Methodology for a Strategic Policy Decision Making and Impact Analysis on Industry

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Chapter 1

Introduction

Chapter 1 gives brief information about the overall thesis and introduces the terms used in this thesis in general framework. In recent years, because of the globalization, mutual interaction have been created between policy making units of nations, nongovernmental organizations, several powerful country unions and business section. From the industrial point of view, that mutual interactions are one of the result of sustainability movement which has gained significant importance in economic, social and especially environmental aspects. Policy making has taken a great place considering the main target; sustainability. Stakeholders realized that economic development is not enough. based on the related issues; climate change, population growth, decreasing volume of natural resources, expectations of civil world for a reasonable social level for society. In this thesis, the research includes three main topics from top to down and two levels of impact analysis of political decisions. Three main topics are; sustainability for industrial development, policy making process by the impacts on the industry and closed-loop supply chain management in organization. Two levels of impact analysis of political decision are the macro level and the micro level impacts(Figure 1.1). According to the problems related to those three main topics, this thesis is generated. In this chapter there is brief explanation and definitions are made.

1.1 Overview of the Three Key Topics in This Thesis

To discuss three main topics, first of all as a start point, we can say that sustainability movements have significantly influenced company management considerations. Since most industry firms carry on commercial trade in more than one country, they are under pressure from both national and international regulations. Industry policies concerning *supply chain* and *reverse logistics* are getting stricter, requiring more sensitivity in *decision-making.* Managers can control every process in *closed-loop supply chain management*(CLSC), including *end of life strategies* especially related to the policies on *sustainability* issues, and various cost reductions. Furthermore, rapidly growing negative impacts on environment and new global trade conditions have caused *international regulations* and *governmental laws* to be more sensitive and strict about sustainability issues in their policy decisions. Therefore, a significant pressure on business has occurred to be more flexible to meet the revisions that affect *industrial structures.* Accordingly, business sustainability has been affected easily by these revisions. Due to the global competition, the conversion from a mass production and consumer society to a recycling society has become more important, in order to reduce environmental burden and user cost.

In the global supply chain of the auto-industry, recycling concerns such as construction problems of recycling logistics and decision problems of reuse part traders have attracted attention over the years. Policy decision making for sustainability is a challenge for all industries, countries, and international directives. Governments and international regulations have been taking several imperative actions and pressure on automobile manufacturers to find innovative and effective solutions to deal with environmental centered sustainability problem. Due to the environmental legislation, closed-loop supply chain management has become an important issue for many companies all over the world. Considering sustainable project management, supplier selection and evaluation phase in CLCS is one of the crucial decision point not only for QCD but also environmental impacts. As well as choosing the suppliers to work with is one of the key points of project management, semi- annually or annually evaluation is very important to keep track of vendors' performance level to be successful on sustainable development. There are, a lot of factors can affect companies' ability to evaluate all suppliers and then to choose the best one. In this step, firms have to define several criteria due to their firm culture, aim and mission. There are various approaches to determine performance level of suppliers.

1.2 Sustainability

Brundtland Commission [112] defined the sustainability as " providing for human needs without compromising the ability of future generations to meet their needs. From a business perspective, the concepts of sustainability are often described as a triple bottom lines; economic viability, Social concerns and natural and ecological issues

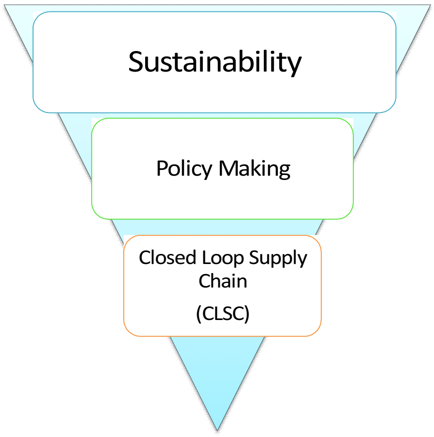

Figure 1.1: Three main topics and the Flow of the Thesis

1.2.1 Trial bottom lines of Sustainability

Economic viability can be defined as the business aspects of a project, program, organization, industry, system or even governments. Social concerns are can be named as the health of human being and all species, and social fare of the society. Natural, ecologic or environmental issues are the environmental stewardship and all kind of impacts of humans, industries etc. The tree bottom line recognizes that a business must be based on more than one ability such as the making profit. They have to consider the environmental and social implications in their decision making processes and reflect those into their strategies.

