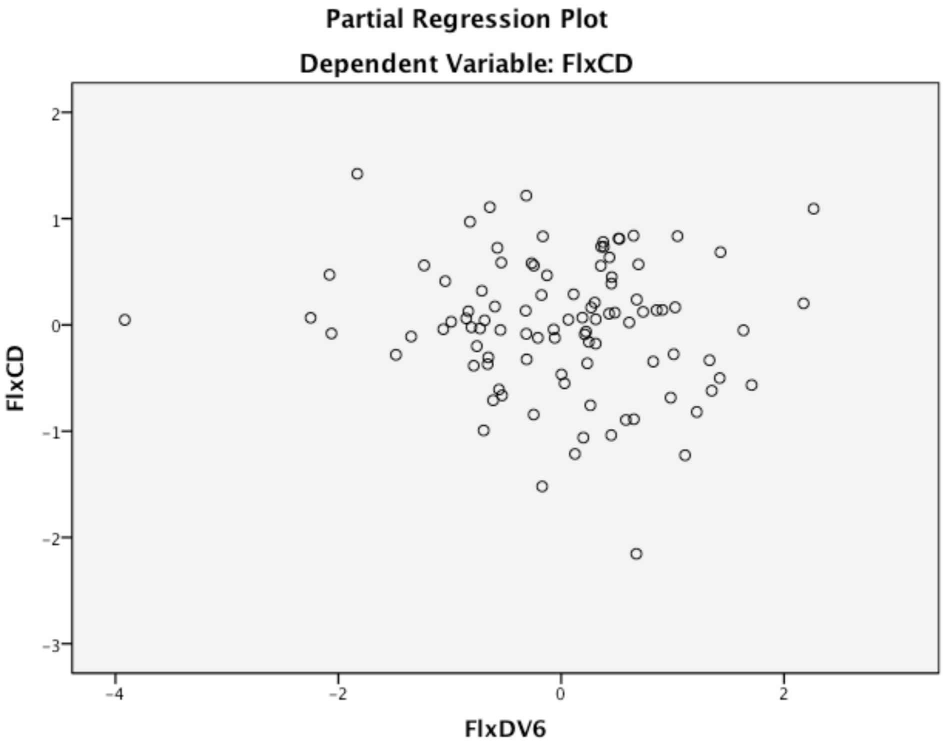

Figure 65: Partial plot of *FlxCD* and *FlxDV6*

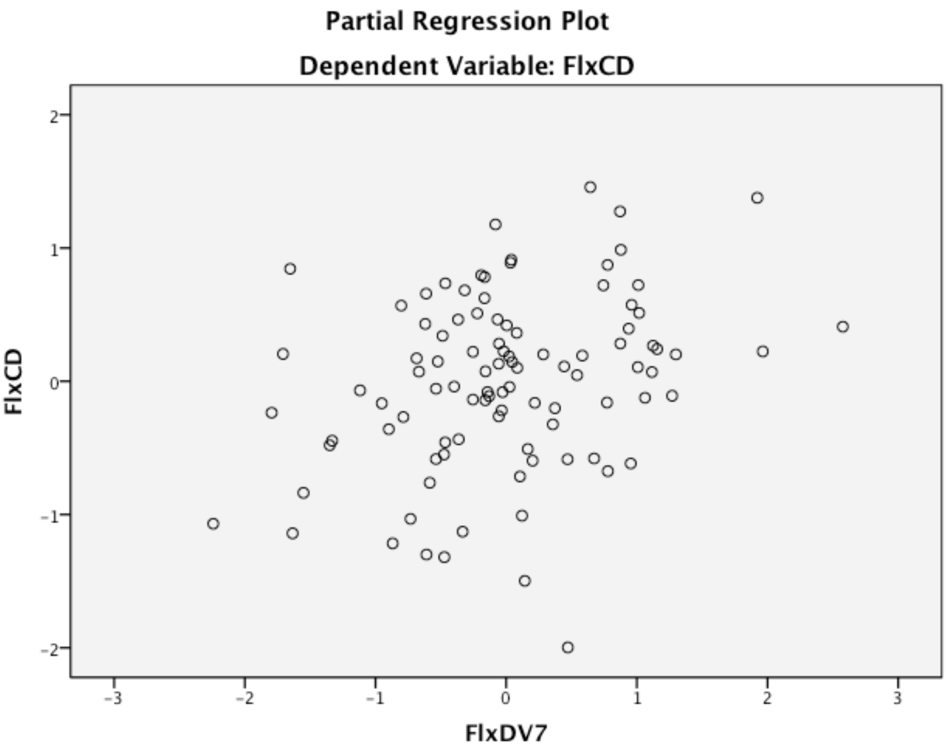

Figure 66: Partial plot of *FlxCD* and *FlxDV7*

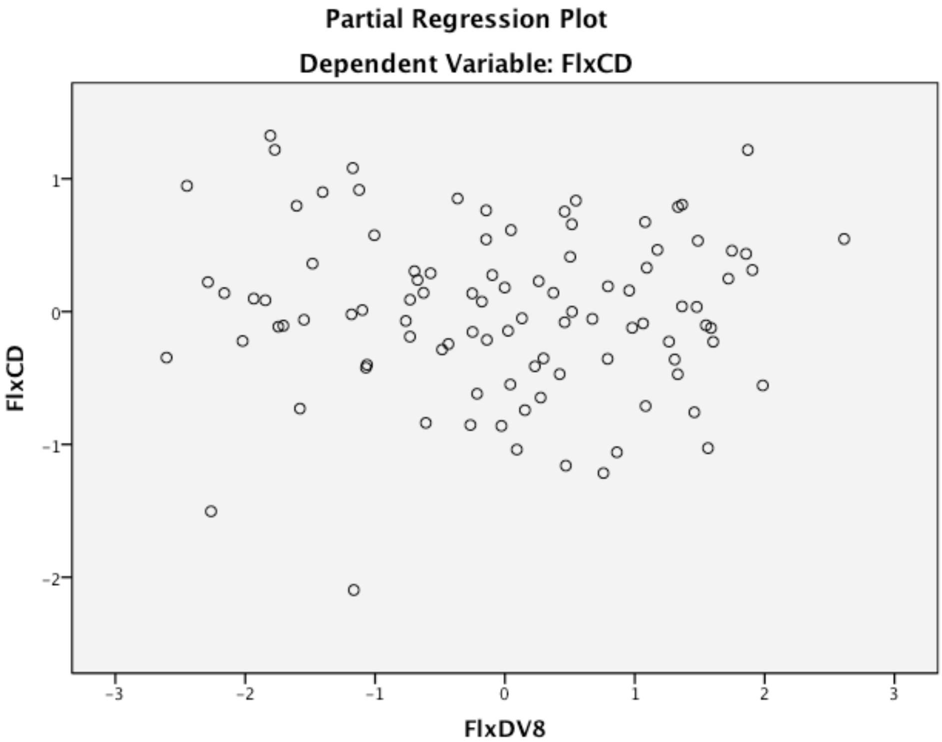

Figure 67: Partial plot of *FlxCD* and *FlxDV8*

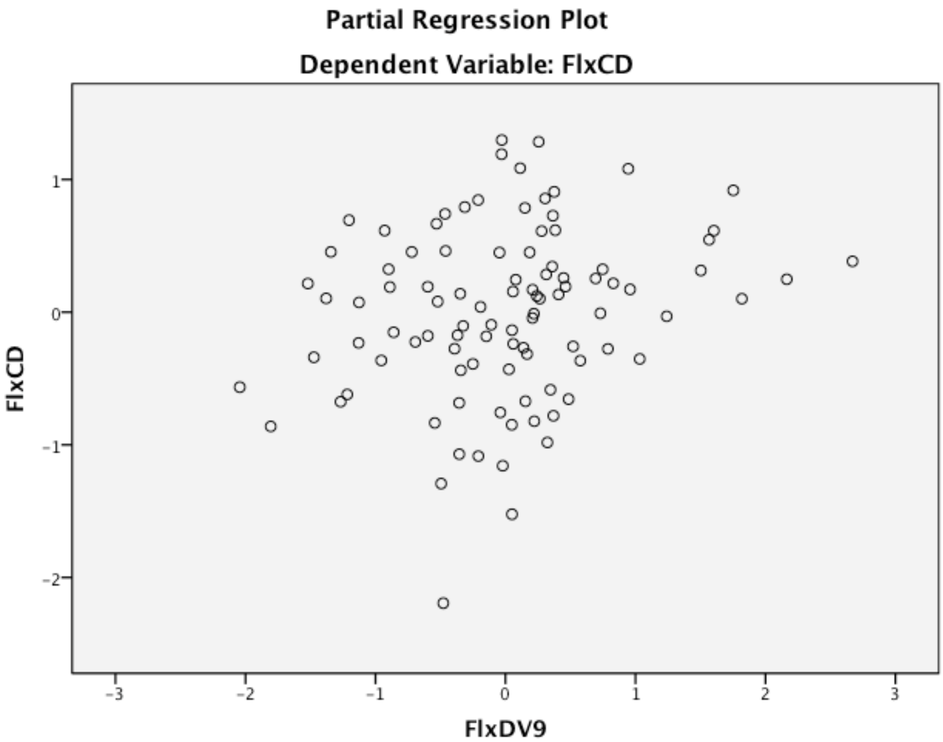

Figure 68: Partial plot of *FlxCD* and *FlxDV9*

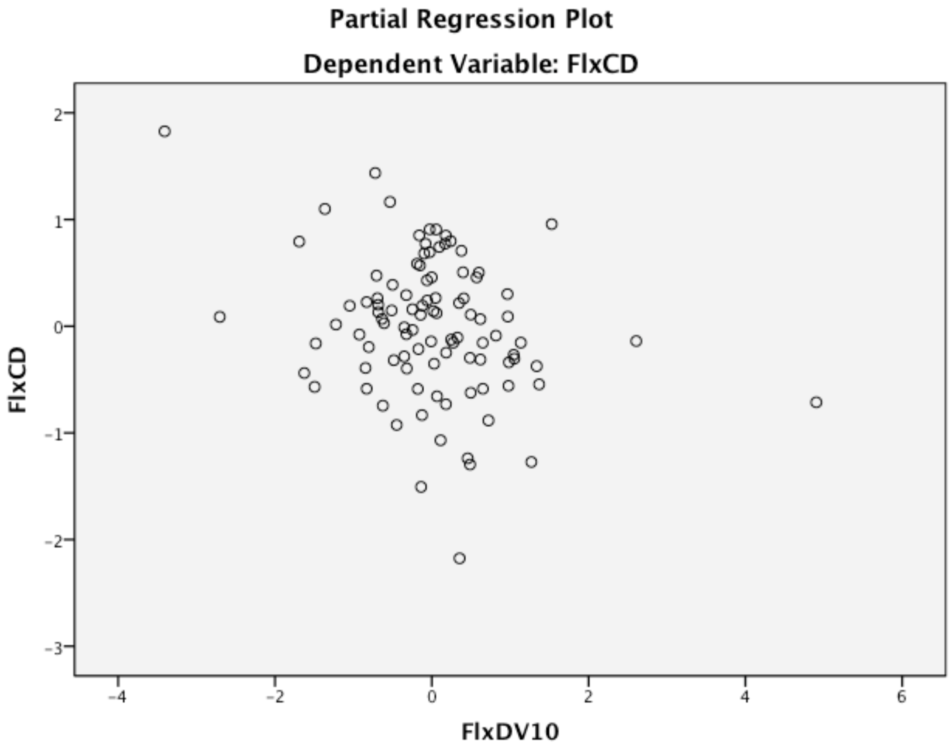

Figure 69: Partial plot of *FlxCD* and *FlxDV10*

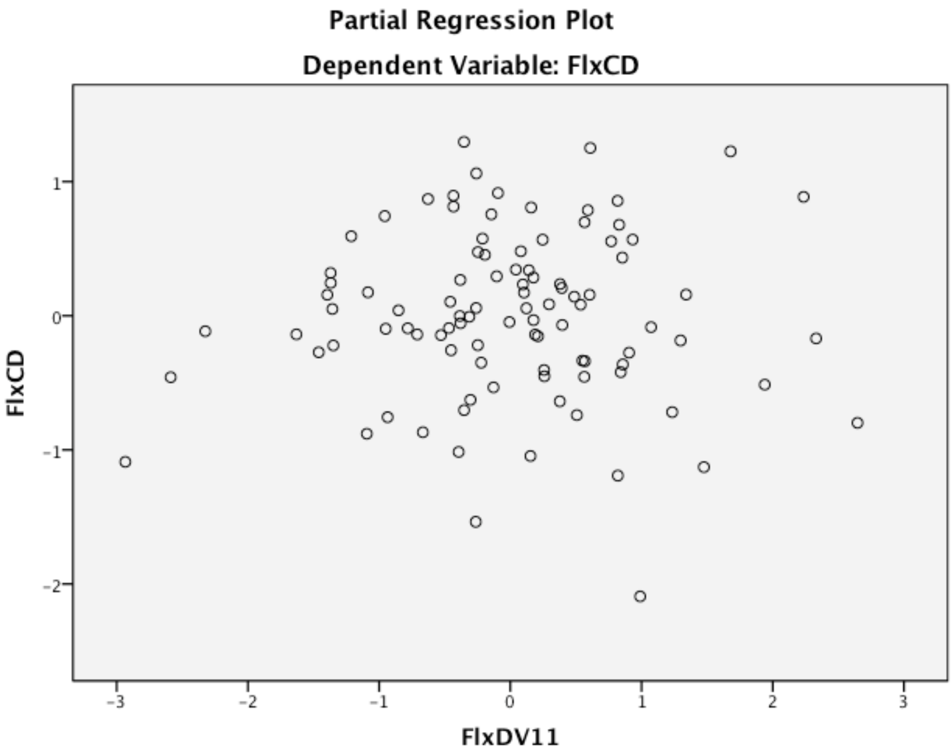

Figure 70: Partial plot of *FlxCD* and *FlxDV11*

APPENDIX 20: SPSS OUTPUTS FOR LOGISTICS FLEXIBILITY MLR MODEL

Table 71: Logistics flexibility regression model's variable correlations

		FlxCL	*FlxLV1*	*FlxLV2*	*FlxLV3*	*FlxLV4*	*FlxLV5*
Pearson Correlation	*FlxCL*	1.000	.717	.810	.810	.759	.797
	FlxLV1	.717	1.000	.678	.654	.647	.625
	FlxLV2	.810	.678	1.000	.811	.705	.776
	FlxLV3	.810	.654	.811	1.000	.728	.816
	FlxLV4	.759	.647	.705	.728	1.000	.738
	FlxLV5	.797	.625	.776	.816	.738	1.000
Sig. (1-tailed)	*FlxCL*	.	.000	.000	.000	.000	.000
	FlxLV1	.000	.	.000	.000	.000	.000
	FlxLV2	.000	.000	.	.000	.000	.000
	FlxLV3	.000	.000	.000	.	.000	.000
	FlxLV4	.000	.000	.000	.000	.	.000
	FlxLV5	.000	.000	.000	.000	.000	.

Table 72: Logistics flexibility regression model's ANOVA results

Model[b]		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	248.629	5	49.726	66.851	.000[a]
	Residual	68.432	92	.744		
	Total	317.061	97			

[a]. Predictors: (Constant), *FlxLV5, FlxLV1, FlxLV4, FlxLV2, FlxLV3*
[b]. Dependent Variable: *FlxCL*

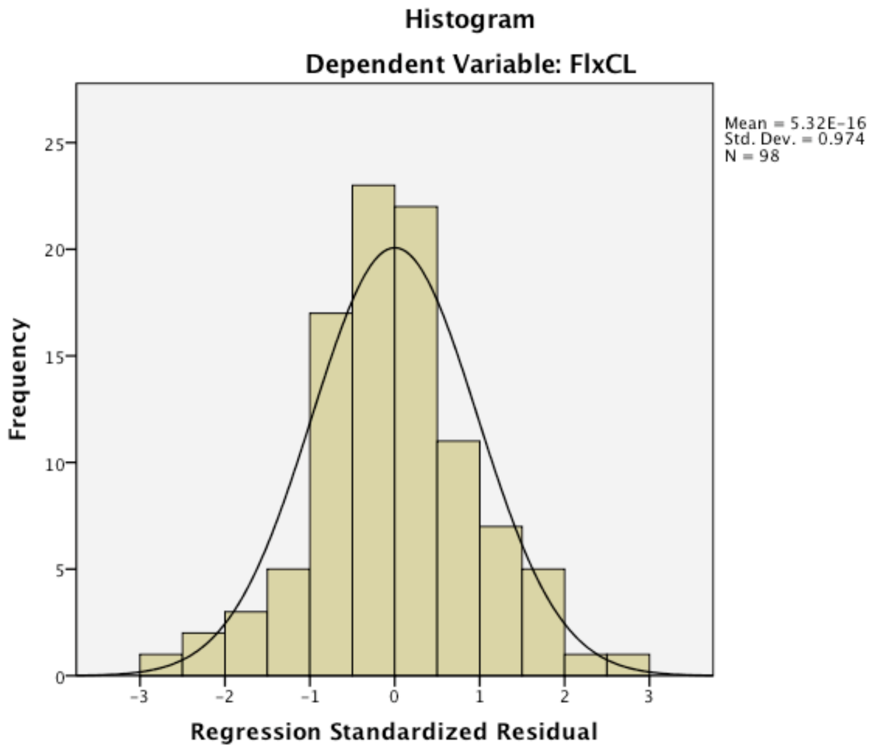

Figure 71: Logistics flexibility regression model's standardized residual histogram

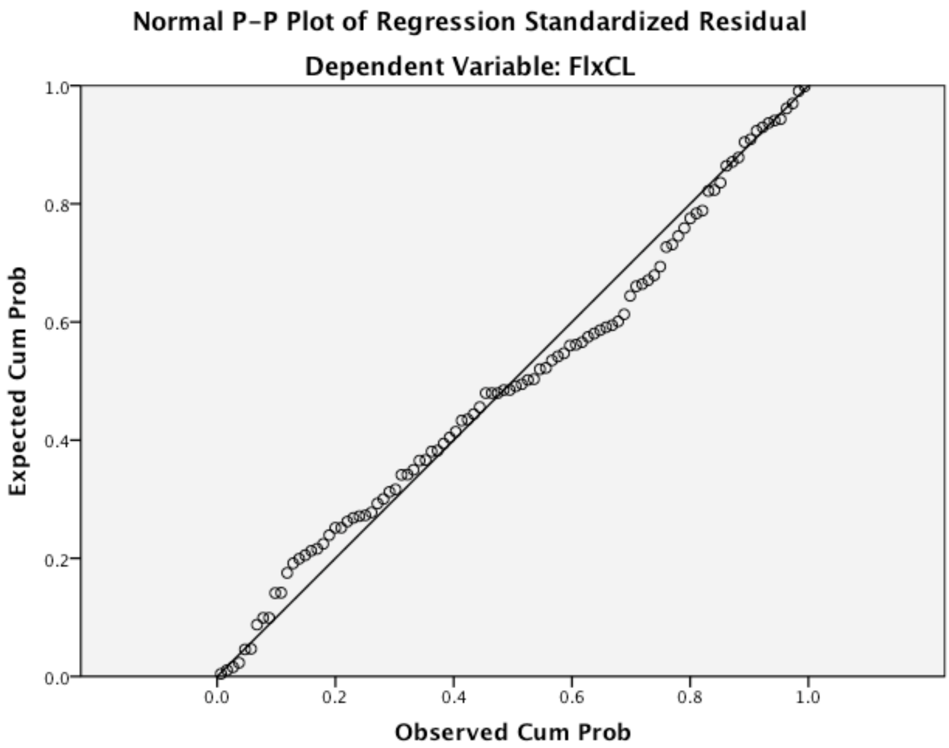

Figure 72: Logistics flexibility regression model's standardized residual normal p-p plot