1.2.2 Relation between Sustainability, Policy making and Industry

The basic challenge of sustainable design for policies is to measure it. Policies are the actions for the measurement of sustainable aims. Governments are the responsible for managing sustainable design through the nationwide, so international directives such as WEEE, REACH, RoHS, ELVs regulations of EU are responsible through the global wide, as well Market regulations are the influent for the industries. Besides the market regulations, governmental policymaking process should capture the social and the environmental objectives and reflect that aims to the markets responsibilities to monitor their economic, environmental and social impacts.

1.3 Policy Making

1.3.1 What is Policy making?

First of all. it should be noted that policy making is the result of the decision making process. In policymaking there are several stakeholders. Each stakeholder has their own aims and they have different expectations form the policy making outputs. If we need to give a definition what is the policy making in general words "Policy-making, or the process of creating and adopting laws, is a multi-stage procedure involving many governmental and non-governmental actors. It is a cycle of ideas and actions that begins with a problem and ends with an implemented solution.

1.3.2 Three Main Stakeholders of Policy Making

In this thesis, we are dealing with the policy making affecting the business environment. In that point of view, we can define three main stakeholders of policy making which have a great impact on industrial policy decisions; international directives, government and then industry itself. Globalization is the main reason to define the international directives as a main influent for the policy making process. The aim of defining government as a main influent is, in global trade world, the governments want to accomplish a great success considering the policies as a driver of the industry. They have to struggle with both global discussions and expressing the importance of several policies which may be unwanted by industry.

1.3.3 Policy Making and Auto Industry

Policy making issues related to the auto industry is one of the major topics related to the policy making discussions. Auto industry is a driver of many developed countries' national economy so the governments are extremely concerned about the policy issues on auto industry. In the sustainable development face of the policy making, the main issues are generally on the environmental problems and generating solutions by new political developments. The tax systems and the decision making process of the policy making is a great topic which requires complicated discussions. Also for other industries it is surely important that from the macro level to micro level effects which are expressed as a case study in this thesis.

1.4 Closed Loop Supply Chain

1.4.1 Definition of Closed Loop Supply Chain (CLSC)

'Closed loop supply chains are supply chains where, in addition to the typical forward flow of materials from suppliers to end customers, there are flows of products back (post-consumer touch or use) to manufacturers.' Examples include product returns flowing back from retailers to the original equipment manufacturers (OEMs), used products (with some remaining useful life) that are traded in for a discount on the purchase price of a new product, end of life lease returns, and end of life products that are turned for disposal or recycling.[35](Figure 1.2)

1.4.2 Network Design of CLSC

In a typical closed loop supply chain network the focus should be on designing the network for collection, processing, and re-manufacturing of used products, as well as re-marketing re-manufactured products. The forward supply chain and reverse logistic should be considered as a whole system and the all type of flows include new parts, products / used part, products should be managed concurrently, not separately.

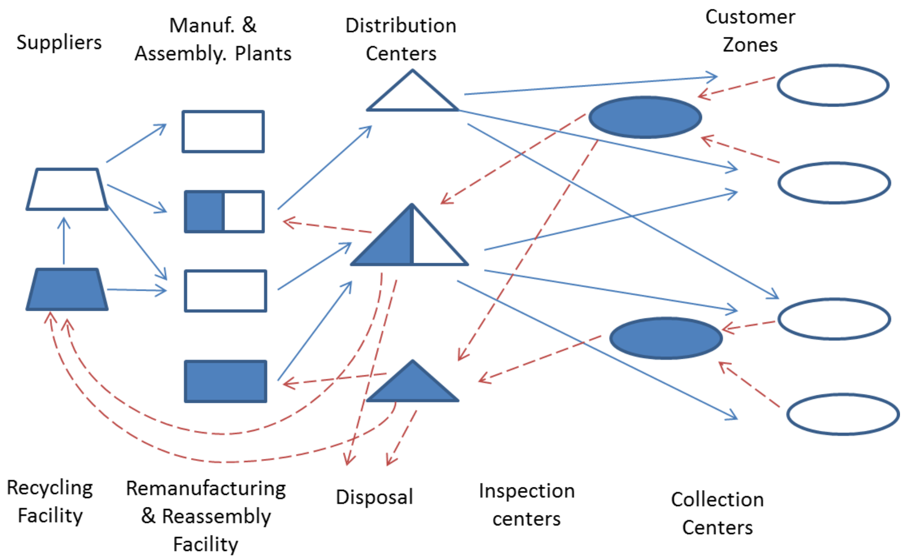

Figure 1.2: A typical CLSC network structure [35]

CLSC in Auto Industry

In this thesis, auto industry and the set up base of the closed loop supply chain of it, is one if the major topics. Considering the auto parts and the volume of them at the end of life product stage, the necessity of management for the 3R activities for the auto industry and the Closed-loop supply chain management is the appropriate approach for this newly arisen problem is obvious. This is a great challenge for the car industry recently have been facing worldwide is how to implement an effective reverse logistic network in closed loop supply chain while manufacturing environmental, cost effective and socially friendly automobiles from limited available resources.Considering the relationship between reduce, reuse, recycle, disposal and how various logistics elements will be impacted by government regulations on a longterm policy decisions are critical issues. In light of this information, the author considers an optimal reverse logistics structure in CLSC of the auto-industry to maximize the total profit of 3R activity side traders. A reverse logistics construction model of the auto-industry is presented from a win-win point of view and optimal and feasible reverse logistics structure can be clarified.

1.5 Contributions of This Thesis

The main topics discussed above and the relation between each of them are very important for the contribution to the academic research. Following sections are the explaining the what kind of supplementary studies are made through the key topics.

1.5.1 Contributions of This Thesis Related to Sustainability

This thesis explains the influence of regulations and policies on sustainable business development and industries' strategic decisions simultaneously. One of the aims is to develop a generic decision making strategy to represent scenario generation mechanism by *Unified Matrix for Interactive Impacts* structure which can define the relations between criteria and functions of closed-loop supply chain from planning to the 3R activities (Reuse, Recover, Recycle) level considering the sustainability issues. Regarding to the trial bottom line, besides the cost effective processes, also socially and maybe the one of the highlighted problem environmental-friendly solutions are discussed. Policy making is beginning of to be a part of the solution sustainable measurements, evaluations,implications in this discussion. Sustainability is on the top of all topic here. Policy making and the Closed-loop supply chain management is starting always considering the sustainability aims and development to be ready for future strategies.

1.5.2 Contributions of This Thesis Related to Policy Making

This thesis has aimed to define the possible future directions of government's policies and international directives'. Government has regulations that may support several type of cars such as mini car, electric car, hybrid car and diesel car etc. One of the objective of this thesis is expressing strategic interaction between government, international directives and industry that depends on all agents' choices. These interactions create many conditions and each of them makes a significant impact on auto industry's future strategies related to the auto industry regulations. Unified Relation Matrix is proposed for the overall picture which has a purpose to enlighten and to see the hidden parts of policy making process and the relation with the mainly descried criteria. Furthermore, based on several expectation related to the policies may be set up by international directives and government, the impact analysis is studied.

1.5.3 Contribution of This Thesis Related to CLSC

This research provides a method for the construction of vehicle recycling logistics to improve reuse rate. That thesis considers an optimal reverse logistics structure of the auto-industry to maximize the total profit of side traders. Also, the feasible and the optimal solutions of the different policy option which can be set by government in future is shown by the scenarios and how to select the appropriate one is important for the robust design of the reverse logistic network.