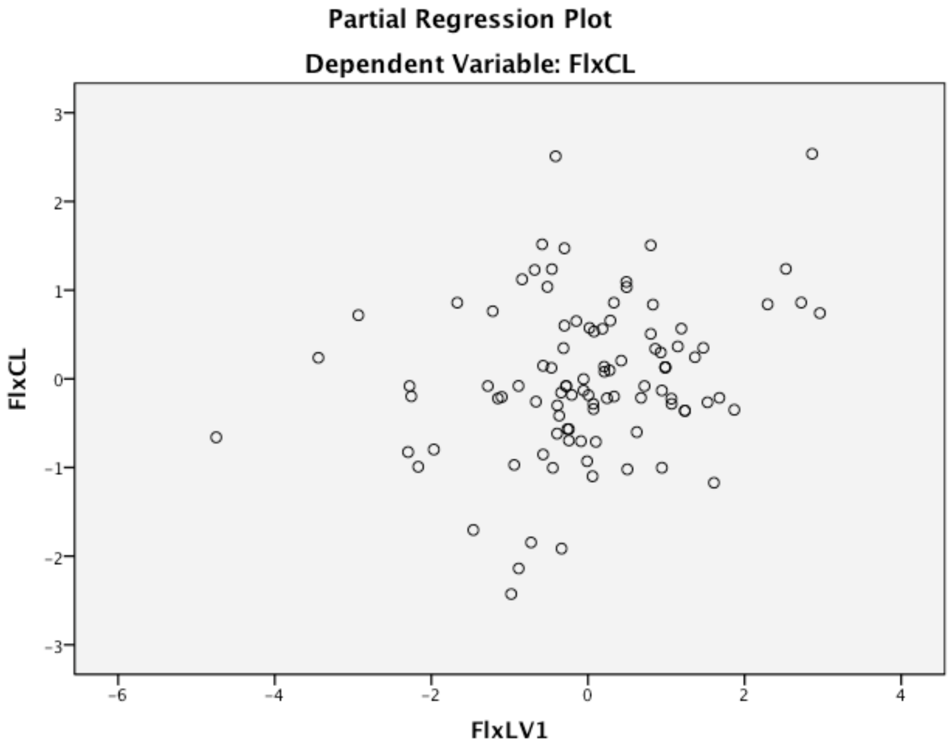

Figure 73: Partial plot of *FlxCL* and *FlxLV1*

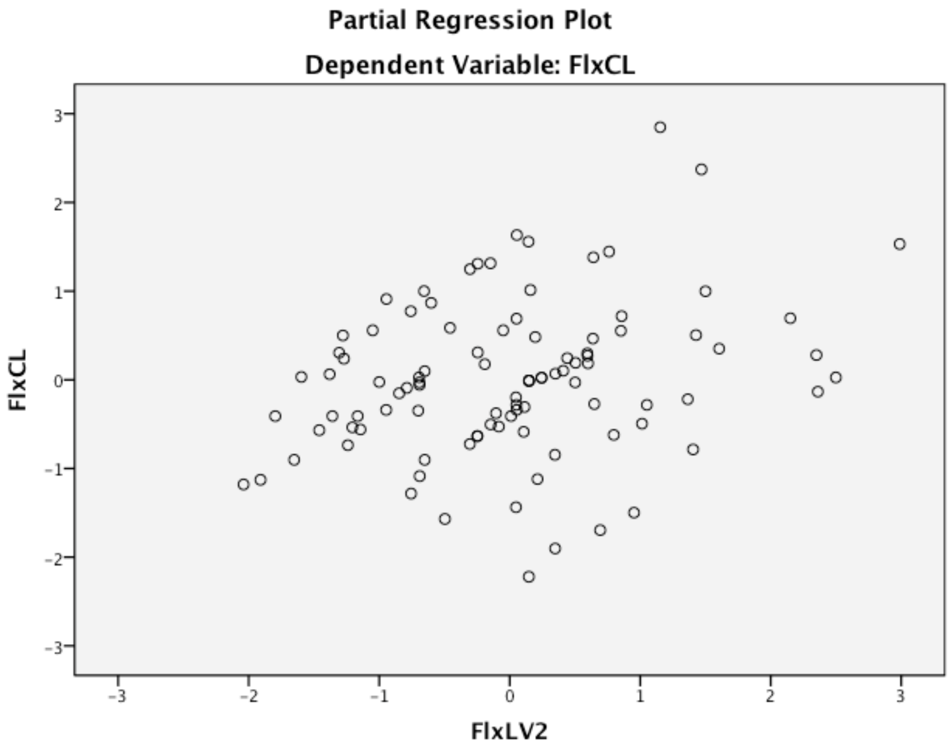

Figure 74: Partial plot of *FlxCL* and *FlxLV2*

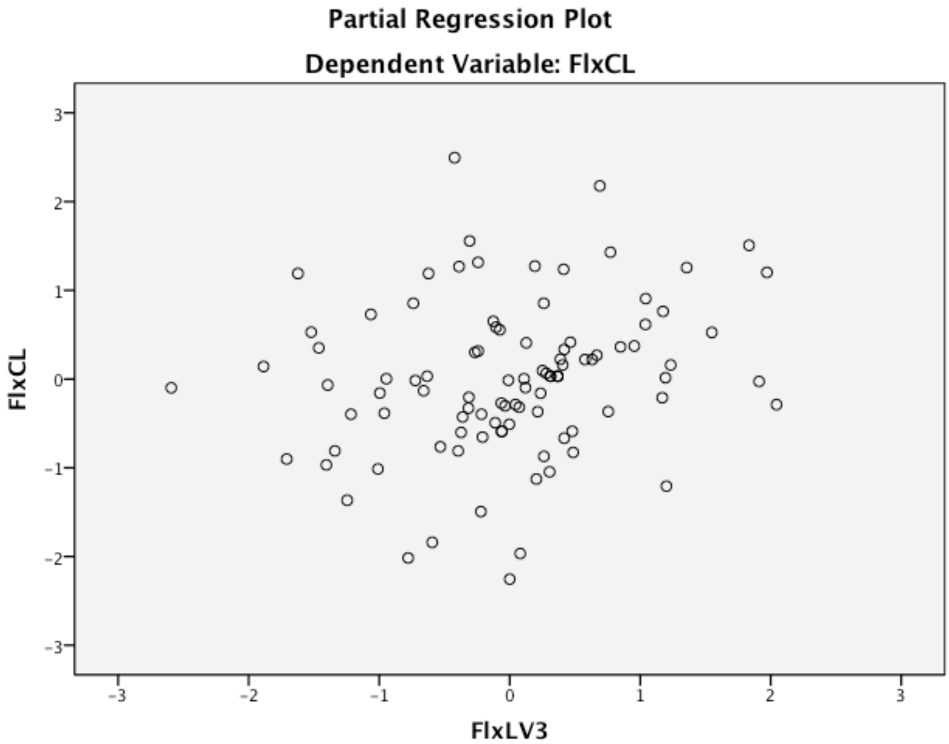

Figure 75: Partial plot of *FlxCL* and *FlxLV3*

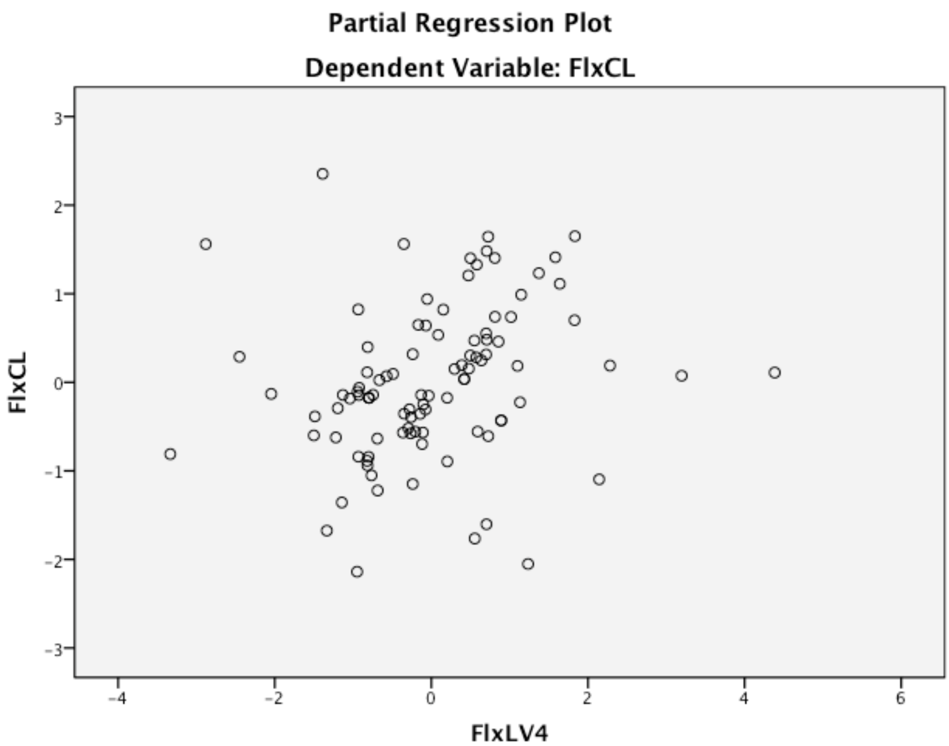

Figure 76: Partial plot of *FlxCL* and *FlxLV4*

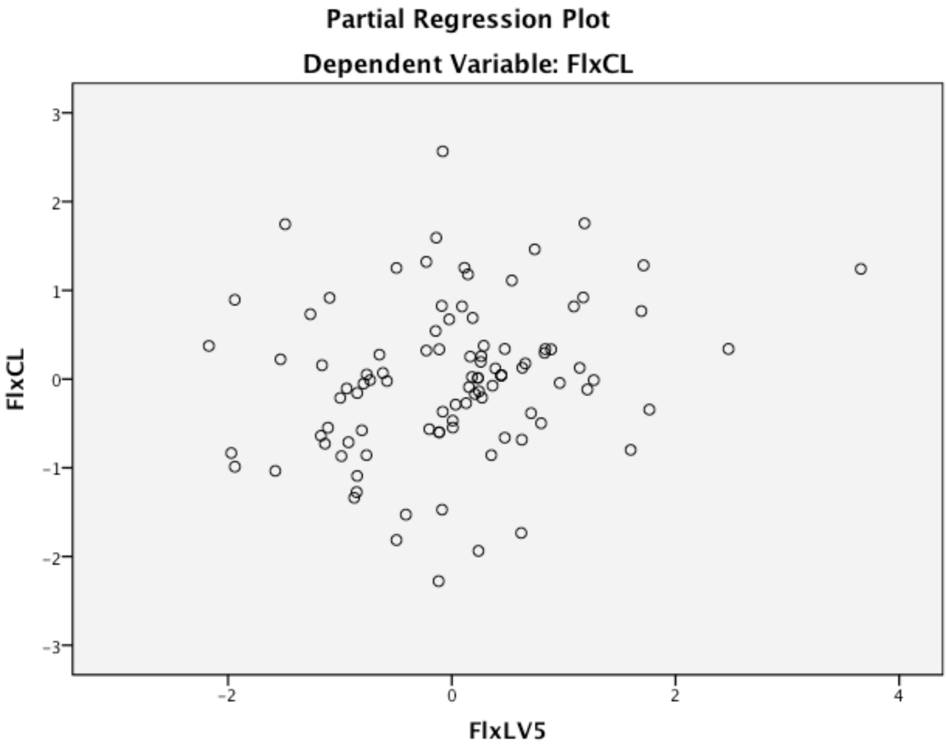

Figure 77: Partial plot of *FlxCL* and *FlxLV5*

APPENDIX 21: SPSS OUTPUTS FOR INFORMATION FLEXIBILITY MLR MODEL

Table 73: Information flexibility regression model's variable correlations

		FlxCI	*FlxIV1*	*FlxIV2*	*FlxIV3*	*FlxIV4*	*FlxIV5*	*FlxIV6*	*FlxIV7*	*FlxIV8*	*FlxIV9*	*FlxIV10*	*FlxIV11*
Pearson Correlation	*FlxCI*	1.000	.854	.782	.828	.800	.855	.800	.850	.779	.761	.703	.863
	FlxIV1	.854	1.000	.843	.811	.720	.784	.741	.784	.785	.786	.815	.766
	FlxIV2	.782	.843	1.000	.741	.632	.693	.719	.654	.696	.760	.883	.686
	FlxIV3	.828	.811	.741	1.000	.741	.808	.756	.826	.868	.749	.678	.829
	FlxIV4	.800	.720	.632	.741	1.000	.746	.745	.729	.736	.726	.588	.766
	FlxIV5	.855	.784	.693	.808	.746	1.000	.754	.800	.810	.738	.650	.839
	FlxIV6	.800	.741	.719	.756	.745	.754	1.000	.702	.768	.790	.680	.743
	FlxIV7	.850	.784	.654	.826	.729	.800	.702	1.000	.763	.710	.625	.879
	FlxIV8	.779	.785	.696	.868	.736	.810	.768	.763	1.000	.749	.659	.783
	FlxIV9	.761	.786	.760	.749	.726	.738	.790	.710	.749	1.000	.695	.781
	FlxIV10	.703	.815	.883	.678	.588	.650	.680	.625	.659	.695	1.000	.633
	FlxIV11	.863	.766	.686	.829	.766	.839	.743	.879	.783	.781	.633	1.000
Sig. (1-tailed)	*FlxCI*	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	FlxIV1	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	FlxIV2	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000
	FlxIV3	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000
	FlxIV4	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000
	FlxIV5	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000
	FlxIV6	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000
	FlxIV7	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000
	FlxIV8	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000
	FlxIV9	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000
	FlxIV10	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000
	FlxIV11	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.

Table 74: Information flexibility regression model's ANOVA results

Model[d]		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	325.741	11	29.613	62.482	.000[a]
	Residual	40.759	86	.474		
	Total	366.500	97			
2	Regression	325.739	10	32.574	69.525	.000[b]
	Residual	40.761	87	.469		
	Total	366.500	97			
3	Regression	324.820	9	36.091	76.200	.000[c]
	Residual	41.680	88	.474		
	Total	366.500	97			

[a]. Predictors: (Constant), *FlxIV11, FlxIV10, FlxIV4, FlxIV6, FlxIV8, FlxIV9, FlxIV5, FlxIV7, FlxIV2, FlxIV3, FlxIV1*
[b]. Predictors: (Constant), *FlxIV11, FlxIV10, FlxIV4, FlxIV6, FlxIV8, FlxIV9, FlxIV5, FlxIV7, FlxIV2, FlxIV1*
[c]. Predictors: (Constant), *FlxIV11, FlxIV10, FlxIV4, FlxIV6, FlxIV9, FlxIV5, FlxIV7, FlxIV2, FlxIV1*
[d]. Dependent Variable: *FlxCI*

Table 75: Information flexibility regression model's variable coefficients

Model[a]		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics
		B	Std. Error	Beta			VIF
1	(Constant)	.055	.177		.309	.758	
	FlxIV1	.254	.092	.250	2.756	.007	6.337
	FlxIV2	.237	.085	.254	2.781	.007	6.438
	FlxIV3	.006	.087	.006	.064	.949	6.312
	FlxIV4	.143	.060	.151	2.359	.021	3.163
	FlxIV5	.187	.072	.201	2.578	.012	4.696
	FlxIV6	.171	.070	.171	2.439	.017	3.780
	FlxIV7	.176	.082	.183	2.141	.035	5.638
	FlxIV8	-.094	.075	-.103	-1.262	.210	5.181
	FlxIV9	-.115	.066	-.129	-1.756	.083	4.141
	FlxIV10	-.138	.078	-.143	-1.777	.079	5.015
	FlxIV11	.185	.090	.193	2.060	.042	6.824
2	(Constant)	.055	.176		.310	.757	
	FlxIV1	.255	.091	.250	2.788	.007	6.289
	FlxIV2	.238	.083	.255	2.860	.005	6.209
	FlxIV4	.143	.060	.151	2.377	.020	3.159
	FlxIV5	.187	.072	.201	2.596	.011	4.694
	FlxIV6	.171	.070	.171	2.458	.016	3.774
	FlxIV7	.178	.080	.184	2.227	.029	5.345
	FlxIV8	-.092	.066	-.101	-1.400	.165	4.056
	FlxIV9	-.116	.065	-.129	-1.772	.080	4.131
	FlxIV10	-.138	.077	-.144	-1.800	.075	4.973
	FlxIV11	.186	.089	.194	2.097	.039	6.715
3	(Constant)	.059	.177		.332	.740	
	FlxIV1	.234	.091	.230	2.582	.011	6.124
	FlxIV2	.240	.084	.256	2.863	.005	6.208
	FlxIV4	.135	.060	.143	2.241	.028	3.130
	FlxIV5	.161	.070	.173	2.303	.024	4.390
	FlxIV6	.152	.069	.152	2.214	.029	3.628
	FlxIV7	.169	.080	.175	2.114	.037	5.314
	FlxIV9	-.122	.065	-.136	-1.859	.066	4.113
	FlxIV10	-.139	.077	-.144	-1.797	.076	4.973
	FlxIV11	.179	.089	.187	2.011	.047	6.694

[a]. Dependent Variable: *FlxCI*

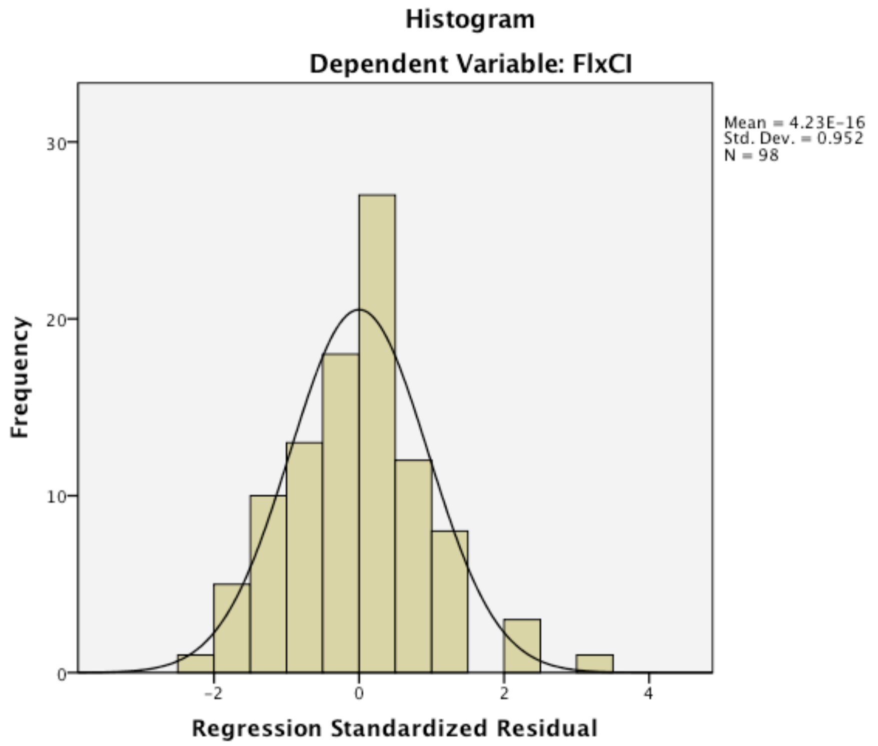

Figure 78: Information flexibility regression model's standardized residual histogram

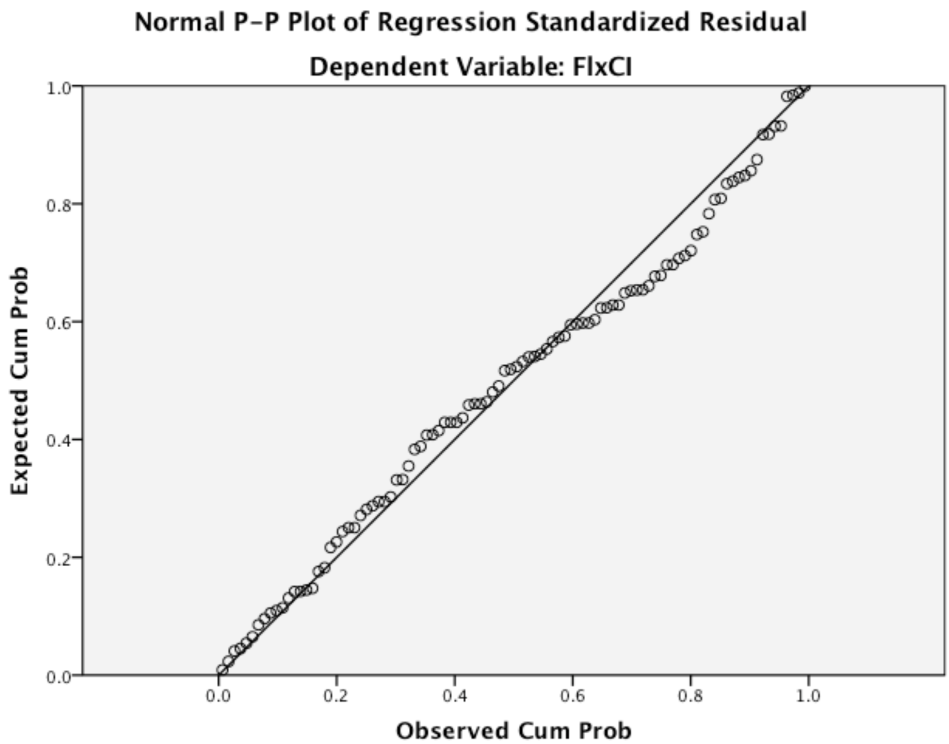

Figure 79: Information flexibility regression model's standardized residual normal p-p plot