For brief explanation; firstly, for the contribution to the sustainable development issues, the necessary and significant relation between the policy making and the important linkage with the CLSC functionality is represented. Secondly, for the contribution to the policy making research, process divided into two logical class; the macro level and the micro level. Also the impacts of them into the organizational structure by shifting the CLSC and make pressure to check the CLSC stakeholders is discussed. Finally, for the contribution to the CLSC research, the flows in a network and the selection of appropriate CLSC structure considering the environmental burden in the reverse logistic side.

Develop countries and developing countries are taking this topic in a different way. So firstly, the current global states of car recycling including Europe, USA, Japan and China are analyzed. Next, a reverse logistics construction model of the auto-industry is presented, and a mathematic formulation is proposed from a win-win point of view. Finally, by using the analytical solution method of the LP (Linear Programming) problem, the optimal and feasible reverse logistics structure can be clarified based on the reused parts demand. Moreover, our results indicate that when the demand rate of companies is well-balanced, the cooperative distribution structure is the optimal logistics constructions; meanwhile, when the internal sourcing costs of related traders are zero (*e.g.*receiving subsidies from the government), the no cooperation distribution structure becomes optimal.

Chapter 2

Literature Review and Problem Formulation

In **Chapter 2** an extensive literature review is represented topic by topic and according to the gaps the author has defined, the objectives of the thesis and the problem statement are expressed. Solutions for each problem is published as a refereed paper and the list is given in this chapter.

2.1 Literature Review for Related Topics

2.1.1 Sustainable Development

In literature, processes of political decision making with sustainability issues are a newly arisen topic to define the impacts on business strategies, though there are not enough researches on introduction and definition of solution methodologies to optimize collaborated outputs. Related literature of background of this research topic has been discussed as the macro level and the micro level sustainability strategies. United Nations Environment Program (UNEP)'s a reference manual [113] on integrated policy making for sustainable development implicates the full value of integrated policy making in its environmental, social and economic dimensions. Spangneberg and Bonniet [21] discussed about the interlink indicators for the macro level policy making which lets key drivers to connect in environment, economy and social relations with the corresponding responses in a way that is appropriate for policy movement for international harmonization. [15] discussed the role of sustainability factors as an evaluation method for sustainability which is an important topic of governance integrity for future analysis. They addressed the potential benefits of indicators for policy; and aimed to find the answers of in what ways can indicators influence governance. Furthermore, [9] expressed that the adaptation to increased climate change - which related o environmental sustainability- may have to have several policy interventions to change behaviors across multiple sectors, requiring policy processes constrained or enabled by institutional settings. They defined that the discussion of how to redesign policy processes and institutions are not much at the crucial scales of national and sub-national policy and planning. Furthermore, [24] mentioned that there has been a noticeable attention within society and policy making stakeholders to take responsibility on the causes and impacts of global changes and deliver appropriate actions for sustainable socio-ecological systems. Combining experiences of functional mechanism by innovative ones and communication between business groups and policy makers as well as scientists is an important step. In another angle, to show the impacts of policy making issues on all kind of business activities, [16] discussed the question of 'Do local and global environmental demands contradict each other at the decision phase of strategies, tactics and operations such as new destination for manufacturing plants or network design of product flow? Furthermore, how does this affect technology management in organizational design perspective?' [17]

2.1.2 Policy Making and Analysis

Policy Analysis Process [51] has a complex structure. According to the [43], it includes several aspects that have to be considered at the same time, although goals of each aspect might have conflicts. It is clear that this process does not work only with lawmakers' decision makings. Communication is remedy of setting up flexibility and is a solution of requisition for transparency and accountability during negotiations and experiencing results. In the beginning, understanding 'statement of problem' entirely and modeling it mathematically and visually, has absolute effects on not only in solution analysis layer, but also in information gathering and communication layers in process, too. [7] [32] Solution methodology should be selected related to problem size and expected results. A type of methodology which helps to include flexibility in each scenario has a great chance to be accepted. Expressing goals and defining constraints in aspects of government and business is another main step in problem analysis layer. To succeed this problem, there should be communication between any stakeholders to be influenced of regulations created. Evaluation criteria are came throughout objectives and constraints defined in problem analysis layer. [8]There is a strong relationship between criteria and policy alternatives. Criteria should be determined as what kind of anticipated outputs will be in particular regulation options. Evaluation step must represent impacts of alternatives for elements of policy analysis to be influenced.Recommendation of actions to be accomplished regarding to options must suggest a great way to see possible outcomes and responsibilities of institutions, government, business, user and sites in charge of 3R activities. Information gathering and communication layers should not exist as a single step to be considered once in a time period Proper data collection and monitoring all consequences of selected alternatives have a key role to find a door to success.[11]