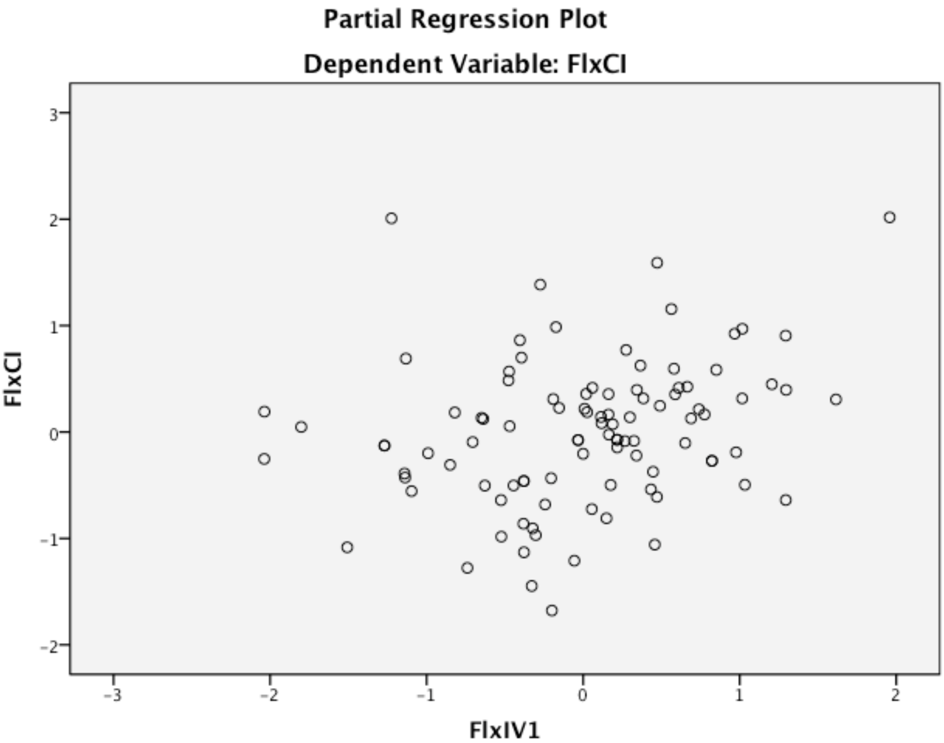

Figure 80: Partial plot of *FlxCI* and *FlxIV1*

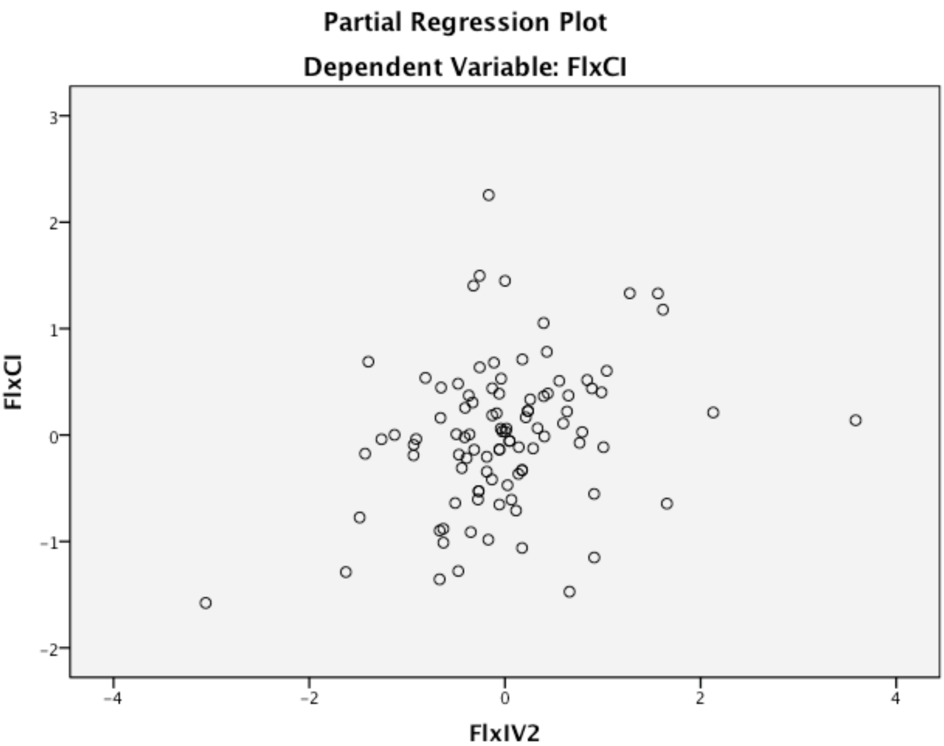

Figure 81: Partial plot of *FlxCI* and *FlxIV2*

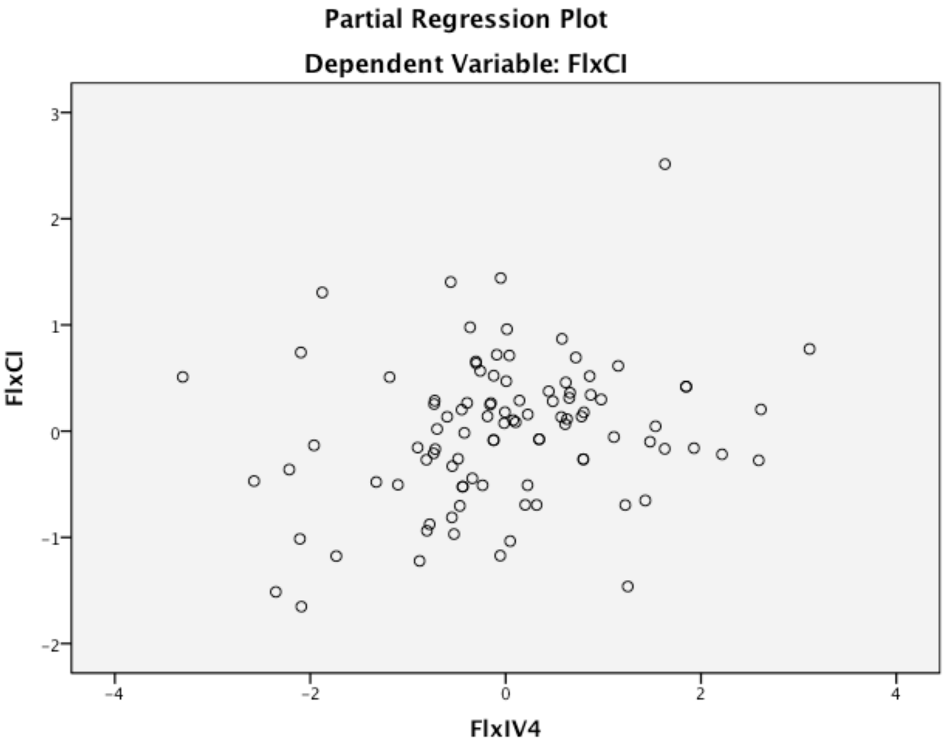

Figure 82: Partial plot of *FlxCI* and *FlxIV4*

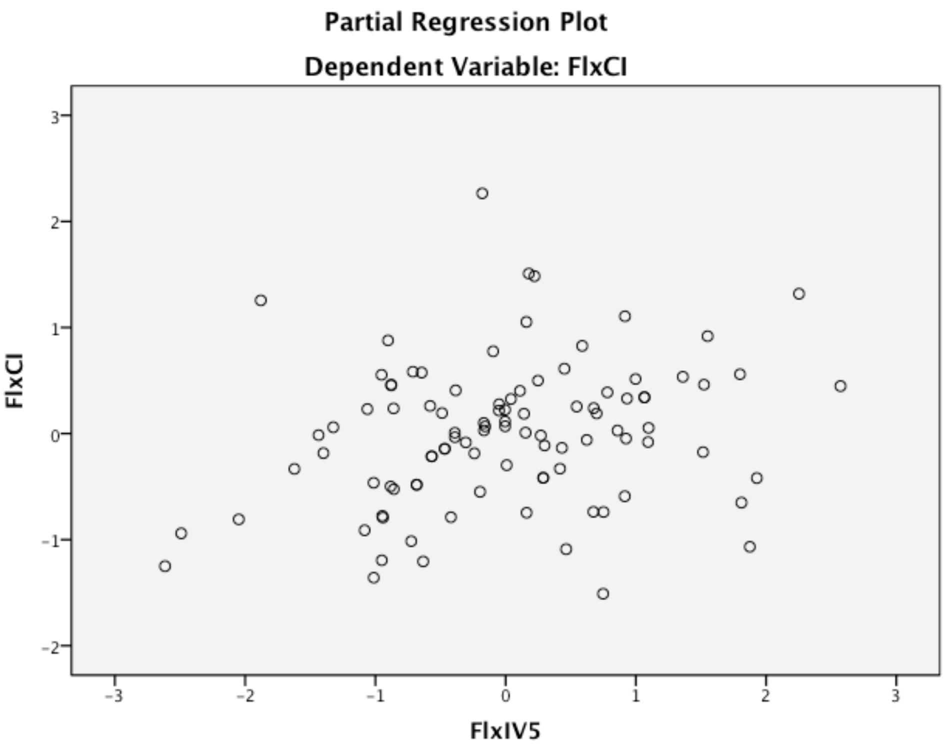

Figure 83: Partial plot of *FlxCI* and *FlxIV5*

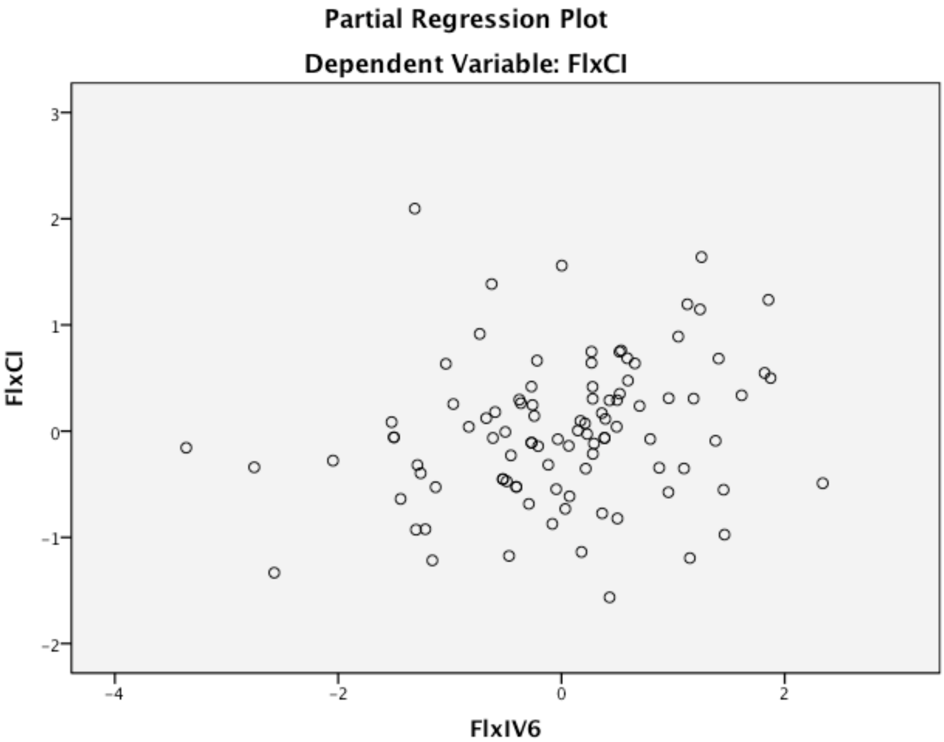

Figure 84: Partial plot of *FlxCI* and *FlxIV6*

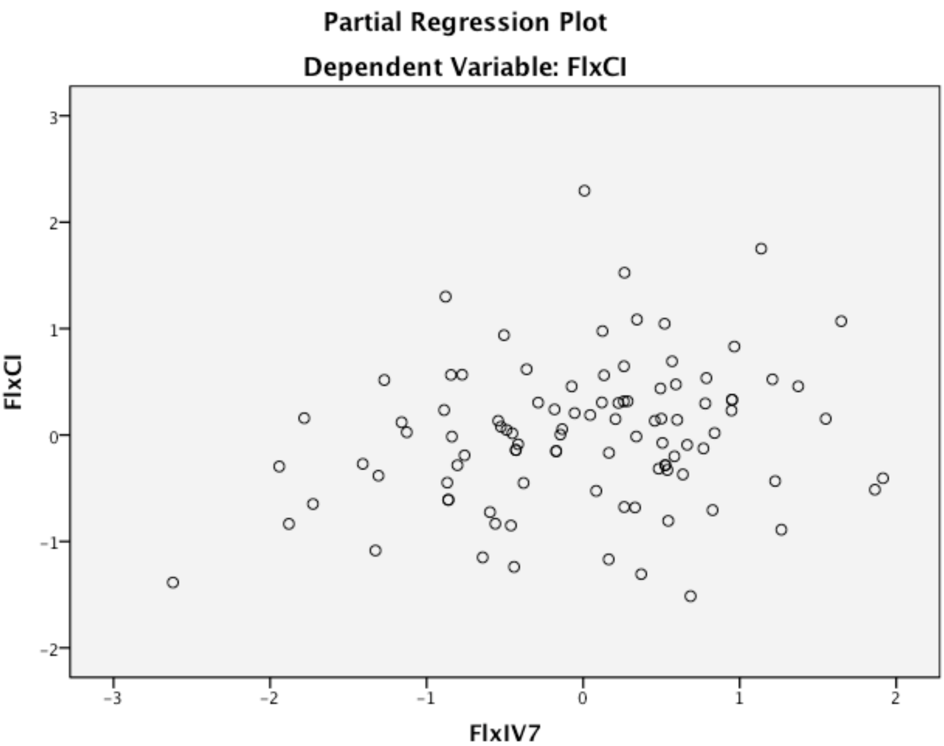

Figure 85: Partial plot of *FlxCI* and *FlxIV7*

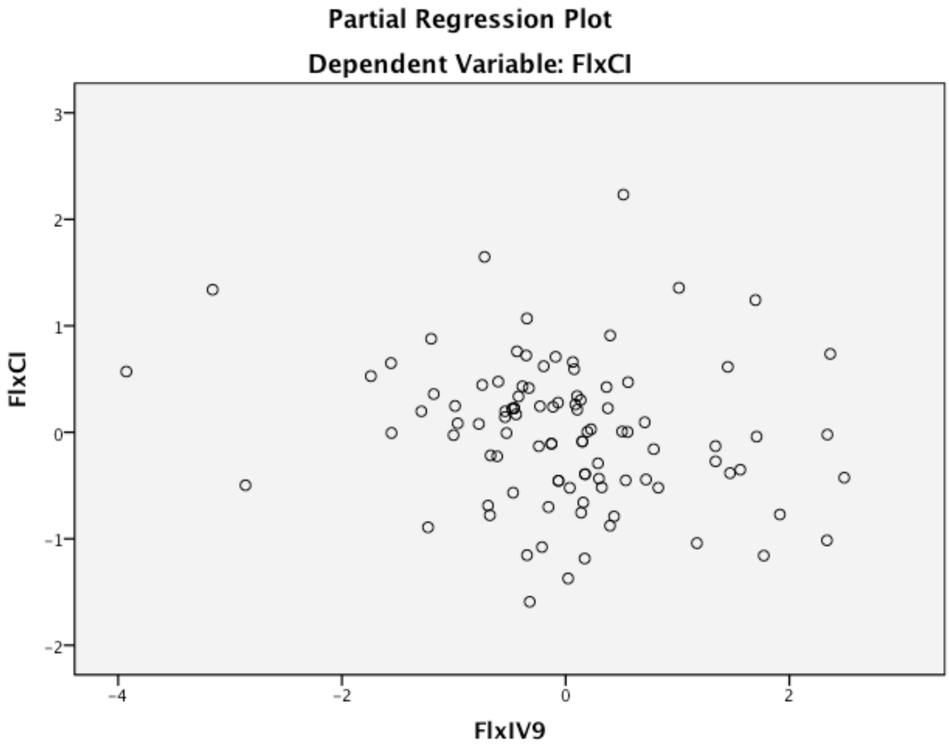

Figure 86: Partial plot of *FlxCI* and *FlxIV9*

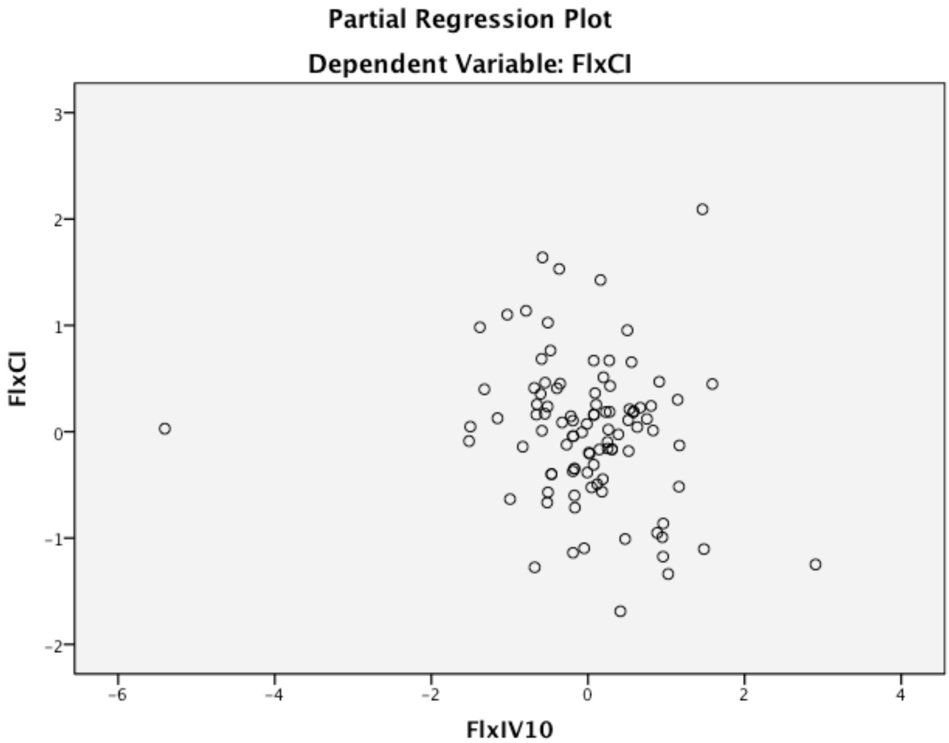

Figure 87: Partial plot of *FlxCI* and *FlxIV10*

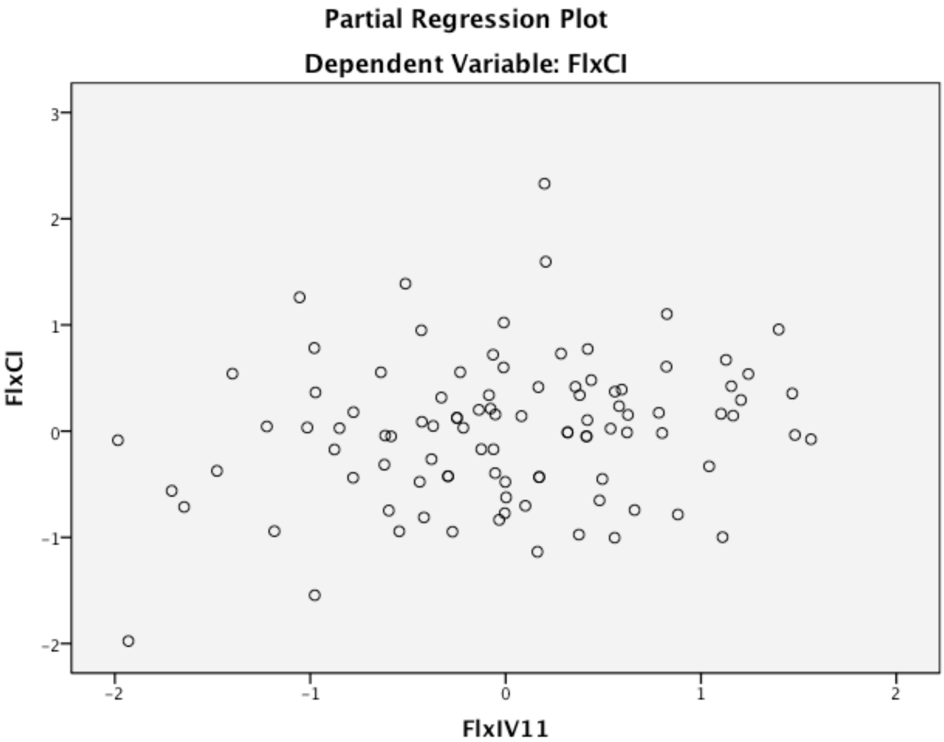

Figure 88: Partial plot of *FlxCI* and *FlxIV11*

APPENDIX 22: SPSS OUTPUTS OF SLR MODEL TO DETERMINE THE EFFECTS OF SCOFS ON SCOPS

Table 76: SCOFS effect on SCOPS regression model variable correlation

		SCOPS	SCOFS
Pearson Correlation	SCOPS	1.000	.844
	SCOFS	.844	1.000
Sig. (1-tailed)	SCOPS	.	.000
	SCOFS	.000	.

Table 77: SCOFS effect on SCOPS regression model ANOVA results

Model[b]		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	164.427	1	164.427	236.821	.000a
	Residual	66.653	96	.694		
	Total	231.080	97			

[a]. Predictors: (Constant), SCOPS
[b]. Dependent Variable: SCOFS

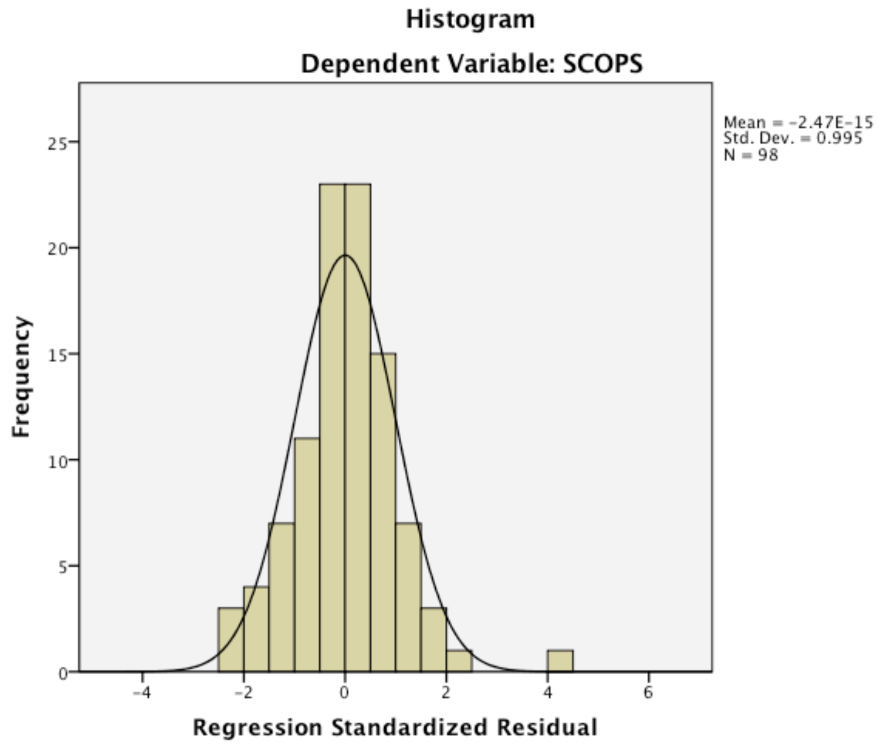

Figure 89: SCOFS effect on SCOPS regression model standardized residual histogram

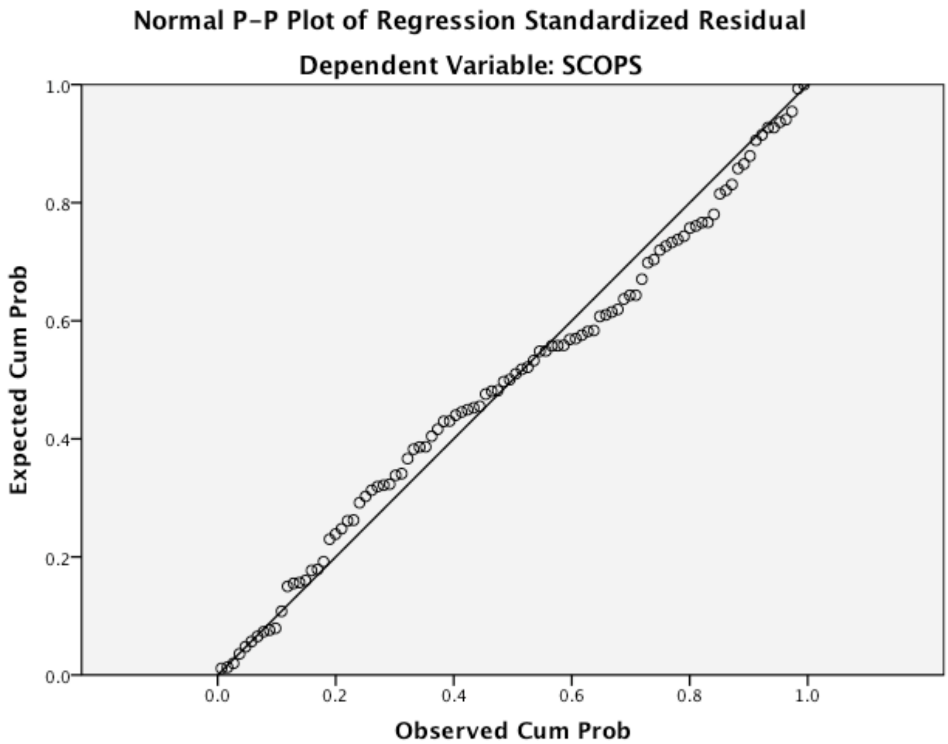

Figure 90: SCOFS effect on SCOPS regression model standardized residual normal p-p plot

APPENDIX 23: SPSS OUTPUTS OF INDEPENDENT SAMPLES T-TEST TO DETERMINE THE EFFECTS OF ERP ON SCOPS

Table 78: ERP effect on SCOPS independent samples t-test results

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Differance	Std. Error Differance	95% Confidence Interval of the Difference Lower	Upper
SCOPS	Equal variances assumed	.011	.916	-4.998	96	.000	-1.40991964	.28211376	-1.96991102	-.84992826
	Equal variances not assumed			-5.027	90.279	.000	-1.40991964	.28047975	-1.96711815	-.85272113

APPENDIX 24: SPSS OUTPUTS OF SLR MODEL TO DETERMINE THE EFFECTS OF ERP ON SCOPS

Table 79: ERP effect on SCOPS regression model variable correlation

		SCOPS	*ERPsuc*
Pearson Correlation	SCOPS	1.000	.894
	ERPsuc	.894	1.000
Sig. (1-tailed)	SCOPS	.	.000
	ERPsuc	.000	.

Table 80: ERP effect on SCOPS regression model ANOVA results

Model[b]		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	120.142	1	120.142	398.475	.000a
	Residual	30.150	100	.302		
	Total	150.292	101			

[a]. Predictors: (Constant), *ERPsuc*

[b]. Dependent Variable: SCOPS

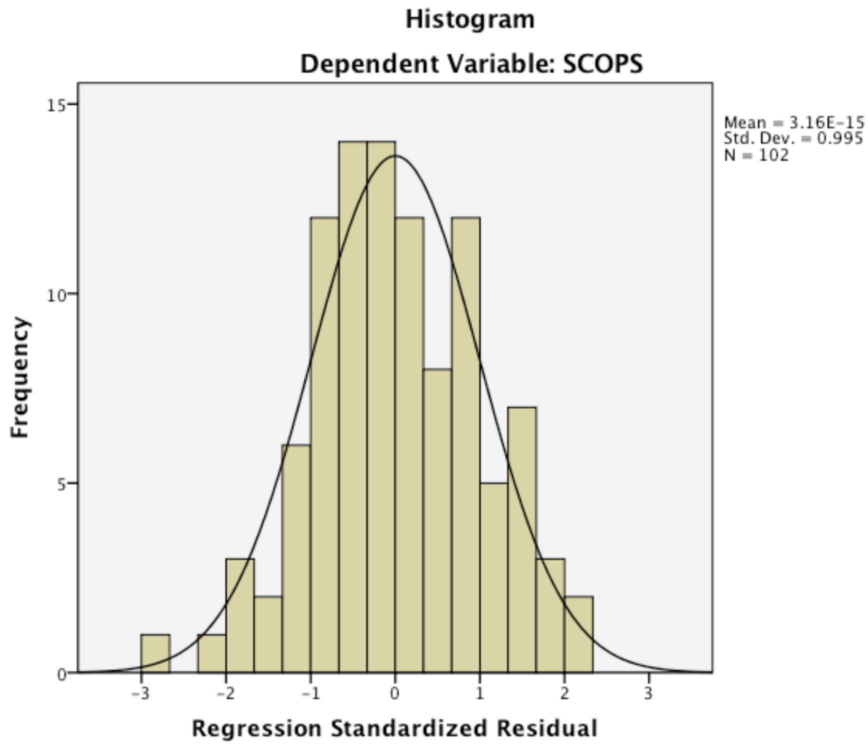

Figure 91: ERP effect on SCOPS regression model standardized residual histogram

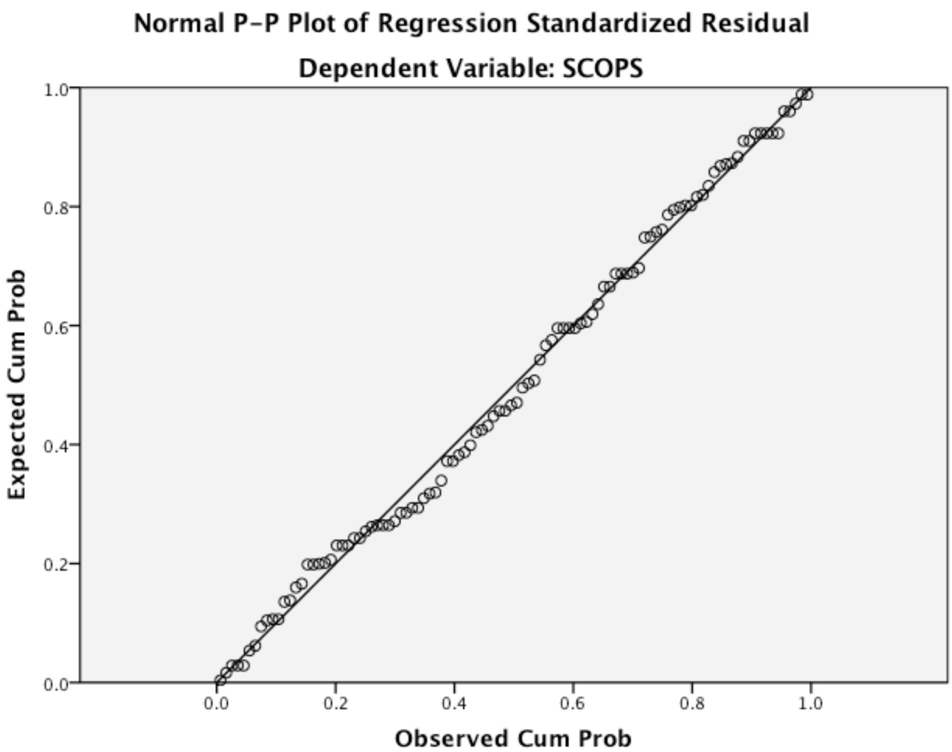

Figure 92: ERP effect on SCOPS regression model standardized residual normal p-p plot

APPENDIX 25: SPSS OUTPUTS OF INDEPENDENT SAMPLES T-TEST TO DETERMINE THE EFFECTS OF ERP ON SCOFS

Table 81: ERP effect on SCOFS independent samples t-test results

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Differance	Std. Error Differance	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper
SCOPS	Equal variances assumed	1.304	.256	-3.467	96	.001	-1.082079549881988	.312128211016776	-1.701649151933727	-.462509947830248
	Equal variances not assumed			-3.546	94.306	.001	-1.082079549881988	.305187460259712	-1.688010777571986	-.476148322191989

APPENDIX 26: SPSS OUTPUTS OF SLR MODEL TO DETERMINE THE EFFECTS OF ERP ON SCOFS

Table 82: ERP effect on SCOFS regression model variable correlation

		SCOPS	*ERPsuc*
Pearson Correlation	SCOFS	1.000	.819
	ERPsuc	.819	1.000
Sig. (1-tailed)	SCOFS	.	.000
	ERPsuc	.000	.

Table 83: ERP effect on SCOFS regression model ANOVA results

Model[b]		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	97.412	1	97.412	109.766	.000a
	Residual	47.922	54	.887		
	Total	145.334	54			

[a]. Predictors: (Constant), *ERPsuc*
[b]. Dependent Variable: SCOFS

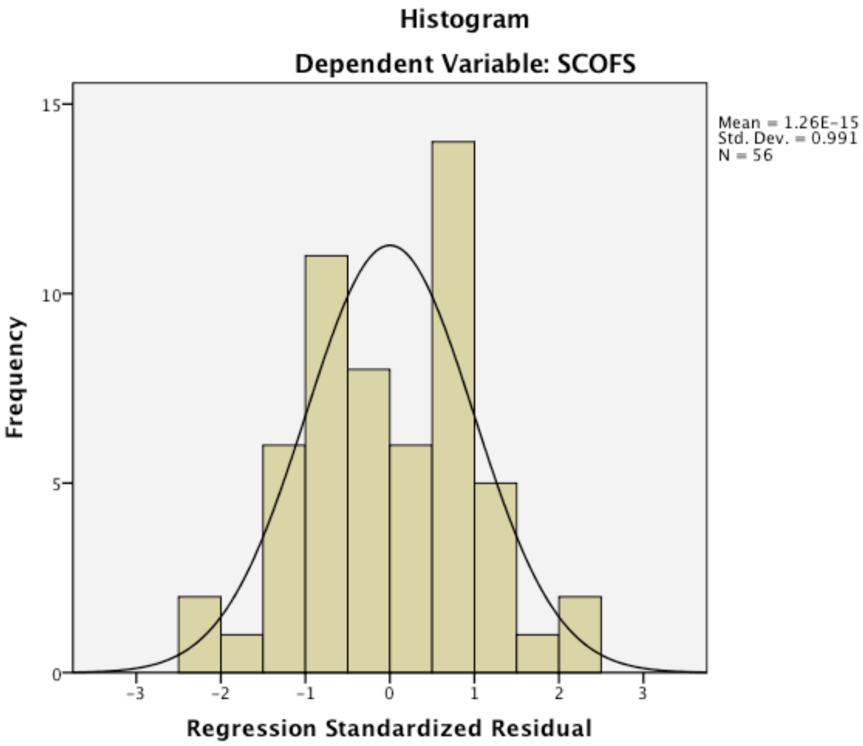

Figure 93: ERP effect on SCOFS regression model standardized residual histogram

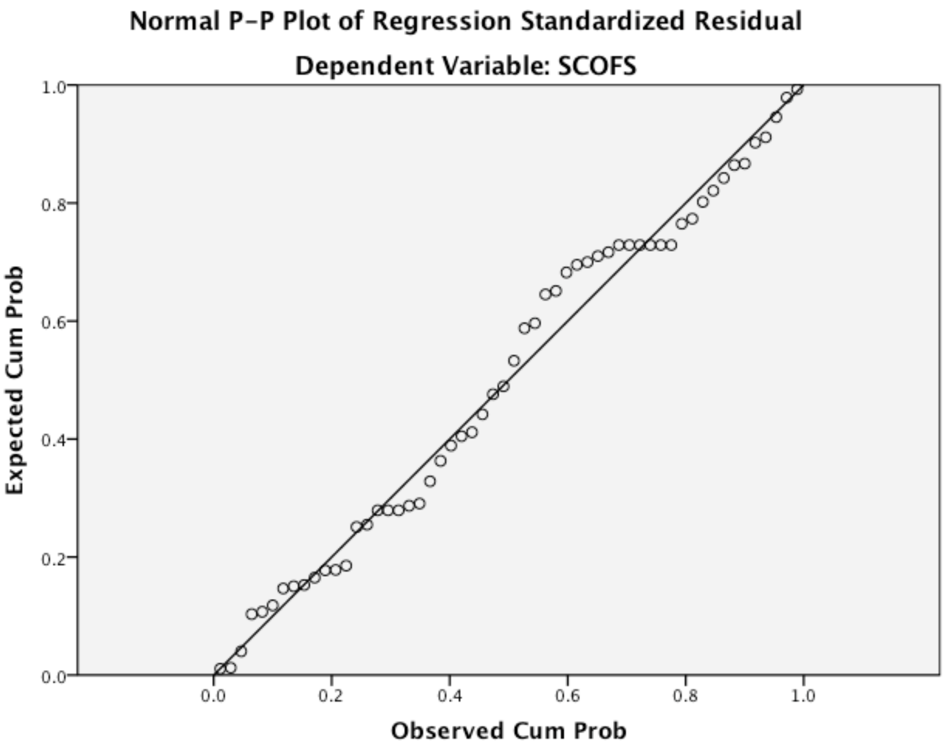

Figure 94: ERP effect on SCOFS regression model standardized residual normal p-p plot

APPENDIX 27: SPSS OUTPUTS OF MLR MODEL TO DETERMINE THE FACTORS EFFECTING ERP SUCCESS

Table 84: ERP success factors regression model variable correlations

		ERP suc	*ERP V1*	*ERP V2*	*ERP V3*	*ERP V4*	*ERP V5*	*ERP V6*	*ERP V7*	*ERP V8*	*ERP V9*	*ERP V10*	*ERP V11*	*ERP V12*	*ERP V13*	*ERP V14*	*ERP V15*	*ERP V16*	*ERP V17*
Pearson Correlation	*ERPsuc*	1.000	.811	.845	.899	.949	.853	.457	.846	.249	.870	.888	.913	.593	.851	-.001	.530	.850	.854
	ERPV1	.811	1.000	.701	.722	.746	.686	.363	.662	.248	.671	.752	.744	.493	.679	-.010	.383	.670	.661
	ERPV2	.845	.701	1.000	.791	.785	.721	.336	.750	.283	.709	.737	.761	.493	.744	-.062	.439	.654	.696
	ERPV3	.899	.722	.791	1.000	.863	.746	.372	.820	.191	.756	.799	.793	.522	.755	-.010	.423	.751	.727
	ERPV4	.949	.746	.785	.863	1.000	.818	.468	.819	.251	.840	.821	.873	.523	.818	-.048	.513	.830	.829
	ERPV5	.853	.686	.721	.746	.818	1.000	.492	.706	.214	.774	.788	.773	.496	.715	-.146	.393	.681	.704
	ERPV6	.457	.363	.336	.372	.468	.492	1.000	.276	.461	.419	.424	.425	.336	.504	-.025	.283	.437	.353
	ERPV7	.846	.662	.750	.820	.819	.706	.276	1.000	.081	.735	.728	.719	.535	.669	-.035	.400	.698	.664
	ERPV8	.249	.248	.283	.191	.251	.214	.461	.081	1.000	.205	.203	.297	-.002	.424	-.085	.114	.197	.272
	ERPV9	.870	.671	.709	.756	.840	.774	.419	.735	.205	1.000	.746	.799	.487	.729	-.043	.413	.782	.736
	ERPV10	.888	.752	.737	.799	.821	.788	.424	.728	.203	.746	1.000	.838	.506	.747	-.015	.485	.750	.744
	ERPV11	.913	.744	.761	.793	.873	.773	.425	.719	.297	.799	.838	1.000	.470	.793	-.056	.499	.816	.813
	ERPV12	.593	.493	.493	.522	.523	.496	.336	.535	-.002	.487	.506	.470	1.000	.544	-.021	.242	.454	.447
	ERPV13	.851	.679	.744	.755	.818	.715	.504	.669	.424	.729	.747	.793	.544	1.000	-.010	.449	.699	.731
	ERPV14	-.001	-.010	-.062	-.010	-.048	-.146	-.025	-.035	-.085	-.043	-.015	-.056	-.021	-.010	1.000	.259	.007	-.020
	ERPV15	.530	.383	.439	.423	.513	.393	.283	.400	.114	.413	.485	.499	.242	.449	.259	1.000	.439	.432
	ERPV16	.850	.670	.654	.751	.830	.681	.437	.698	.197	.782	.750	.816	.454	.699	.007	.439	1.000	.750
	ERPV17	.854	.661	.696	.727	.829	.704	.353	.664	.272	.736	.744	.813	.447	.731	-.020	.432	.750	1.000
Sig. (1-tailed)	*ERPsuc*	.	.000	.000	.000	.000	.000	.000	.000	.006	.000	.000	.000	.000	.000	.494	.000	.000	.000
	ERPV1	.000	.	.000	.000	.000	.000	.000	.000	.006	.000	.000	.000	.000	.000	.459	.000	.000	.000
	ERPV2	.000	.000	.	.000	.000	.000	.000	.000	.002	.000	.000	.000	.000	.000	.267	.000	.000	.000
	ERPV3	.000	.000	.000	.	.000	.000	.000	.000	.027	.000	.000	.000	.000	.000	.461	.000	.000	.000
	ERPV4	.000	.000	.000	.000	.	.000	.000	.000	.006	.000	.000	.000	.000	.000	.318	.000	.000	.000
	ERPV5	.000	.000	.000	.000	.000	.	.000	.000	.015	.000	.000	.000	.000	.000	.071	.000	.000	.000
	ERPV6	.000	.000	.000	.000	.000	.000	.	.002	.000	.000	.000	.000	.000	.000	.400	.002	.000	.000
	ERPV7	.000	.000	.000	.000	.000	.000	.002	.	.208	.000	.000	.000	.000	.000	.364	.000	.000	.000
	ERPV8	.006	.006	.002	.027	.006	.015	.000	.208	.	.020	.020	.001	.493	.000	.198	.127	.024	.003
	ERPV9	.000	.000	.000	.000	.000	.000	.000	.000	.020	.	.000	.000	.000	.000	.333	.000	.000	.000
	ERPV10	.000	.000	.000	.000	.000	.000	.000	.000	.020	.000	.	.000	.000	.000	.441	.000	.000	.000
	ERPV11	.000	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.	.000	.000	.286	.000	.000	.000
	ERPV12	.000	.000	.000	.000	.000	.000	.000	.000	.493	.000	.000	.000	.	.000	.418	.007	.000	.000
	ERPV13	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.459	.000	.000	.000
	ERPV14	.494	.459	.267	.461	.318	.071	.400	.364	.198	.333	.441	.286	.418	.459	.	.004	.471	.421
	ERPV15	.000	.000	.000	.000	.000	.000	.002	.000	.127	.000	.000	.000	.007	.000	.004	.	.000	.000
	ERPV16	.000	.000	.000	.000	.000	.000	.000	.000	.024	.000	.000	.000	.000	.000	.471	.000	.	.000
	ERPV17	.000	.000	.000	.000	.000	.000	.000	.000	.003	.000	.000	.000	.000	.000	.421	.000	.000	.

Table 85: ERP success factors regression model ANOVA results

Model[p]		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	204.585	1	204.585	902.452	.000[a]
	Residual	22.670	100	.227		
	Total	227.255	101			
2	Regression	212.880	2	106.440	733.074	.000[b]
	Residual	14.375	99	.145		
	Total	227.255	101			
3	Regression	215.954	3	71.985	624.222	.000[c]
	Residual	11.301	98	.115		
	Total	227.255	101			
4	Regression	217.746	4	54.437	555.306	.000[d]
	Residual	9.509	97	.098		
	Total	227.255	101			
5	Regression	218.855	5	43.771	500.225	.000[e]
	Residual	8.400	96	.088		
	Total	227.255	101			
6	Regression	220.010	6	36.668	480.842	.000[f]
	Residual	7.245	95	.076		
	Total	227.255	101			
7	Regression	220.835	7	31.548	461.957	.000[g]
	Residual	6.419	94	.068		
	Total	227.255	101			
8	Regression	221.578	8	27.697	453.774	.000[h]
	Residual	5.676	93	.061		
	Total	227.255	101			
9	Regression	222.042	9	24.671	435.371	.000[i]
	Residual	5.213	92	.057		
	Total	227.255	101			
10	Regression	222.372	10	22.237	414.416	.000[j]
	Residual	4.883	91	.054		
	Total	227.255	101			
11	Regression	222.699	11	20.245	399.951	.000[k]
	Residual	4.556	90	.051		
	Total	227.255	101			
12	Regression	223.019	12	18.585	390.500	.000[l]
	Residual	4.236	89	.048		
	Total	227.255	101			

Table 85: (continued)

13	Regression	223.262	13	17.174	378.471	.000[m]
	Residual	3.993	88	.045		
	Total	227.255	101			
14	Regression	223.469	14	15.962	366.818	.000[n]
	Residual	3.786	87	.044		
	Total	227.255	101			
15	Regression	223.680	15	14.912	358.706	.000[o]
	Residual	3.575	86	.042		
	Total	227.255	101			

[a]. Predictors: (Constant), *ERPV4*
[b]. Predictors: (Constant), *ERPV4, ERPV10*
[c]. Predictors: (Constant), *ERPV4, ERPV10, ERPV2*
[d]. Predictors: (Constant), *ERPV4, ERPV10, ERPV2, ERPV9*
[e]. Predictors: (Constant), *ERPV4, ERPV10, ERPV2, ERPV9, ERPV3*
[f]. Predictors: (Constant), *ERPV4, ERPV10, ERPV2, ERPV9, ERPV3, ERPV17*
[g]. Predictors: (Constant), *ERPV4, ERPV10, ERPV2, ERPV9, ERPV3, ERPV17, ERPV12*
[h]. Predictors: (Constant), *ERPV4, ERPV10, ERPV2, ERPV9, ERPV3, ERPV17, ERPV12, ERPV11*
[i]. Predictors: (Constant), *ERPV4, ERPV10, ERPV2, ERPV9, ERPV3, ERPV17, ERPV12, ERPV11, ERPV1*
[j]. Predictors: (Constant), *ERPV4, ERPV10, ERPV2, ERPV9, ERPV3, ERPV17, ERPV12, ERPV11, ERPV1, ERPV15*
[k]. Predictors: (Constant), *ERPV4, ERPV10, ERPV2, ERPV9, ERPV3, ERPV17, ERPV12, ERPV11, ERPV1, ERPV15, ERPV7*
[l]. Predictors: (Constant), *ERPV4, ERPV10, ERPV2, ERPV9, ERPV3, ERPV17, ERPV12, ERPV11, ERPV1, ERPV15, ERPV7, ERPV5*
[m]. Predictors: (Constant), *ERPV4, ERPV10, ERPV2, ERPV9, ERPV3, ERPV17, ERPV12, ERPV11, ERPV1, ERPV15, ERPV7, ERPV5, ERPV14*
[n]. Predictors: (Constant), *ERPV4, ERPV10, ERPV2, ERPV9, ERPV3, ERPV17, ERPV12, ERPV11, ERPV1, ERPV15, ERPV7, ERPV5, ERPV14, ERPV16*
[o]. Predictors: (Constant), *ERPV4, ERPV10, ERPV2, ERPV9, ERPV3, ERPV17, ERPV12, ERPV11, ERPV1, ERPV15, ERPV7, ERPV5, ERPV14, ERPV16, ERPV13*
[p]. Dependent Variable: *ERPsuc*

Table 86: ERP success factors regression model variable coefficients

Model[a]		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics
		B	Std. Error	Beta			VIF
1	(Constant)	.433	.152		2.844	.005	
	ERPV4	.930	.031	.949	30.041	.000	1.000
2	(Constant)	.400	.122		3.281	.001	
	ERPV4	.661	.043	.674	15.228	.000	3.067
	ERPV10	.292	.039	.335	7.559	.000	3.067
3	(Constant)	.257	.112		2.288	.024	
	ERPV4	.556	.044	.567	12.710	.000	3.919
	ERPV10	.244	.036	.279	6.837	.000	3.292
	ERPV2	.189	.037	.194	5.162	.000	2.795
4	(Constant)	.168	.106		1.590	.115	
	ERPV4	.450	.047	.458	9.492	.000	5.408
	ERPV10	.222	.033	.255	6.693	.000	3.367
	ERPV2	.173	.034	.179	5.117	.000	2.827
	ERPV9	.165	.038	.167	4.276	.000	3.556
5	(Constant)	.133	.100		1.331	.186	
	ERPV4	.377	.049	.384	7.661	.000	6.534
	ERPV10	.195	.032	.224	6.030	.000	3.571
	ERPV2	.137	.034	.142	4.092	.000	3.109
	ERPV9	.161	.036	.164	4.427	.000	3.559
	ERPV3	.147	.041	.153	3.559	.001	4.804
6	(Constant)	.050	.096		.518	.606	
	ERPV4	.300	.050	.306	5.992	.000	7.752
	ERPV10	.175	.031	.201	5.729	.000	3.670
	ERPV2	.127	.031	.131	4.029	.000	3.132
	ERPV9	.149	.034	.151	4.361	.000	3.590
	ERPV3	.155	.039	.162	4.022	.000	4.819
	ERPV17	.131	.034	.131	3.893	.000	3.389
7	(Constant)	-.020	.093		-.212	.832	
	ERPV4	.292	.047	.298	6.162	.000	7.769
	ERPV10	.166	.029	.191	5.720	.000	3.700
	ERPV2	.118	.030	.122	3.952	.000	3.154
	ERPV9	.142	.032	.144	4.380	.000	3.604
	ERPV3	.144	.037	.150	3.934	.000	4.855
	ERPV17	.133	.032	.133	4.165	.000	3.389
	ERPV12	.057	.016	.073	3.476	.001	1.450

Table 86: (continued)

8	(Constant)	-.082	.090		-.911	.364	
	ERPV4	.250	.046	.255	5.391	.000	8.329
	ERPV10	.131	.029	.150	4.450	.000	4.214
	ERPV2	.105	.028	.108	3.685	.000	3.210
	ERPV9	.124	.031	.126	4.000	.000	3.703
	ERPV3	.145	.035	.151	4.187	.000	4.855
	ERPV17	.106	.031	.106	3.387	.001	3.618
	ERPV12	.061	.016	.078	3.918	.000	1.458
	ERPV11	.139	.040	.139	3.489	.001	5.915
9	(Constant)	-.134	.088		-1.519	.132	
	ERPV4	.241	.045	.246	5.386	.000	8.368
	ERPV10	.113	.029	.129	3.895	.000	4.419
	ERPV2	.094	.028	.097	3.378	.001	3.276
	ERPV9	.123	.030	.125	4.128	.000	3.704
	ERPV3	.139	.033	.144	4.140	.000	4.878
	ERPV17	.106	.030	.106	3.513	.001	3.618
	ERPV12	.056	.015	.071	3.711	.000	1.477
	ERPV11	.126	.039	.125	3.242	.002	6.006
	ERPV1	.074	.026	.076	2.859	.005	2.816
10	(Constant)	-.213	.092		-2.328	.022	
	ERPV4	.220	.044	.225	4.966	.000	8.678
	ERPV10	.104	.028	.119	3.662	.000	4.489
	ERPV2	.089	.027	.091	3.275	.001	3.295
	ERPV9	.129	.029	.131	4.413	.000	3.724
	ERPV3	.147	.033	.153	4.480	.000	4.927
	ERPV17	.108	.029	.108	3.698	.000	3.623
	ERPV12	.058	.015	.073	3.903	.000	1.479
	ERPV11	.117	.038	.117	3.097	.003	6.054
	ERPV1	.077	.025	.079	3.071	.003	2.825
	ERPV15	.041	.016	.045	2.481	.015	1.423
11	(Constant)	-.226	.089		-2.530	.013	
	ERPV4	.191	.045	.195	4.288	.000	9.292
	ERPV10	.100	.028	.115	3.631	.000	4.501
	ERPV2	.076	.027	.078	2.848	.005	3.410
	ERPV9	.121	.028	.123	4.231	.000	3.771
	ERPV3	.123	.033	.128	3.696	.000	5.363
	ERPV17	.114	.028	.114	3.997	.000	3.646
	ERPV12	.052	.014	.067	3.630	.000	1.508
	ERPV11	.127	.037	.126	3.424	.001	6.113
	ERPV1	.077	.024	.080	3.170	.002	2.825
	ERPV15	.042	.016	.047	2.625	.010	1.424
	ERPV7	.072	.028	.075	2.542	.013	3.922

Table 86: (continued)

12	(Constant)	-.219	.087		-2.537	.013	
	ERPV4	.166	.044	.169	3.744	.000	9.764
	ERPV10	.082	.028	.094	2.954	.004	4.819
	ERPV2	.068	.026	.070	2.613	.011	3.457
	ERPV9	.105	.028	.107	3.730	.000	3.941
	ERPV3	.126	.032	.131	3.901	.000	5.370
	ERPV17	.116	.028	.116	4.198	.000	3.649
	ERPV12	.050	.014	.064	3.586	.001	1.513
	ERPV11	.125	.036	.124	3.476	.001	6.116
	ERPV1	.075	.024	.078	3.186	.002	2.828
	ERPV15	.046	.016	.051	2.958	.004	1.439
	ERPV7	.073	.027	.076	2.657	.009	3.923
	ERPV5	.063	.024	.073	2.593	.011	3.767
13	(Constant)	-.344	.100		-3.434	.001	
	ERPV4	.173	.043	.177	3.990	.000	9.814
	ERPV10	.079	.027	.091	2.919	.004	4.828
	ERPV2	.073	.026	.075	2.854	.005	3.480
	ERPV9	.101	.028	.103	3.669	.000	3.956
	ERPV3	.118	.032	.123	3.741	.000	5.426
	ERPV17	.112	.027	.112	4.148	.000	3.663
	ERPV12	.050	.014	.063	3.636	.000	1.514
	ERPV11	.132	.035	.132	3.760	.000	6.170
	ERPV1	.072	.023	.074	3.099	.003	2.841
	ERPV15	.033	.016	.037	2.066	.042	1.626
	ERPV7	.073	.027	.076	2.721	.008	3.923
	ERPV5	.074	.024	.085	3.049	.003	3.910
	ERPV14	.033	.014	.036	2.312	.023	1.206
14	(Constant)	-.343	.098		-3.492	.001	
	ERPV4	.154	.043	.157	3.538	.001	10.247
	ERPV10	.075	.027	.086	2.806	.006	4.857
	ERPV2	.080	.025	.083	3.179	.002	3.543
	ERPV9	.087	.028	.089	3.148	.002	4.175
	ERPV3	.114	.031	.119	3.670	.000	5.449
	ERPV17	.107	.027	.107	4.015	.000	3.695
	ERPV12	.050	.013	.063	3.692	.000	1.514
	ERPV11	.114	.035	.114	3.224	.002	6.526
	ERPV1	.070	.023	.072	3.089	.003	2.844
	ERPV15	.034	.016	.038	2.153	.034	1.626
	ERPV7	.071	.026	.074	2.714	.008	3.926
	ERPV5	.080	.024	.093	3.363	.001	3.973
	ERPV14	.031	.014	.034	2.229	.028	1.210
	ERPV16	.062	.028	.061	2.183	.032	4.038