Government should set a clear policy direction and provide as much as possible subsidies regarding to conditions and regulatory certainty [34]. Secondly, authority must produce and manage connections within industry and society. When setting up policies, managing this simultaneity problem is one of the most difficult tasks for policy makers [50]. So on, if government can succeed to work in partnership with businesses in all parts of the economy to encourage and spread best practice in waste prevention and resource management, as a result of this action, the economic and environmental benefits for society and the economy can be obtained.[30]

The most common expectations of policy maker from businesses can be sum up as given below:

- Focus on using resources more efficiently;
- Explore new business models which can be profitable through recycle management
- Re-use products and materials wherever possible, recycle where not;
- Take greater responsibility for the products from design to disposal
- Promote sustainable procurement for their own supply chain models

On the other hand, industry might have several expectations from governments and / or policy makers. They can be expressed such as:

- Setting a clear policy direction;
- Bearing down on illegal businesses and operators;
- Ensuring that businesses can reach to user-friendly information easily about their own legal obligations alongside guidance on resource efficiency;
- Sharing all possible evidences, researches and best practices;
- Facilitating voluntary ”responsibility deals” in key sectors

- Practicing sustainable procurement in their own operations [50].

From lawmakers' perspective, objective might be the reduction of environmental hazard impact by forcing reverse logistic structures to create appropriate recycle management systems and in general words, maximize total social welfare. On the contrary, most probably the aim that is undeniably hard to realize for manufacturers in policy making process is, to comply with regulations at minimum cost.

2.1.3 Closed Loop Supply Chain

The term 'value chain' was proposed by Michael Porter, and he defined a company's value chain as a system of independent activities which are connected by linkages. Linkages exist when the way in which one activity is performed affects the cost or effectiveness of other activities [19]. So in global scale, it can be expressed in that way; from upper level to lower level, policy making stakeholders are affecting each other and they create linkages. These linkages influence the activities of the other two stakeholders' values chain mechanism. Consequence of the global trade world conditions, politically critical three main aspects have come out; international directives, governments and industry. These elements have had to start mutual interactions in decision making process of their main objectives and they realized the imperative necessity to collaborate to create sustainable supply chains in organizations. [22] [31]

Supply chain management of industries should make a lot of efforts to reduce costs and at the same time to be innovative while maintaining the acceptable environmental performance [18]. So, the green innovation mechanism in supply chain management is an emergency to improve the competitiveness. Organizations have realized that they cannot maintain their supply chain not only as it is but also pushed them to close the loop at the end of their supply chain which creates the closed loop supply chain management (CLSC) topic[33]. [98] defined the 'Closed loop supply chain', as a system in which materials are returned and reused by the same originator, as the supplier or the manufacturer brings product back in, remanufactures it, refurbishes it then resells it. In CLSC, recoverable and reusable end of life products and the design of these products and materials have become an increasingly important stage of the overall strategic movement in industry towards environmental centered sustainability [26] [27] [77]

In literature, [22] expressed the opinions on future research directions on closed-loop supply chains and considered the management scope of it. He provided an overview of decisions in CLSCs and breakdowns them into three groups such as strategic, tactical and operational. He considered that network design was one of the main strategic decisions and had a long-term impact in years on the firm's operations.[3] considered the design of take-back legislation that maximizes society welfare as a key issue in sustainability of the society but they did not consider the effect of take-back legislations on network design. Also, he expressed that strategic decisions like CLSC structure drive most of the 'profits and environmental impacts'. [23] defined a CLSC network model with two manufacturers, two recyclers, and a market for recycled material, in the context of take-back legislation is analyzed and they compared recycling costs with two different conditions: first one is in a monopolistic and second one is in a competitive scheme. E-waste take-back system mandated by legislation is considered for second scenario.