Table 86: (continued)

15	(Constant)	-.436	.105		-4.172	.000	
	ERPV4	.133	.043	.135	3.047	.003	10.750
	ERPV10	.072	.026	.082	2.762	.007	4.867
	ERPV2	.070	.025	.072	2.767	.007	3.675
	ERPV9	.084	.027	.086	3.107	.003	4.184
	ERPV3	.109	.030	.114	3.601	.001	5.472
	ERPV17	.104	.026	.104	3.977	.000	3.706
	ERPV12	.043	.013	.055	3.208	.002	1.587
	ERPV11	.102	.035	.102	2.910	.005	6.687
	ERPV1	.069	.022	.072	3.135	.002	2.844
	ERPV15	.034	.016	.038	2.188	.031	1.626
	ERPV7	.079	.026	.083	3.079	.003	4.013
	ERPV5	.080	.023	.092	3.415	.001	3.973
	ERPV14	.029	.014	.032	2.142	.035	1.214
	ERPV16	.065	.028	.064	2.335	.022	4.046
	ERPV13	.075	.033	.059	2.251	.027	3.767

[a]. Dependent Variable: *ERPsuc*

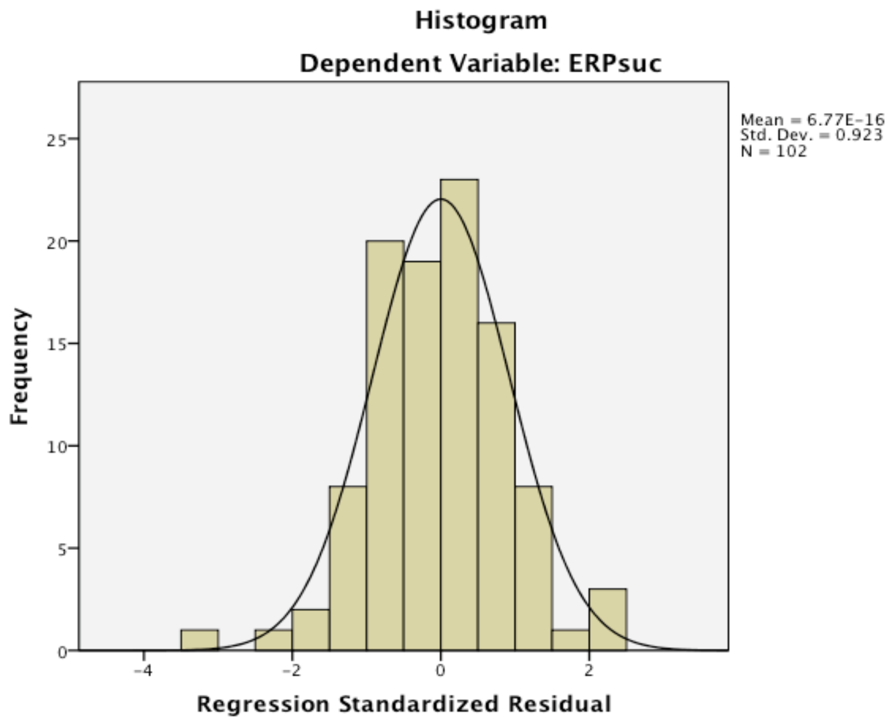

Figure 95: ERP success factors regression model standardized residual histogram

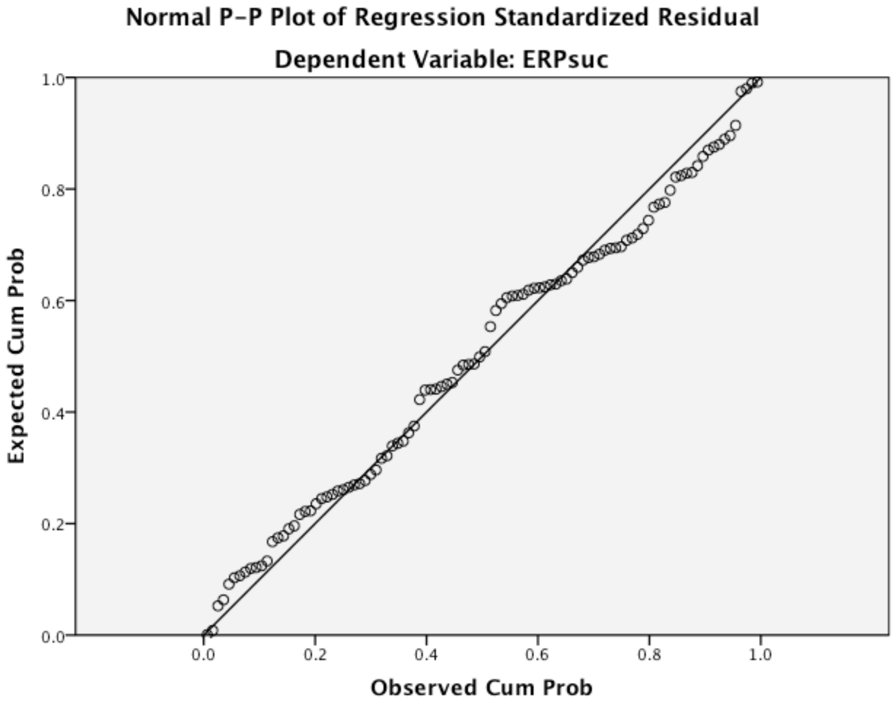

Figure 96: ERP success factors regression model standardized residual normal p-p plot

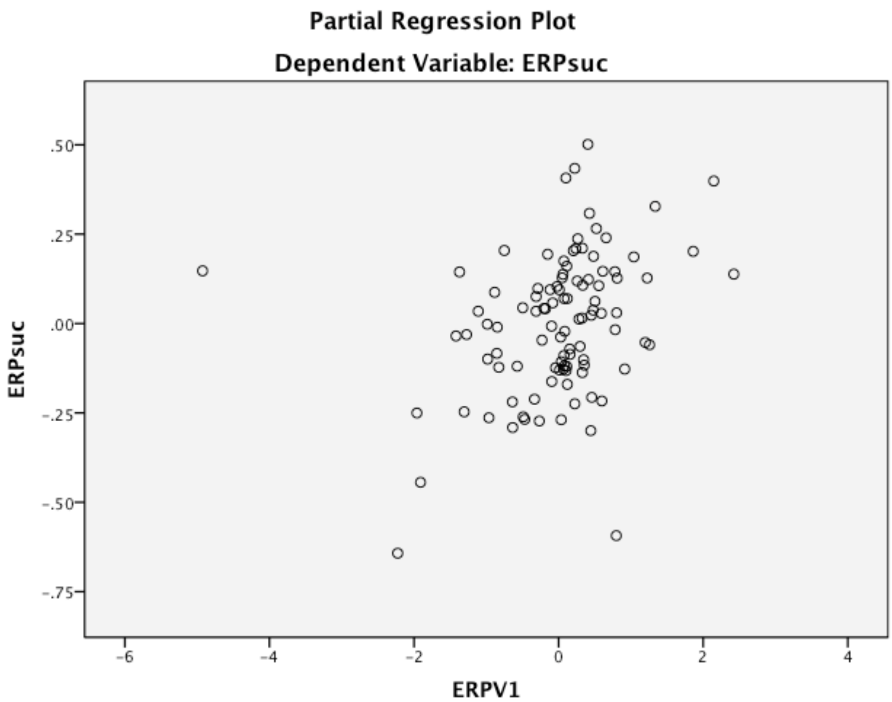

Figure 97: Partial plot of *ERPsuc* and *ERPV1*

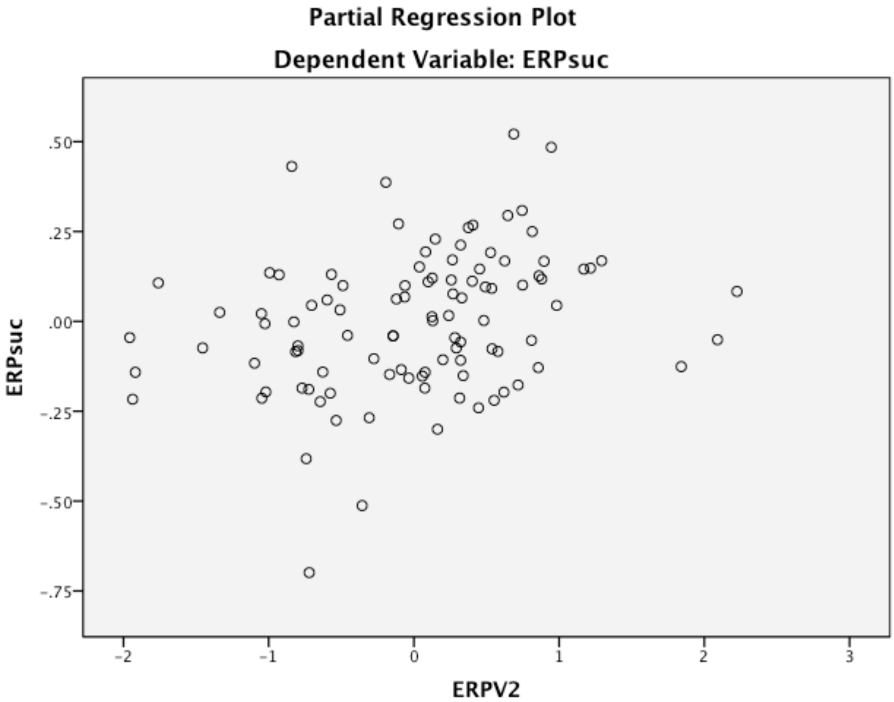

Figure 98: Partial plot of *ERPsuc* and *ERPV2*

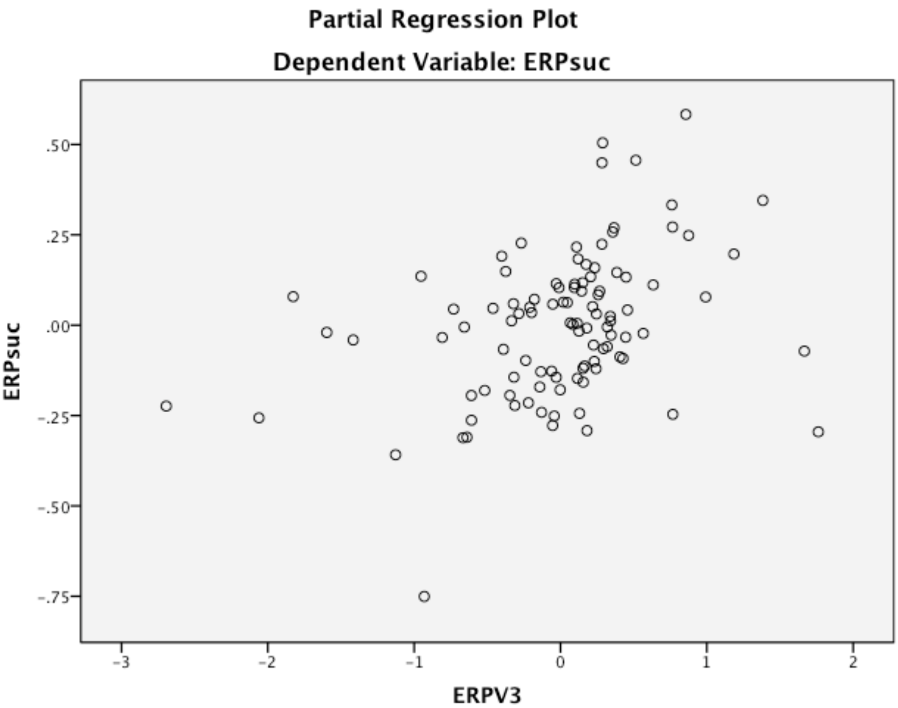

Figure 99: Partial plot of *ERPsuc* and *ERPV3*

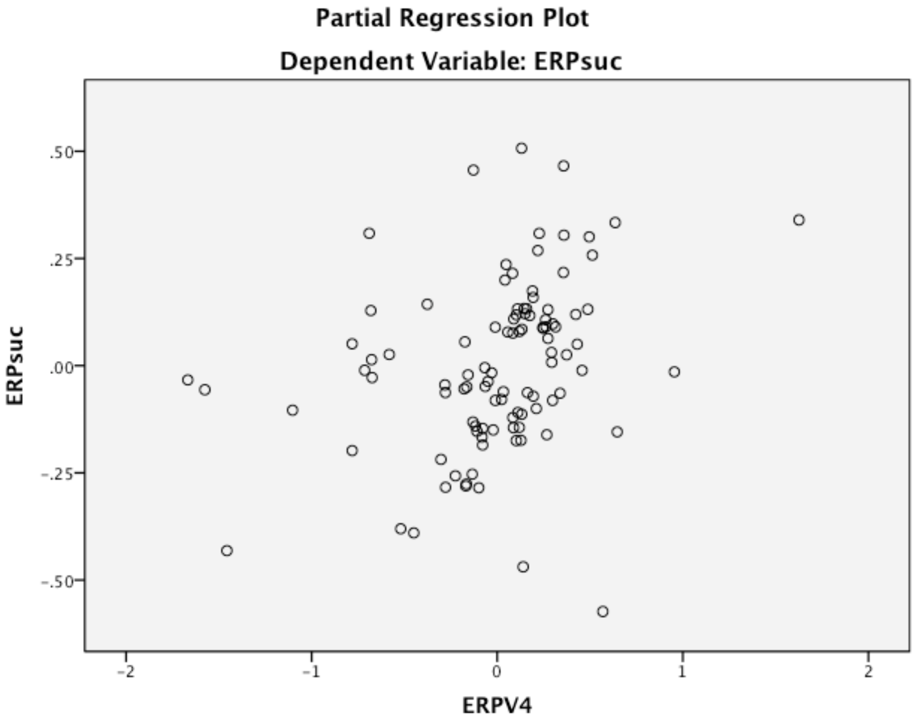

Figure 100: Partial plot of *ERPsuc* and *ERPV4*

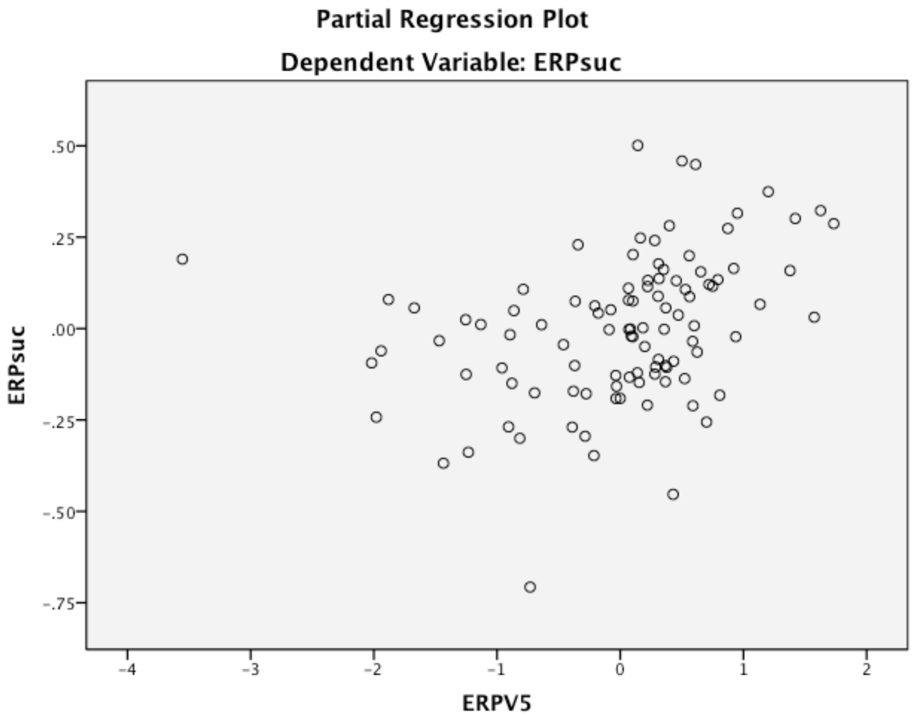

Figure 101: Partial plot of *ERPsuc* and *ERPV5*

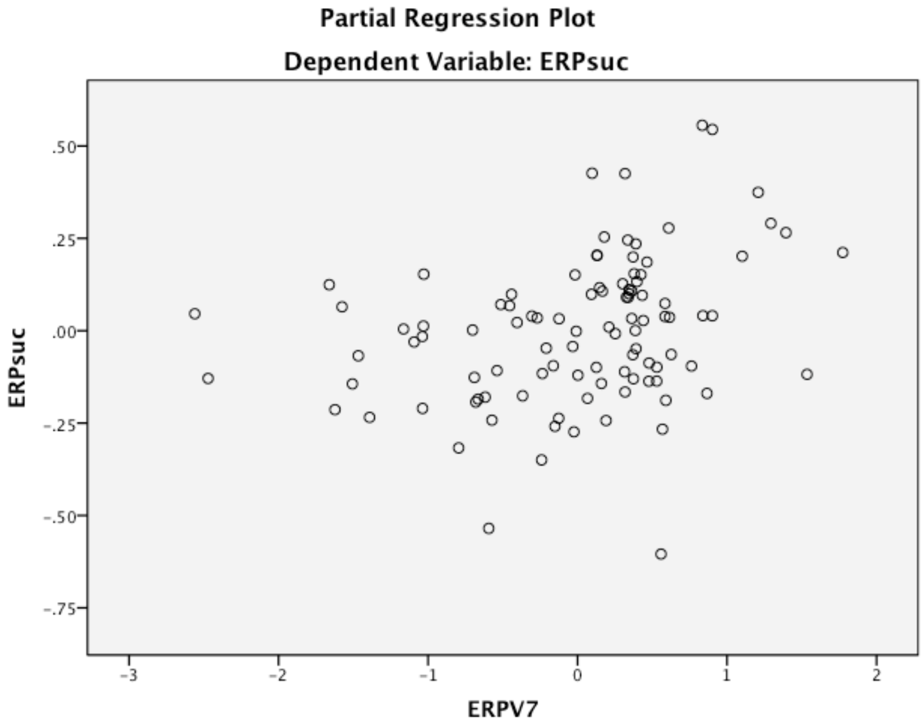

Figure 102: Partial plot of *ERPsuc* and *ERPV7*

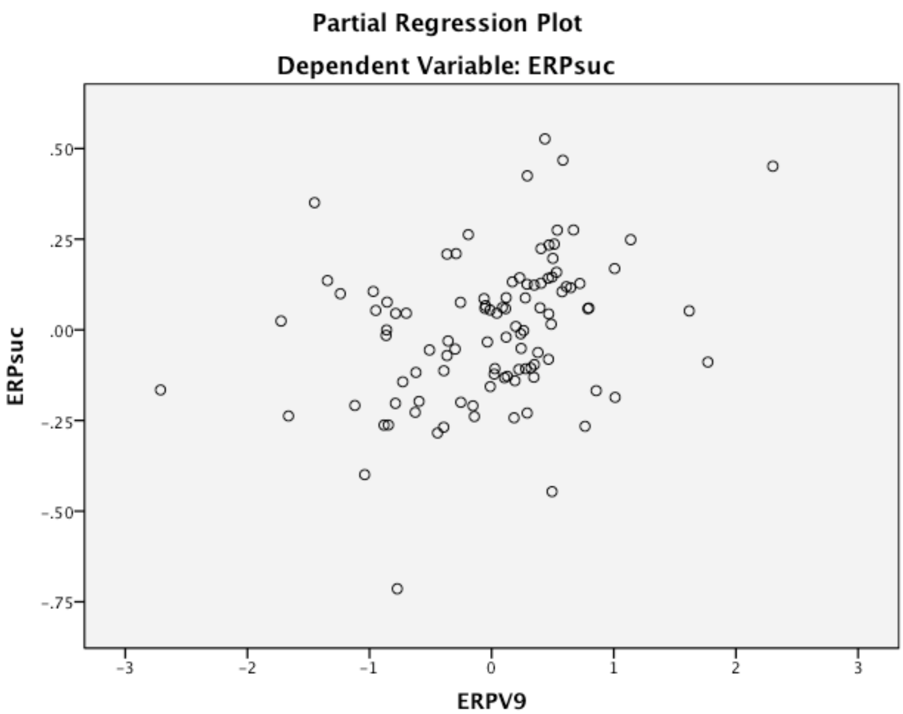

Figure 103: Partial plot of *ERPsuc* and *ERPV9*

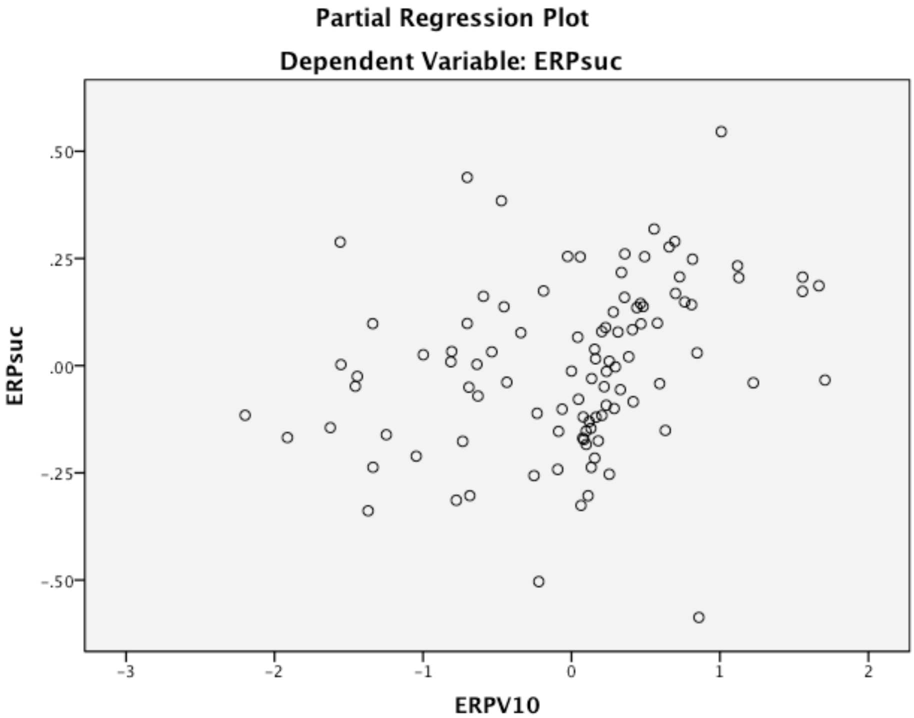

Figure 104: Partial plot of *ERPsuc* and *ERPV10*

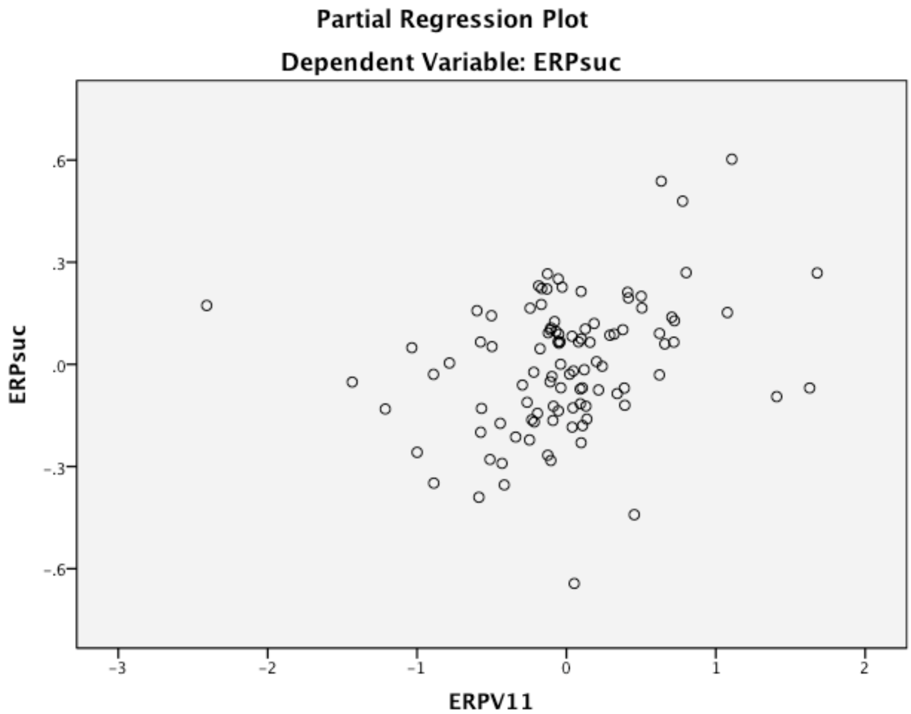

Figure 105: Partial plot of *ERPsuc* and *ERPV11*

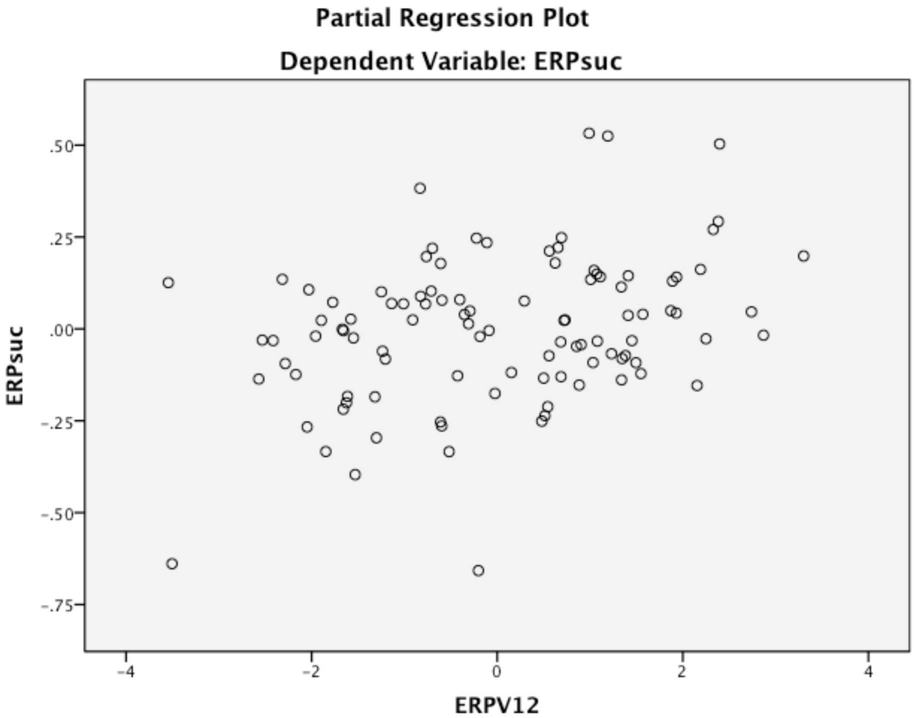

Figure 106: Partial plot of *ERPsuc* and *ERPV12*

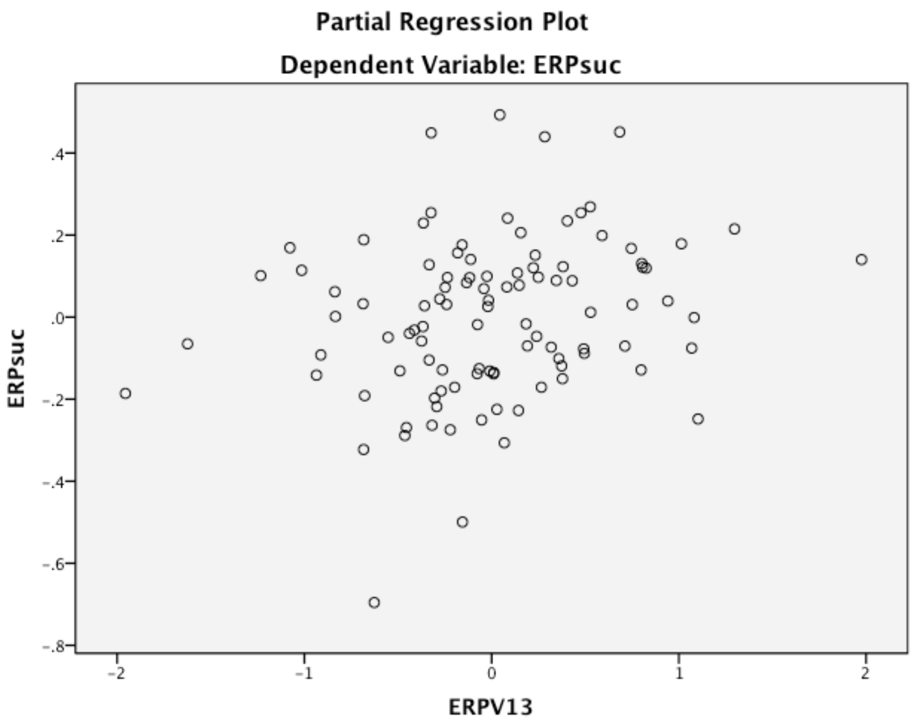

Figure 107: Partial plot of *ERPsuc* and *ERPV13*

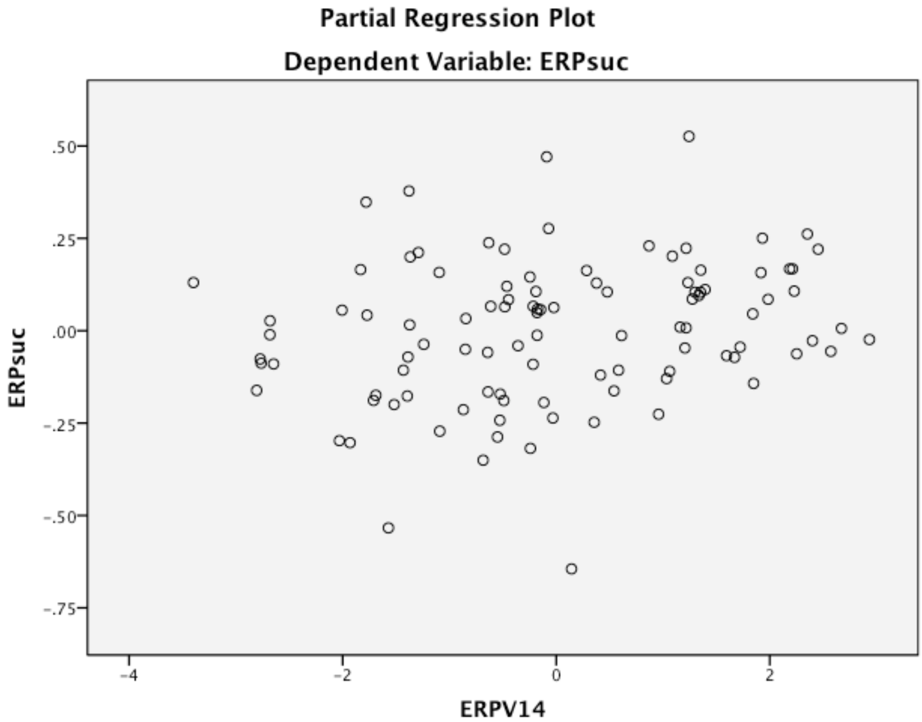

Figure 108: Partial plot of *ERPsuc* and *ERPV14*

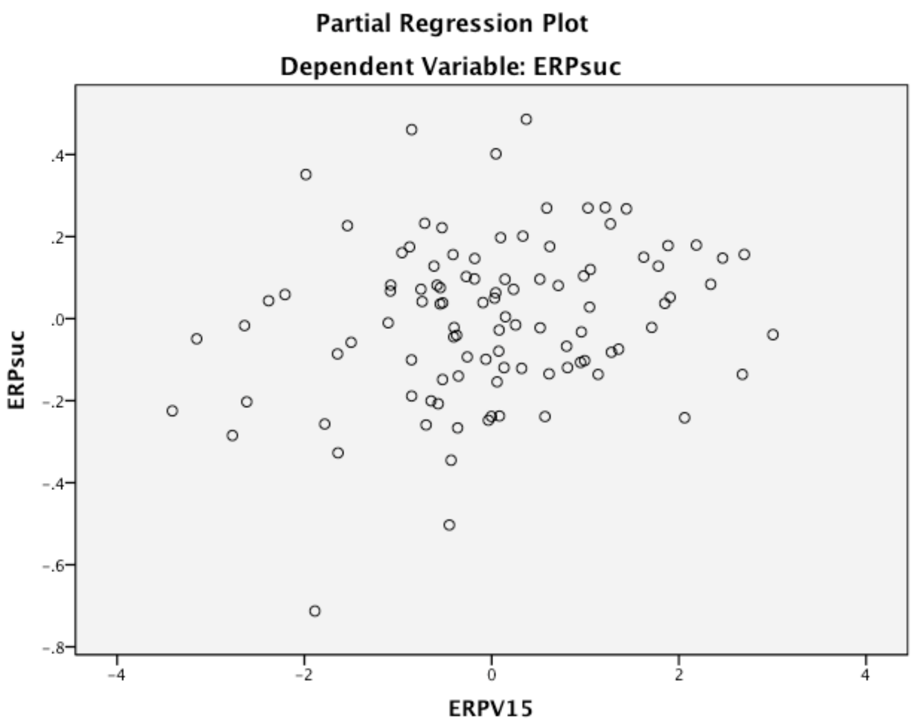

Figure 109: Partial plot of *ERPsuc* and *ERPV15*

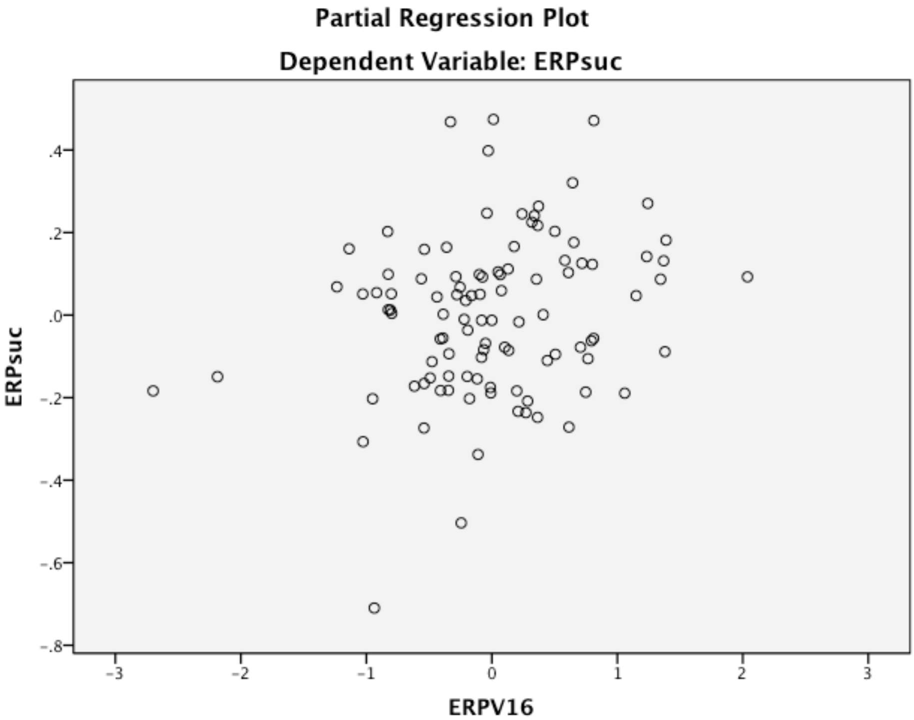

Figure 110: Partial plot of *ERPsuc* and *ERPV16*

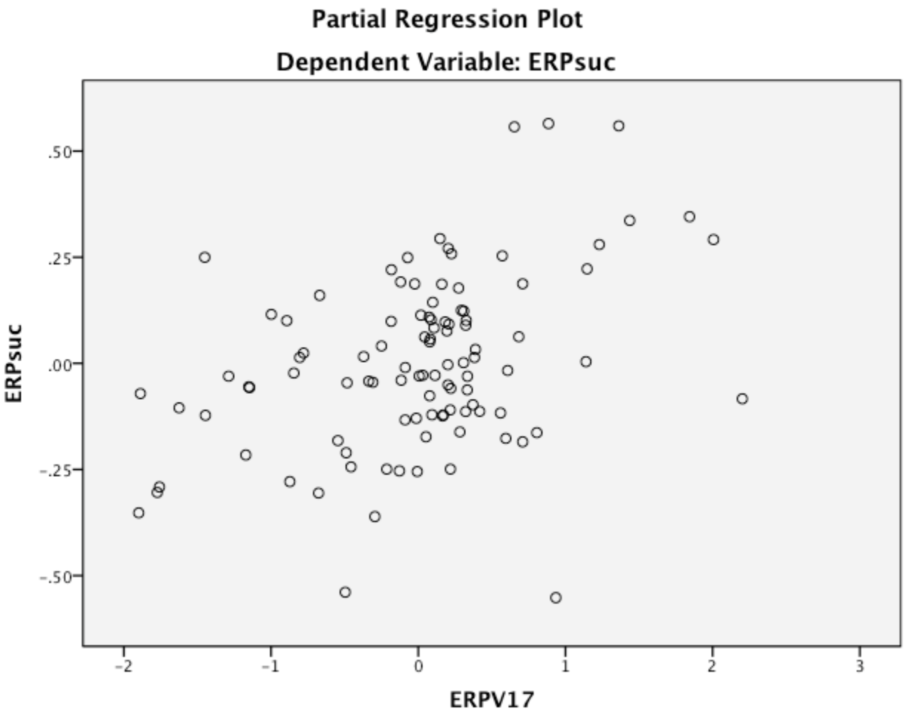

Figure 111: Partial plot of *ERPsuc* and *ERPV17*

APPENDIX 28: SPSS OUTPUTS OF INDEPENDENT SAMPLES T-TEST TO DETERMINE THE EFFECTS OF BPR ON SCOPS

Table 87: BPR effect on SCOPS independent samples t-test results

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Differance	Std. Error Differance	95% Confidence Interval of the Difference Lower	Upper
SCOPS	Equal variances assumed	1.558	.215	-3.834	100	.000	-.92179015	.24043382	-1.39880400	-.44477629
	Equal variances not assumed			-3.616	56.866	.001	-.92179015	.25491363	-1.43227199	-.41130831

APPENDIX 29: SPSS OUTPUTS OF SLR MODEL TO DETERMINE THE EFFECTS OF BPR ON SCOPS

Table 88: BPR effect on SCOPS regression model variable correlation

		SCOPS	*BPRsuc*
Pearson Correlation	SCOPS	1.000	.742
	BPRsuc	.742	1.000
Sig. (1-tailed)	SCOPS	.	.000
	BPRsuc	.000	.

Table 89: BPR effect on SCOPS regression model ANOVA results

Model[b]		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	42.500	1	42.500	81.035	.000a
	Residual	34.615	66	.524		
	Total	77.115	67			

[a]. Predictors: (Constant), *BPRsuc*
[b]. Dependent Variable: SCOPS

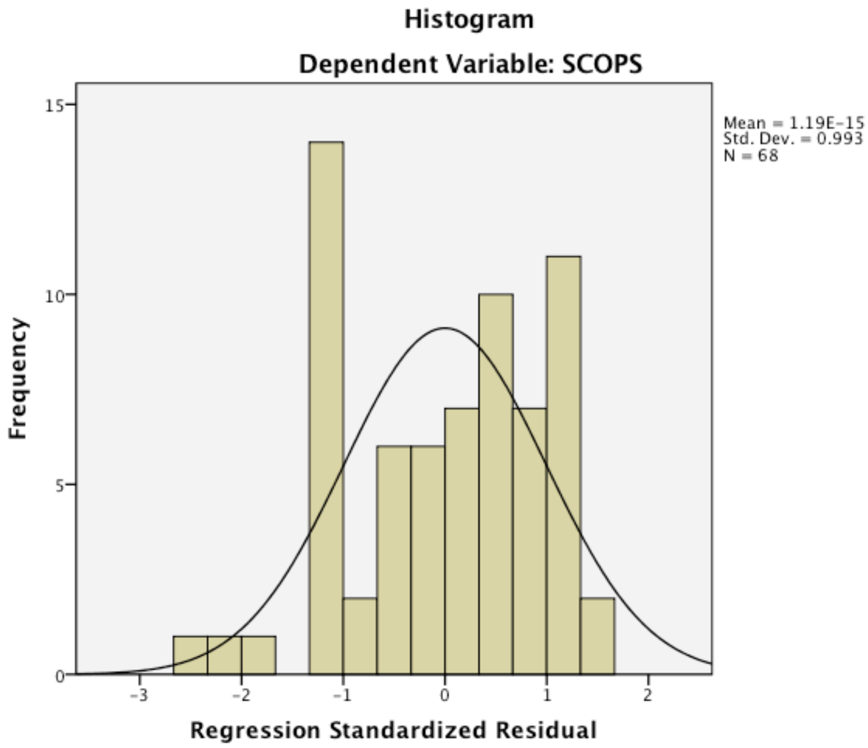

Figure 112: BPR effect on SCOPS regression model standardized residual histogram

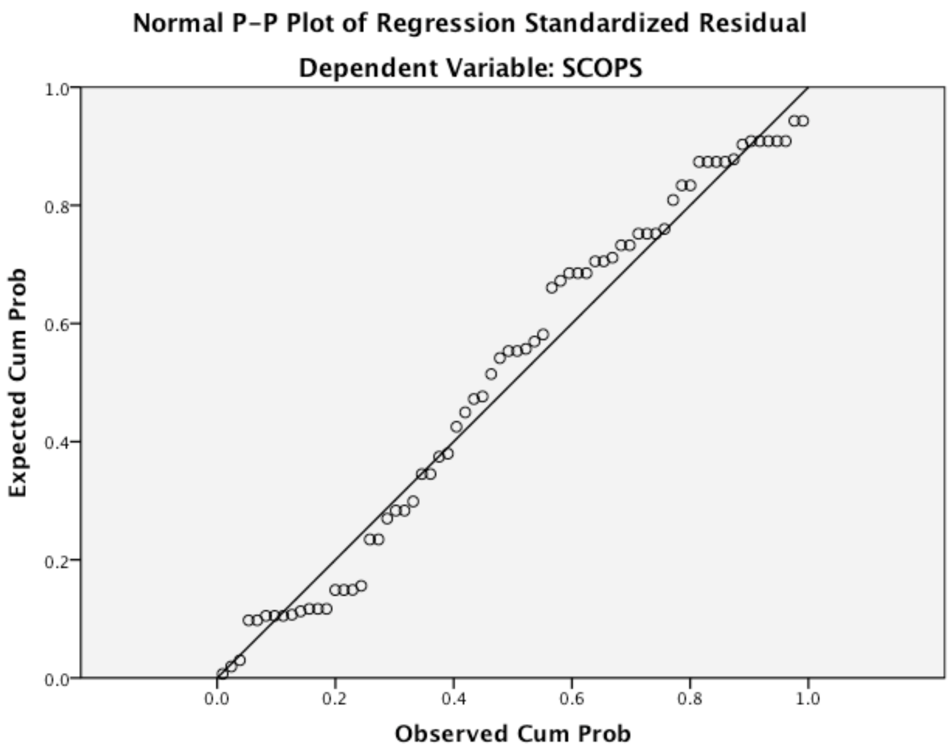

Figure 113: BPR effect on SCOPS regression model standardized residual normal p-p plot

APPENDIX 30: SPSS OUTPUTS OF INDEPENDENT SAMPLES T-TEST TO DETERMINE THE EFFECTS OF BPR ON ERP

Table 90: BPR effect on ERP independent samples t-test results

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Differance	Std. Error Differance	95% Confidence Interval of the Difference Lower	Upper
ERPsuc	Equal variances assumed	.365	.547	-4.178	100	.000	-1.221	.292	-1.800	-.641
	Equal variances not assumed			-4.127	64.022	.000	-1.221	.296	-1.811	-.630

APPENDIX 31: SPSS OUTPUTS OF SLR MODEL TO DETERMINE THE EFFECTS OF BPR ON ERP

Table 91: BPR effect on ERP regression model variable correlation

		ERPsuc	*BPRsuc*
Pearson Correlation	*ERPsuc*	1.000	.846
	BPRsuc	.846	1.000
Sig. (1-tailed)	*ERPsuc*	.	.000
	BPRsuc	.000	.