Even though the CLSC is a proper way for significant environmental motivations, closing the loop is affected by government policies and international regulatory which play an important role in adoption across industries ([14]; [13]). It is clear that there should be a manageable connection between the government and international directive and they could have direct effects on firms' decision of supply chain structure. [10] and [20] discussed the how direct impacts are existed.

Many studies have analyzed different purposes of reverse logistics. [73] analyzed the flow of products from the consumer back to the manufacturer or another party in the supply chain. [74] considered the resulting market dynamics of a remanufactured product competing with new products. [75] studied how a firm can create and capture value by converting a waste stream into a useful and sale-able by-product (i.e., implementing by-product synergy (BPS)), and shows that BPS creates an operational synergy between two products that are jointly produced.

From an economic point of view, [76] discussed the simulation based evaluation of supply chain involving reverse logistics, [77] suggested various approaches for certain crucial issues in strategic planning of a reverse supply chain, [78] proposed a CLSC model including vendor managed inventory (VMI).

The auto industry has a large-scale influence on the world economy. Most works on innovation and performance in the forward automotive supply chain have focused in product design, manufacturing technology and inventory strategy rather than used cars in the reverse logistics. For instance, [79] analyzed the effect of several products and organizational capabilities on new product development lead times. [80] compared the automobile producers of U.S. and Japan, which includes labor, capital, and total factor productivity. [81] studied the impact of product variety and manufacturing performance and consumer perceived quality using data from international automotive assembly plants. [82] presented a framework for analyzing the benefits of flexibility in a multistage supply chain and developed a flexibility measure and guidelines for flexibility investment. [83] studied the deployment of manufacturing flexibility of the North American automotive industry. [84] reported substantial and persistent differences in finished-goods inventory levels in the U.S. auto industry supply chain, and their paper identified and measured the effect of several factors on finished-goods inventory in this industry, found that two of these factors, production flexibility and the number of dealerships. Hopp et al. (2010) focused specifically on the impact of variability on the optimal placement of logistics and process flexibility in a multi-product supply chain. Little attention has been placed on the management of reverse logistics from the used car to the reuse (or recycling) side in the green auto industry supply chain, which is the focus of this thesis.

In the global auto supply chain, the amount of new car demanded in the world has increased in the most recent 10 years. Specifically, the demand from developing countries has expanded greatly such as India, Brazil and China. Therefore, vehicle recycling is a significant part of global industry strategy. Consideration of global auto recycling will be described in the next section.

On the other hand, in recent years, there has been an increasing concern about coordination and sharing-information in supply chain. As related literature of sharing-information in supply chain, [86] discussed how a manufacturer can use contracts to share private demand information credibly with a supplier when the information cannot be verified. [87] investigated how the sharing of inventory information among suppliers impacts the performance of a two-echelon assembly system with one manufacturer and multiple suppliers. [88] examined how a manufacturer can use a market based pricing scheme to aggregate demand forecast information from competing retailers to coordinate their ordering and forecast capability decisions.

Supply chain coordination (SCC) is a broad term spanning over the design, planning, operation, service and recycling of supply chain. Different definitions and perspectives on SCC exist in [89]. A company in a supply chain usually holds a win-win or lose-lose relationship with its upstream players (suppliers) and downstream players (customers). They are partners and need to coordinate together to achieve win-win and avoid lose-lose by mitigating supply chain risks [90]. An example of strong coordinating relations among supply chain players is the structure of the assembler-supplier relation of Japanese auto makers. This structure is called as "keiretsu", which enables Japanese auto assemblers to remain lean and flexible while enjoying a level of control over supply chain akin to that of vertical integration ([28]; [91];[92]). In this thesis, from a win-win point of view, we consider the optimal reverse logistics structure of the automobile-industry where traders share the partial information in used part market.