Table 92: BPR effect on ERP regression model ANOVA results

Model[b]		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	90.452	1	90.452	165.541	.000[a]
	Residual	36.063	66	.546		
	Total	126.515	67			

[a]. Predictors: (Constant), *BPRsuc*
[b]. Dependent Variable: *ERPsuc*

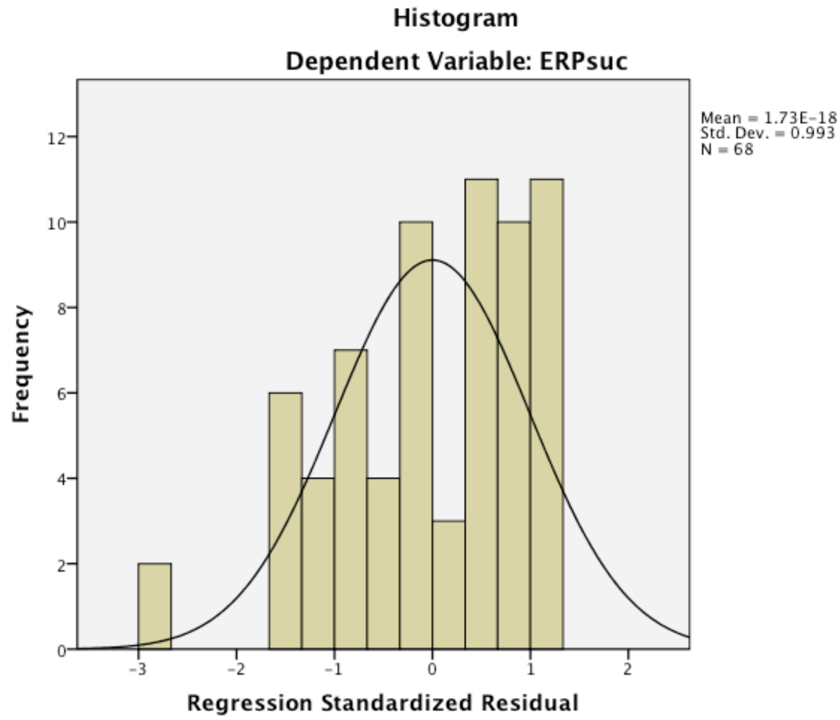

Figure 114: BPR effect on ERP regression model standardized residual histogram

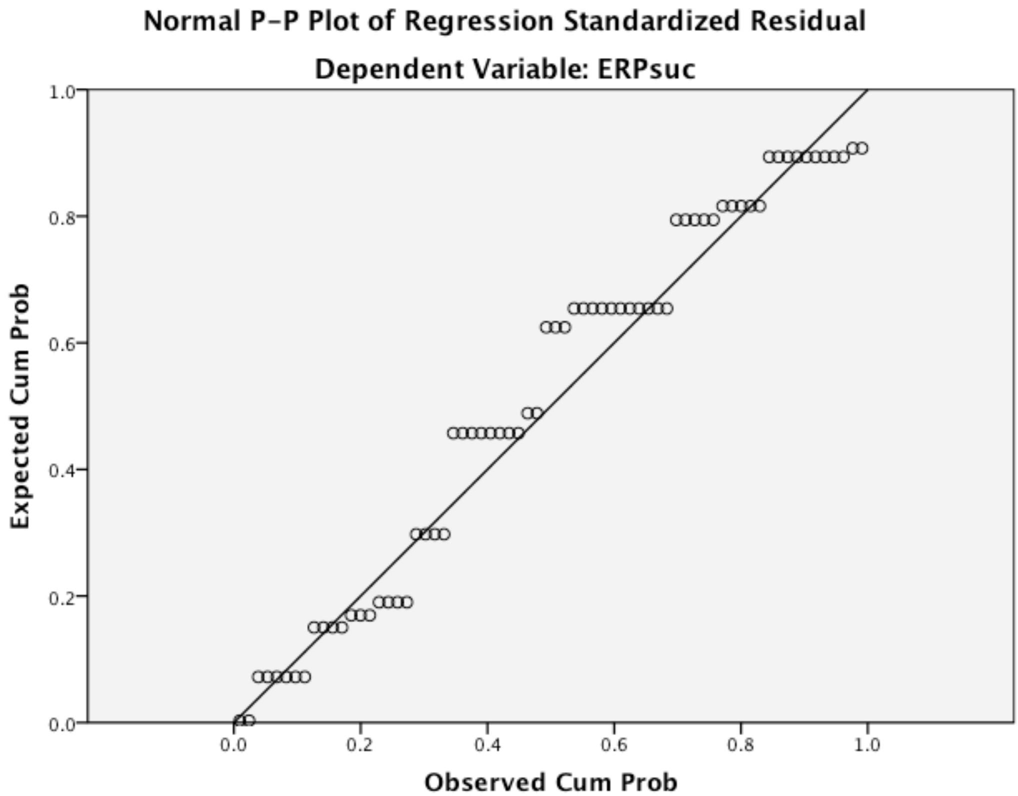

Figure 115: BPR effect on ERP regression model standardized residual normal p-p plot

APPENDIX 32: SPSS OUTPUTS OF MLR MODEL TO DETERMINE THE FACTORS EFFECTING BPR SUCCESS

Table 93: BPR success factors regression model variable correlations

		BPR suc	*BPR V1*	*BPR V2*	*BPR V3*	*BPR V4*	*BPR V5*	*BPR V6*	*BPR V7*	*BPR V8*	*BPR V9*	*BPR V10*	*BPR V11*	*BPR V12*	*BPR V13*	*BPR V14*	*BPR V15*
Pearson Correlation	*BPRsuc*	1.000	.742	.837	.823	.723	.743	.375	.710	.814	.859	.548	.819	.671	.587	.530	.597
	BPRV1	.742	1.000	.624	.698	.616	.626	.197	.552	.658	.547	.644	.749	.540	.550	.633	.480
	BPRV2	.837	.624	1.000	.622	.509	.607	.403	.544	.667	.649	.251	.617	.480	.525	.213	.580
	BPRV3	.823	.698	.622	1.000	.614	.647	.456	.653	.759	.658	.516	.722	.608	.362	.535	.436
	BPRV4	.723	.616	.509	.614	1.000	.489	.280	.513	.615	.560	.576	.627	.529	.502	.552	.363
	BPRV5	.743	.626	.607	.647	.489	1.000	.198	.554	.578	.615	.407	.678	.486	.462	.390	.372
	BPRV6	.375	.197	.403	.456	.280	.198	1.000	.256	.252	.299	.152	.278	.174	.350	.176	.313
	BPRV7	.710	.552	.544	.653	.513	.554	.256	1.000	.598	.590	.478	.733	.657	.500	.448	.498
	BPRV8	.814	.658	.667	.759	.615	.578	.252	.598	1.000	.655	.466	.686	.728	.454	.445	.452
	BPRV9	.859	.547	.649	.658	.560	.615	.299	.590	.655	1.000	.359	.647	.477	.344	.456	.391
	BPRV10	.548	.644	.251	.516	.576	.407	.152	.478	.466	.359	1.000	.678	.435	.556	.682	.409
	BPRV11	.819	.749	.617	.722	.627	.678	.278	.733	.686	.647	.678	1.000	.584	.603	.630	.432
	BPRV12	.671	.540	.480	.608	.529	.486	.174	.657	.728	.477	.435	.584	1.000	.485	.387	.450
	BPRV13	.587	.550	.525	.362	.502	.462	.350	.500	.454	.344	.556	.603	.485	1.000	.473	.668
	BPRV14	.530	.633	.213	.535	.552	.390	.176	.448	.445	.456	.682	.630	.387	.473	1.000	.342
	BPRV15	.597	.480	.580	.436	.363	.372	.313	.498	.452	.391	.409	.432	.450	.668	.342	1.000
Sig. (1-tailed)	*BPRsuc*	.	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000
	BPRV1	.000	.	.000	.000	.000	.000	.054	.000	.000	.000	.000	.000	.000	.000	.000	.000
	BPRV2	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.019	.000	.000	.000	.041	.000
	BPRV3	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000
	BPRV4	.000	.000	.000	.000	.	.000	.010	.000	.000	.000	.000	.000	.000	.000	.000	.001
	BPRV5	.000	.000	.000	.000	.000	.	.053	.000	.000	.000	.000	.000	.000	.000	.001	.001
	BPRV6	.001	.054	.000	.000	.010	.053	.	.017	.019	.007	.107	.011	.078	.002	.076	.005
	BPRV7	.000	.000	.000	.000	.000	.000	.017	.	.000	.000	.000	.000	.000	.000	.000	.000
	BPRV8	.000	.000	.000	.000	.000	.000	.019	.000	.	.000	.000	.000	.000	.000	.000	.000
	BPRV9	.000	.000	.000	.000	.000	.000	.007	.000	.000	.	.001	.000	.000	.002	.000	.000
	BPRV10	.000	.000	.019	.000	.000	.000	.107	.000	.000	.001	.	.000	.000	.000	.000	.000
	BPRV11	.000	.000	.000	.000	.000	.000	.011	.000	.000	.000	.000	.	.000	.000	.000	.000
	BPRV12	.000	.000	.000	.000	.000	.000	.078	.000	.000	.000	.000	.000	.	.000	.001	.000
	BPRV13	.000	.000	.000	.001	.000	.000	.002	.000	.000	.002	.000	.000	.000	.	.000	.000
	BPRV14	.000	.000	.041	.000	.000	.001	.076	.000	.000	.000	.000	.000	.001	.000	.	.002
	BPRV15	.000	.000	.000	.000	.001	.001	.005	.000	.000	.000	.000	.000	.000	.000	.002	.

Table 94: BPR success factors regression model ANOVA results

Model[j]		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	141.676	1	141.676	185.375	.000[a]
	Residual	50.442	66	.764		
	Total	192.118	67			
2	Regression	167.752	2	83.876	223.753	.000[b]
	Residual	24.366	65	.375		
	Total	192.118	67			
3	Regression	179.502	3	59.834	303.551	.000[c]
	Residual	12.615	64	.197		
	Total	192.118	67			
4	Regression	183.318	4	45.830	328.123	.000[d]
	Residual	8.799	63	.140		
	Total	192.118	67			
5	Regression	185.226	5	37.045	333.298	.000[e]
	Residual	6.891	62	.111		
	Total	192.118	67			
6	Regression	186.083	6	31.014	313.518	.000[f]
	Residual	6.034	61	.099		
	Total	192.118	67			
7	Regression	186.660	7	26.666	293.143	.000[g]
	Residual	5.458	60	.091		
	Total	192.118	67			
8	Regression	187.053	8	23.382	272.387	.000[h]
	Residual	5.065	59	.086		
	Total	192.118	67			

Table 94: (continued)

9	Regression	187.396	9	20.822	255.772	.000[i]
	Residual	4.722	58	.081		
	Total	192.118	67			

[a]. Predictors: (Constant), *BPRV9*
[b]. Predictors: (Constant), *BPRV9, BPRV2*
[c]. Predictors: (Constant), *BPRV9, BPRV2, BPRV10*
[d]. Predictors: (Constant), *BPRV9, BPRV2, BPRV10, BPRV3*
[e]. Predictors: (Constant), *BPRV9, BPRV2, BPRV10, BPRV3, BPRV12*
[f]. Predictors: (Constant), *BPRV9, BPRV2, BPRV10, BPRV3, BPRV12, BPRV4*
[g]. Predictors: (Constant), *BPRV9, BPRV2, BPRV10, BPRV3, BPRV12, BPRV4, BPRV5*
[h]. Predictors: (Constant), *BPRV9, BPRV2, BPRV10, BPRV3, BPRV12, BPRV4, BPRV5, BPRV15*
[i]. Predictors: (Constant), *BPRV9, BPRV2, BPRV10, BPRV3, BPRV12, BPRV4, BPRV5, BPRV15, BPRV11*
[j]. Dependent Variable: *BPRsuc*

Table 95: BPR success factors regression model variable coefficients

Model[a]		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Collinearity Statistics VIF
1	(Constant)	.950	.296		3.215	.002	
	BPRV9	.774	.057	.859	13.615	.000	1.000
2	(Constant)	.627	.211		2.978	.004	
	BPRV9	.491	.052	.545	9.388	.000	1.726
	BPRV2	.376	.045	.484	8.340	.000	1.726
3	(Constant)	-.204	.187		-1.092	.279	
	BPRV9	.410	.039	.455	10.421	.000	1.858
	BPRV2	.369	.033	.476	11.299	.000	1.727
	BPRV10	.259	.034	.265	7.721	.000	1.149
4	(Constant)	-.311	.159		-1.963	.054	
	BPRV9	.344	.035	.382	9.725	.000	2.125
	BPRV2	.314	.029	.404	10.637	.000	1.985
	BPRV10	.192	.031	.196	6.185	.000	1.387
	BPRV3	.211	.040	.219	5.227	.000	2.408
5	(Constant)	-.403	.143		-2.812	.007	
	BPRV9	.337	.032	.374	10.658	.000	2.131
	BPRV2	.297	.027	.383	11.179	.000	2.030
	BPRV10	.169	.028	.173	5.993	.000	1.441
	BPRV3	.164	.038	.170	4.342	.000	2.647
	BPRV12	.120	.029	.130	4.143	.000	1.703
6	(Constant)	-.472	.137		-3.442	.001	
	BPRV9	.321	.030	.357	10.592	.000	2.201
	BPRV2	.286	.025	.368	11.247	.000	2.080
	BPRV10	.137	.029	.140	4.736	.000	1.691
	BPRV3	.150	.036	.156	4.191	.000	2.691
	BPRV12	.108	.028	.117	3.904	.000	1.742
	BPRV4	.098	.033	.098	2.943	.005	2.145
7	(Constant)	-.570	.137		-4.156	.000	
	BPRV9	.306	.030	.339	10.272	.000	2.302
	BPRV2	.270	.025	.348	10.728	.000	2.218
	BPRV10	.128	.028	.130	4.574	.000	1.719
	BPRV3	.131	.035	.135	3.699	.000	2.832
	BPRV12	.103	.026	.112	3.888	.000	1.750
	BPRV4	.100	.032	.100	3.127	.003	2.147
	BPRV5	.084	.033	.079	2.517	.015	2.104

Table 95: (continued)

8	(Constant)	-.572	.133		-4.296	.000	
	BPRV9	.307	.029	.341	10.630	.000	2.304
	BPRV2	.243	.028	.313	8.805	.000	2.820
	BPRV10	.108	.029	.111	3.780	.000	1.914
	BPRV3	.133	.034	.138	3.887	.000	2.836
	BPRV12	.093	.026	.101	3.541	.001	1.812
	BPRV4	.107	.031	.107	3.447	.001	2.176
	BPRV5	.090	.033	.085	2.760	.008	2.118
	BPRV15	.052	.024	.061	2.141	.036	1.788
9	(Constant)	-.527	.132		-4.004	.000	
	BPRV9	.297	.029	.330	10.402	.000	2.374
	BPRV2	.226	.028	.291	8.071	.000	3.074
	BPRV10	.072	.033	.074	2.193	.032	2.670
	BPRV3	.123	.034	.127	3.624	.001	2.906
	BPRV12	.085	.026	.092	3.303	.002	1.850
	BPRV4	.108	.030	.108	3.547	.001	2.176
	BPRV5	.073	.033	.069	2.249	.028	2.252
	BPRV15	.059	.024	.070	2.495	.015	1.834
	BPRV11	.079	.038	.085	2.052	.045	4.094

[a]. Dependent Variable: *BPRsuc*

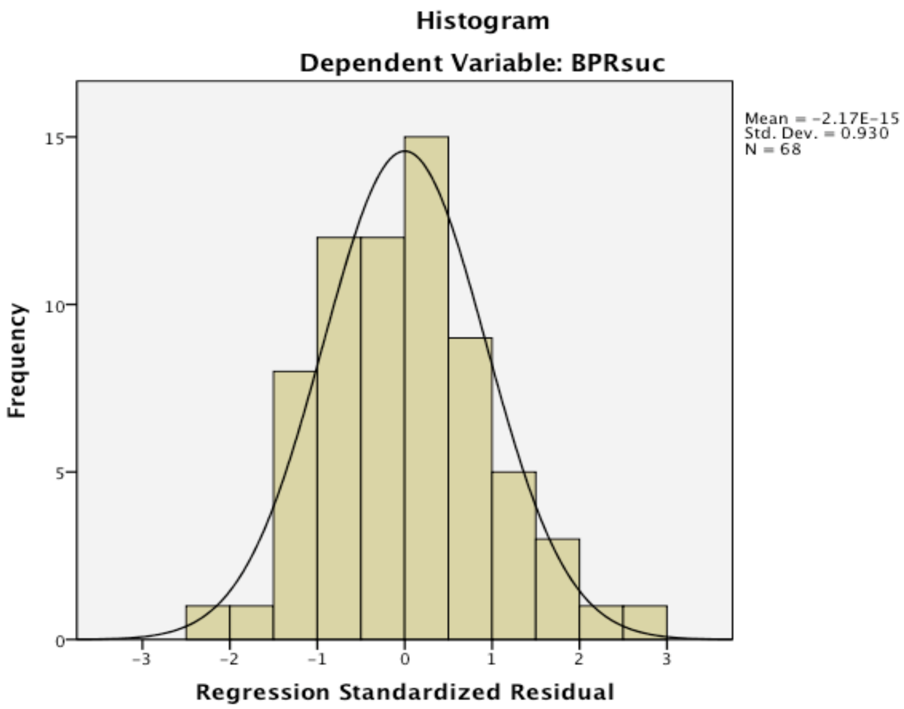

Figure 116: BPR success factors regression model standardized residual histogram

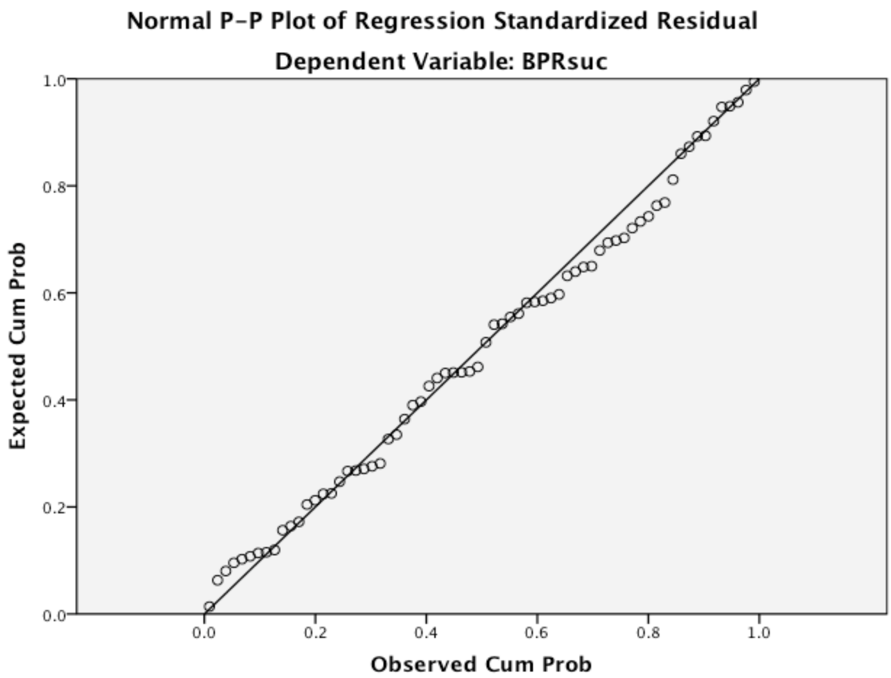

Figure 117: BPR success factors regression model standardized residual normal p-p plot

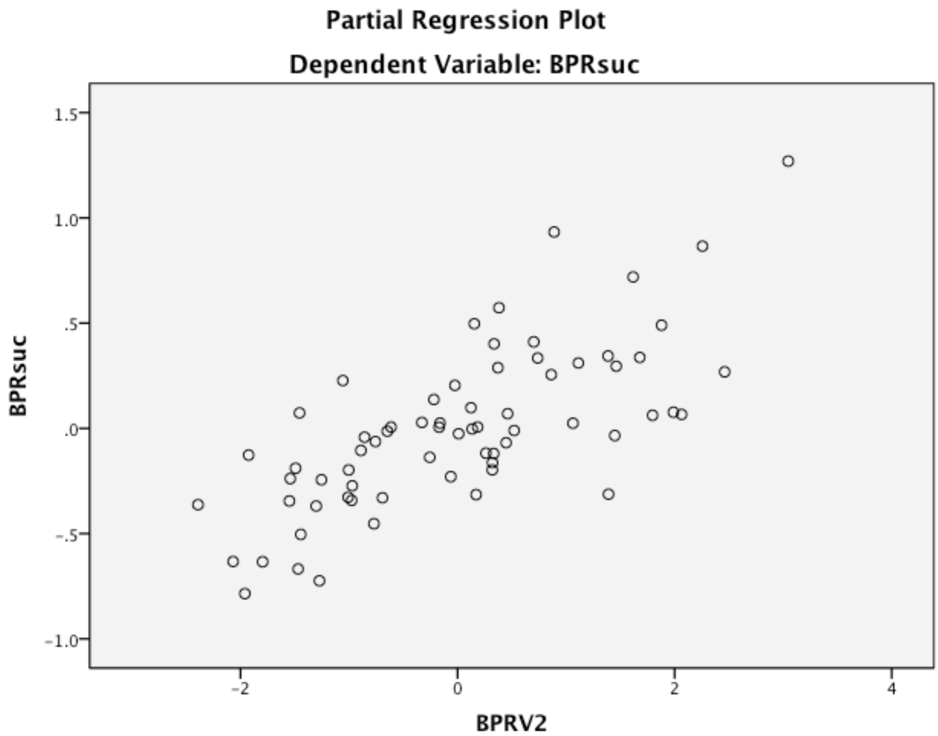

Figure 118: Partial plot of *BPRsuc* and *BPRV2*

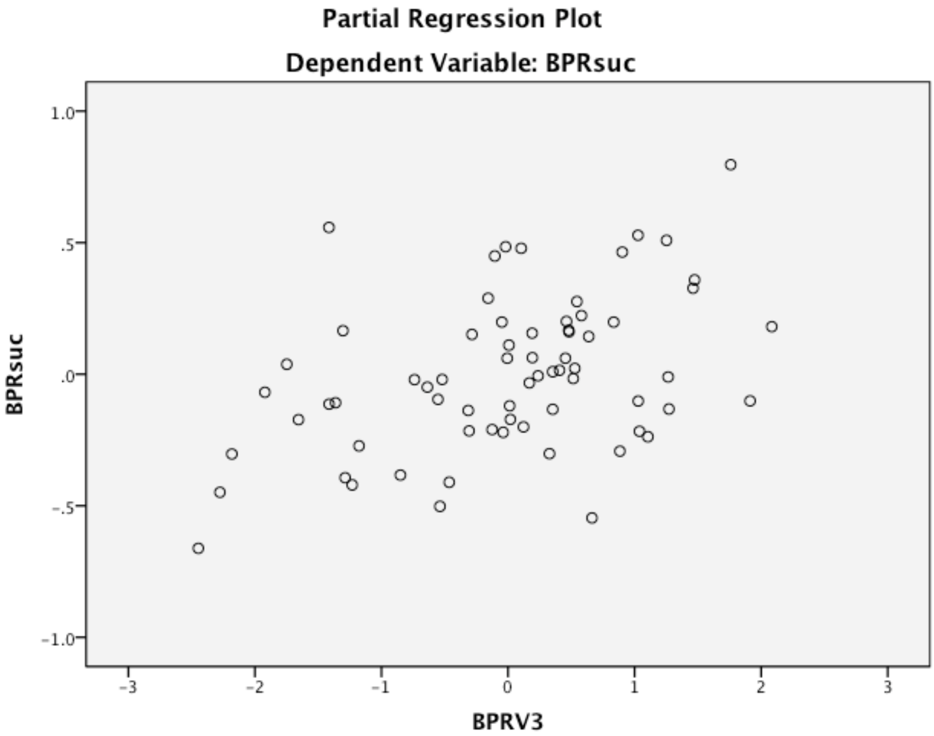

Figure 119: Partial plot of *BPRsuc* and *BPRV3*

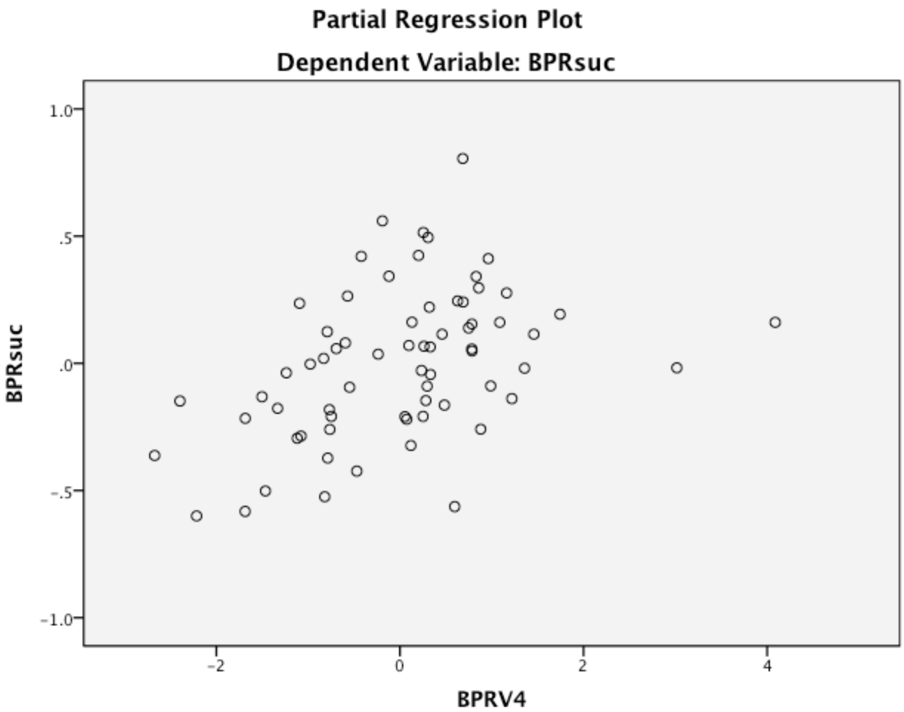

Figure 120: Partial plot of *BPRsuc* and *BPRV4*

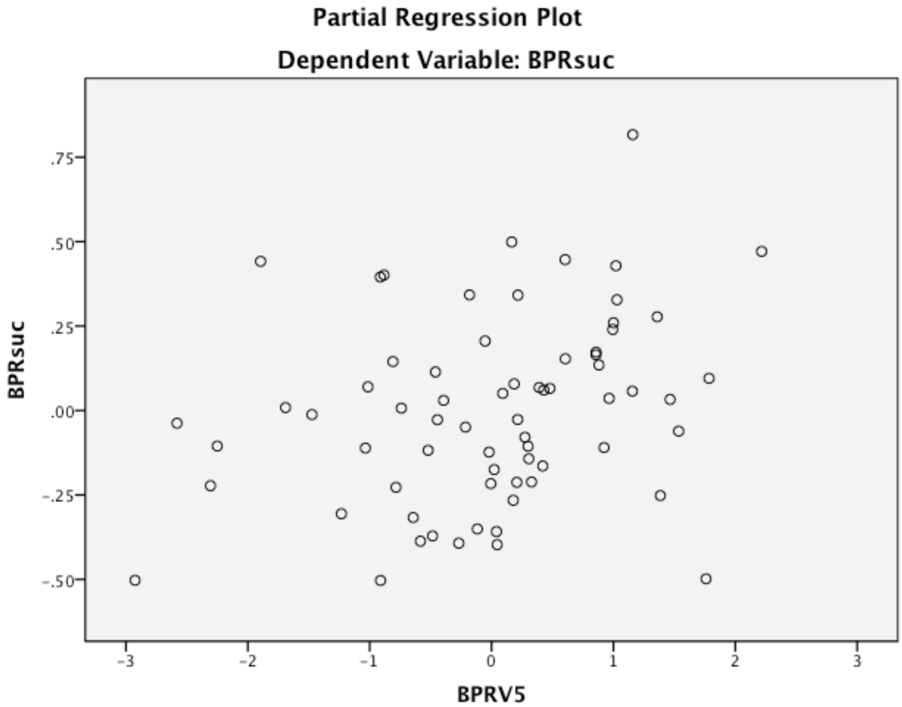

Figure 121: Partial plot of *BPRsuc* and *BPRV5*

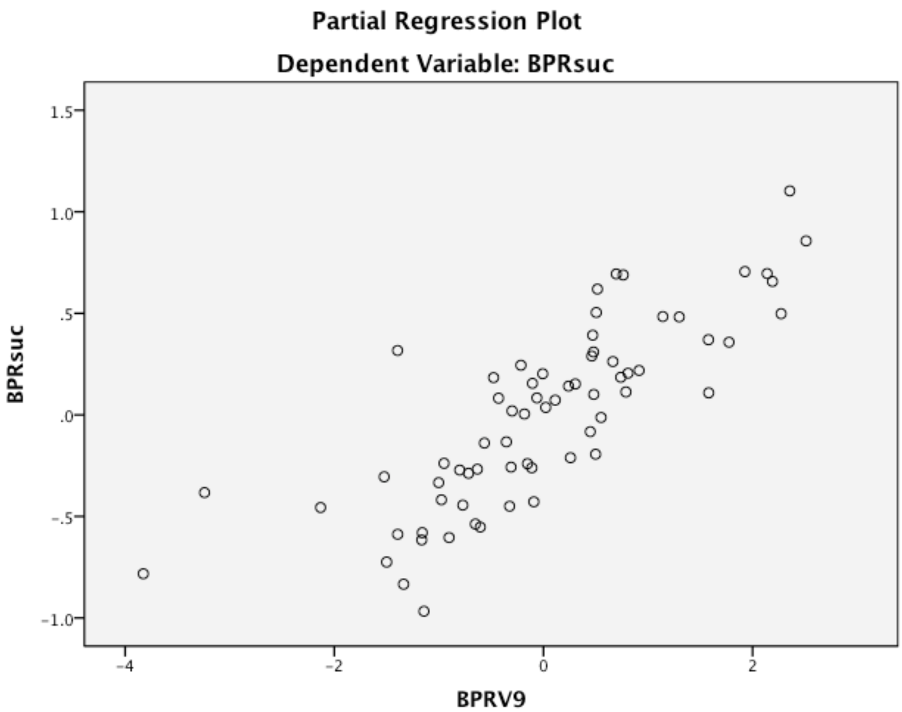

Figure 122: Partial plot of *BPRsuc* and *BPRV9*

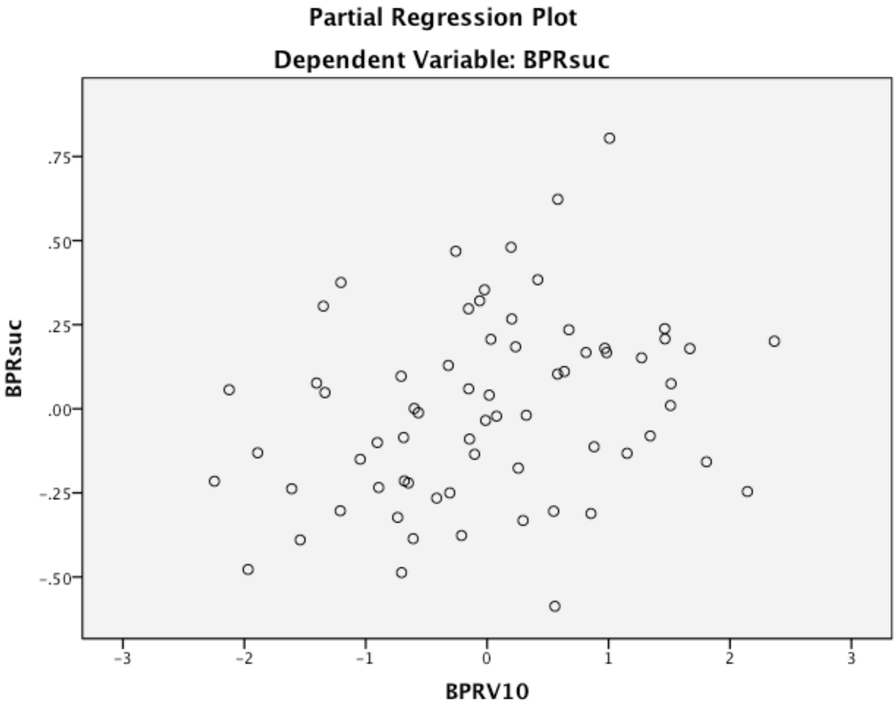

Figure 123: Partial plot of *BPRsuc* and *BPRV10*

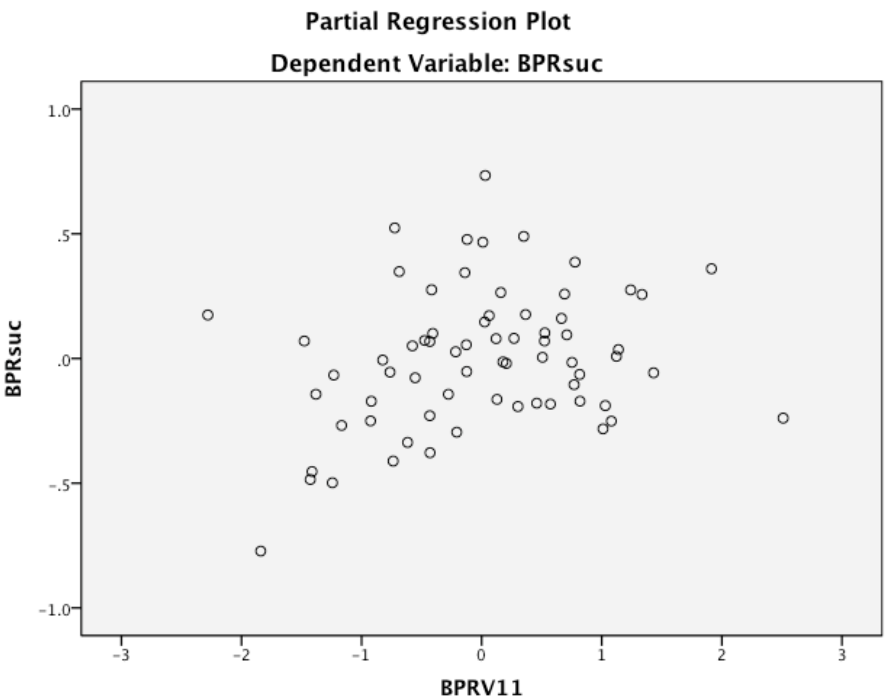

Figure 124: Partial plot of *BPRsuc* and *BPRV11*

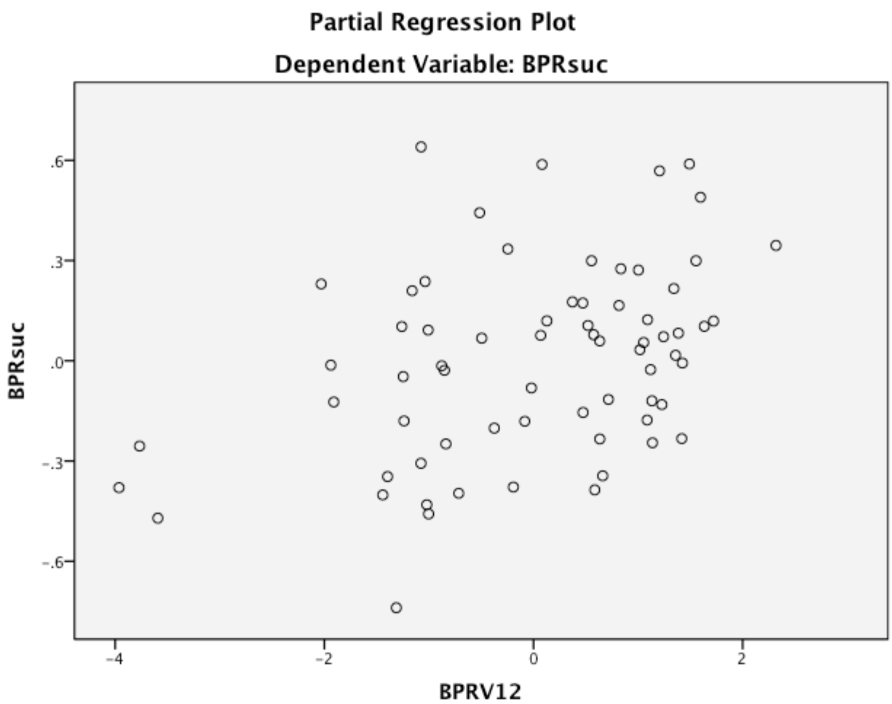

Figure 125: Partial plot of *BPRsuc* and *BPRV12*

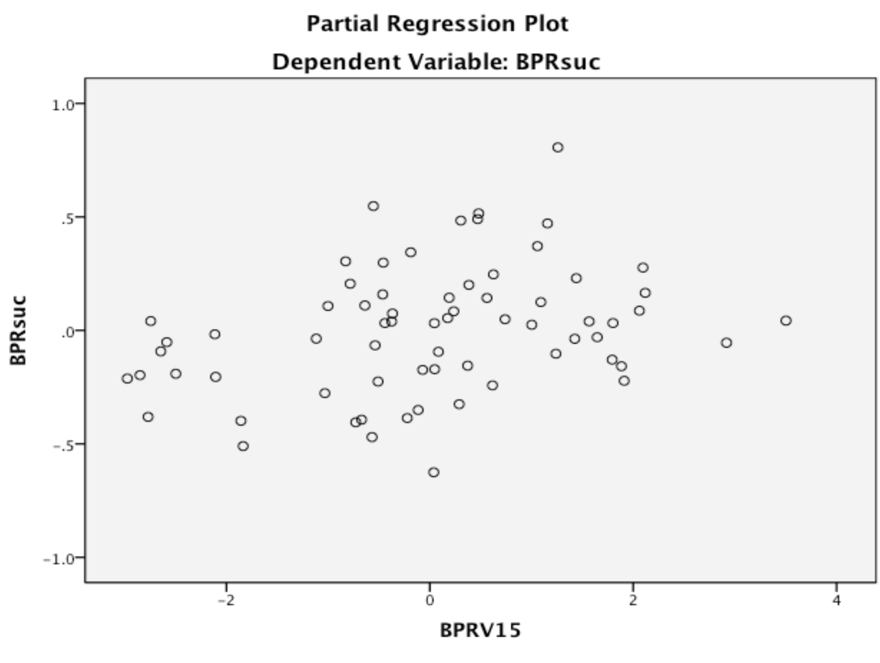

Figure 126: Partial plot of *BPRsuc* and *BPRV15*

APPENDIX 33: SUPER DECISIONS ANP MODEL STRUCTURE

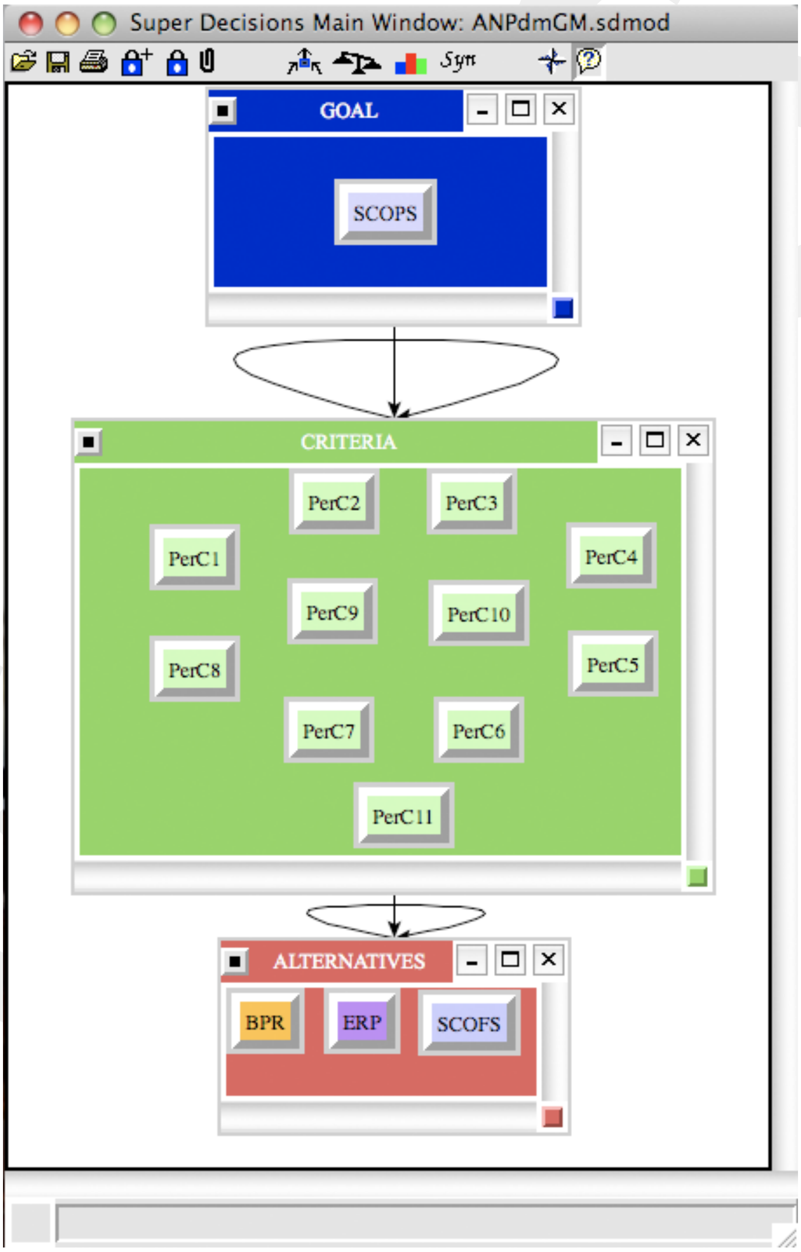

Figure 127: Super Decisions ANP model hierarchy

APPENDIX 34: UNWEIGHTED&WEIGHTED SUPERMATRICES AND LIMIT MATRIX OF STRATEGY SELECTION ANP MODEL

Table 96: Performance investment strategies evaluation ANP model unweighted supermatrix

		ALTERNATIVES			CRITERIA											GOAL
		BPR	**ERP**	**SCOFS**	***PerC1***	***PerC2***	***PerC3***	***PerC4***	***PerC5***	***PerC6***	***PerC7***	***PerC8***	***PerC9***	***PerC10***	***PerC11***	**SCOPS**
ALTERNATIVES	**BPR**	0.00000	1.00000	0.00000	0.39114	0.25185	0.27695	0.17207	0.26896	0.18577	0.18580	0.19580	0.31110	0.31110	0.19525	0.00000
	ERP	0.00000	0.00000	1.00000	0.34786	0.58889	0.50324	0.63964	0.51206	0.66850	0.61498	0.60840	0.46468	0.46468	0.63607	0.00000
	SCOFS	0.00000	0.00000	0.00000	0.26100	0.15926	0.21981	0.18829	0.21898	0.14573	0.19922	0.19580	0.22422	0.22422	0.16868	0.00000
CRITERIA	***PerC1***	0.00000	0.00000	0.00000	0.00000	0.00000	0.50000	0.23077	0.00000	0.00000	0.33333	0.08000	0.00000	0.00000	0.00000	0.15973
	PerC2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.33333	0.00000	0.08000	0.00000	0.00000	0.16667	0.04573
	PerC3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.15385	0.00000	0.00000	0.22222	0.00000	0.00000	0.00000	0.00000	0.18646
	PerC4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.16667	0.10618
	PerC5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.22222	0.12000	0.00000	0.00000	0.00000	0.14480
	PerC6	0.00000	0.00000	0.00000	0.25000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.12000	0.62500	0.62500	0.25000	0.05678
	PerC7	0.00000	0.00000	0.00000	0.00000	0.40000	0.00000	0.00000	0.00000	0.33333	0.00000	0.00000	0.00000	0.00000	0.25000	0.06920
	PerC8	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.46154	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.16667	0.09842
	PerC9	0.00000	0.00000	0.00000	0.25000	0.00000	0.00000	0.00000	0.66667	0.00000	0.00000	0.16000	0.00000	0.00000	0.00000	0.05266
	PerC10	0.00000	0.00000	0.00000	0.25000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.24000	0.00000	0.00000	0.00000	0.05266
	PerC11	0.00000	0.00000	0.00000	0.25000	0.60000	0.50000	0.15385	0.33333	0.33333	0.22222	0.20000	0.37500	0.37500	0.00000	0.02737
GOAL	**SCOPS**	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

Table 97: Performance investment strategies evaluation ANP model weighted supermatrix

		ALTERNATIVES			CRITERIA											GOAL
		BPR	**ERP**	**SCOFS**	***PerC1***	***PerC2***	***PerC3***	***PerC4***	***PerC5***	***PerC6***	***PerC7***	***PerC8***	***PerC9***	***PerC10***	***PerC11***	**SCOPS**
ALTERNATIVES	**BPR**	0.00000	1.00000	0.00000	0.19557	0.12593	0.13848	0.08604	0.13448	0.09289	0.09290	0.09790	0.15555	0.15555	0.09763	0.00000
	ERP	0.00000	0.00000	1.00000	0.17393	0.29445	0.25162	0.31982	0.25603	0.33425	0.30749	0.30420	0.23234	0.23234	0.31803	0.00000
	SCOFS	0.00000	0.00000	0.00000	0.13050	0.07963	0.10991	0.09415	0.10949	0.07287	0.09961	0.09790	0.11211	0.11211	0.08434	0.00000
CRITERIA	***PerC1***	0.00000	0.00000	0.00000	0.00000	0.00000	0.25000	0.11539	0.00000	0.00000	0.16667	0.04000	0.00000	0.00000	0.00000	0.15973
	PerC2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.16667	0.00000	0.04000	0.00000	0.00000	0.08333	0.04573
	PerC3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.07692	0.00000	0.00000	0.11111	0.00000	0.00000	0.00000	0.00000	0.18646
	PerC4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.08333	0.10618
	PerC5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.11111	0.06000	0.00000	0.00000	0.00000	0.14480
	PerC6	0.00000	0.00000	0.00000	0.12500	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.06000	0.31250	0.31250	0.12500	0.05678
	PerC7	0.00000	0.00000	0.00000	0.00000	0.20000	0.00000	0.00000	0.00000	0.16667	0.00000	0.00000	0.00000	0.00000	0.12500	0.06920
	PerC8	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.23077	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.08333	0.09842
	PerC9	0.00000	0.00000	0.00000	0.12500	0.00000	0.00000	0.00000	0.33333	0.00000	0.00000	0.08000	0.00000	0.00000	0.00000	0.05266
	PerC10	0.00000	0.00000	0.00000	0.12500	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.12000	0.00000	0.00000	0.00000	0.05266
	PerC11	0.00000	0.00000	0.00000	0.12500	0.30000	0.25000	0.07692	0.16667	0.16667	0.11111	0.10000	0.18750	0.18750	0.00000	0.02737
GOAL	**SCOPS**	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

Table 98: Performance investment strategies evaluation ANP model limit matrix

		ALTERNATIVES			CRITERIA											GOAL
		BPR	**ERP**	**SCOFS**	***PerC1***	***PerC2***	***PerC3***	***PerC4***	***PerC5***	***PerC6***	***PerC7***	***PerC8***	***PerC9***	***PerC10***	***PerC11***	**SCOPS**
ALTERNATIVES	**BPR**	0.00000	0.00000	0.00000	0.50000	0.50000	0.50000	0.50000	0.50000	0.50000	0.50000	0.50000	0.50000	0.50000	0.50000	0.50000
	ERP	0.00000	0.00000	0.00000	0.22317	0.22317	0.22317	0.22317	0.22317	0.22317	0.22317	0.22317	0.22317	0.22317	0.22317	0.22317
	SCOFS	0.00000	0.00000	0.00000	0.04388	0.04388	0.04388	0.04388	0.04388	0.04388	0.04388	0.04388	0.04388	0.04388	0.04388	0.04388
CRITERIA	***PerC1***	0.00000	0.00000	0.00000	0.01957	0.01957	0.01957	0.01957	0.01957	0.01957	0.01957	0.01957	0.01957	0.01957	0.01957	0.01957
	PerC2	0.00000	0.00000	0.00000	0.02226	0.02226	0.02226	0.02226	0.02226	0.02226	0.02226	0.02226	0.02226	0.02226	0.02226	0.02226
	PerC3	0.00000	0.00000	0.00000	0.00922	0.00922	0.00922	0.00922	0.00922	0.00922	0.00922	0.00922	0.00922	0.00922	0.00922	0.00922
	PerC4	0.00000	0.00000	0.00000	0.00962	0.00962	0.00962	0.00962	0.00962	0.00962	0.00962	0.00962	0.00962	0.00962	0.00962	0.00962
	PerC5	0.00000	0.00000	0.00000	0.00943	0.00943	0.00943	0.00943	0.00943	0.00943	0.00943	0.00943	0.00943	0.00943	0.00943	0.00943
	PerC6	0.00000	0.00000	0.00000	0.03456	0.03456	0.03456	0.03456	0.03456	0.03456	0.03456	0.03456	0.03456	0.03456	0.03456	0.03456
	PerC7	0.00000	0.00000	0.00000	0.03485	0.03485	0.03485	0.03485	0.03485	0.03485	0.03485	0.03485	0.03485	0.03485	0.03485	0.03485
	PerC8	0.00000	0.00000	0.00000	0.01405	0.01405	0.01405	0.01405	0.01405	0.01405	0.01405	0.01405	0.01405	0.01405	0.01405	0.01405
	PerC9	0.00000	0.00000	0.00000	0.01343	0.01343	0.01343	0.01343	0.01343	0.01343	0.01343	0.01343	0.01343	0.01343	0.01343	0.01343
	PerC10	0.00000	0.00000	0.00000	0.00827	0.00827	0.00827	0.00827	0.00827	0.00827	0.00827	0.00827	0.00827	0.00827	0.00827	0.00827
	PerC11	0.00000	0.00000	0.00000	0.05769	0.05769	0.05769	0.05769	0.05769	0.05769	0.05769	0.05769	0.05769	0.05769	0.05769	0.05769
GOAL	**SCOPS**	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

APPENDIX 35: SUPER DECISIONS SCOPS IMPROVEMENT STRATEGIES ANP MODEL PRIORITIES

Name	Normalized by Cluster	Limiting
BPR	0.65185	0.500000
ERP	0.29094	0.223166
SCOFS	0.05721	0.043883
PerC1	0.08401	0.019571
PerC2	0.09556	0.022260
PerC3	0.03959	0.009223
PerC4	0.04128	0.009616
PerC5	0.04048	0.009430
PerC6	0.14836	0.034561
PerC7	0.14959	0.034848
PerC8	0.06033	0.014054
PerC9	0.05764	0.013428
PerC10	0.03548	0.008266
PerC11	0.24767	0.057694
SCOPS	0.00000	0.000000

Figure 128: Performance investment strategies evaluation ANP model priorities