Due to the global competition, the changeover from a mass production and consumer society to a sustainable society has become more important, in order to reduce environmental burden and user costs. In supply chains that cover the automobile life-cycle, the discussion of the formation of logistics among auto dismantling traders, reused parts traders and scrap metal traders have attracted attention over the years [93].

Behind above background, the authors, therefore, consider an optimal reverse logistics structure of the automobile-industry to maximize the total profit of said traders from a win-win point of view. In this thesis, first, the reverse logistics problem of the auto-industry is analyzed based on the current global state including Europe, USA, Japan and China of car recycling. Next, based on the current state of vehicle recycling in Japan, the mathematic formulation of the reverse logistics is proposed for reuse rate improvement. Finally, by using the analytical solution method of the LP (Linear Programming) problem, the optimal and feasible reverse logistics structure can be clarified based on the reused parts demand.

In most articles, scholars agree that selection and evaluation of vendors are complicated and difficult because of the large number of both quantitative and qualitative criteria to be conceived [99]. In the past, a number of methods are used for supplier selection and evaluation problem. Most of these approaches have limitations such as evaluation is based on just operational scales, subjective judgment, lack of information and relative evaluation between all suppliers [100]. In order to deal with these limitations supplier selection and evaluation problem should be solved by using multi-criteria decision making approaches (MCDM). Multi-criteria decision making can be defined as the evaluation of the alternatives for the purpose of selection and evaluation or, using a number of qualitative and / or quantitative criteria that have different measurement units [101]. There are several common methodologies for MCDM, such as simple additive weighting (SAW), the technique for order preference by similarity to ideal solution (TOPSIS), analytical hierarchy process (AHP),analytical network process (ANP), data envelopment analysis (DEA) and so on [102]. However these evaluation methods use only one rating scale to find final score for each vendor, despite the characteristic of criteria is quantitative or qualitative. Unlike these methods, in order to fill the gap in those methodologies, Grey Relational Analysis this is a mathematical analysis of the systems that are partly known and partly unknown and defined as weak knowledge and insufficient data, was introduced by Deng in 1982. Grey theory examines the interaction analysis when the decision making process is not clear [101].Grey Relational analysis is used in many decision making problems such as supplier selection, facility layout selection, and finance performance evaluation and material selection. [2] [3]

2.2 Summary for Literature Review

According to the literature review, the author realized several problems to be considered in this thesis. The main topic which are expressed in literature, the uncertainty of sustainable development analysis, the fuzzy process of the policy making and now considering the global conditions, it get more complicated and there is a need for the new point of views. The CLSC is also a new topic and is being discussed recently so the topic still needs to be improved by the results of several implication, sharing information with society related to the improvement issues and how to set up the CLSC aims and the network design.

2.3 Objectives and Problem Statements

2.3.1 Objectives of the Research

In the first step, according to the findings based on literature review, we realize the gap between scenario generation and policy making mechanism issues; so, we aimed to express hidden areas by criteria and functionality by our newly developed unified matrix. Furthermore, the decision making for the future strategies, the current and the situation of the policy making stakeholders are discussed considering the dominant and minor impacts on each other's decisions. In second step, policy decision making process and selections of appropriate scenario based in requirements are aimed to be analyzed by scenario analysis. The reverse logistic sturuture for the closedloop supply chain management is discussed considering the global an future automobile recycling management. Finally, in third step, we aimed to propose a fundamental evaluation framework in CLSC especially in large scale industry such as auto industry, considering interrelation points within crucial levels of product life-cycle.

In first step, the author would like to explain all the influences of international regulations and policies on industries' strategic decisions simultaneously. We aim to develop a generic decision making strategy to define scenario generation mechanism by Unified Matrix for Interactive Impacts structure which can define the relations between factors and functions of closed-loop supply chain from planning to the recycling level. To describe the current and the future situations, by using the evolutionary game theory.

Second phase, considering near future‘s urgent recycling needs, construction for CLSC of Hybrid Car and Electric car, centered on 3R (Reduce, reuse, recycle) Centers to reclamation of valuable parts - electric motor, hybrid engine and battery- was created. Input - output analysis of proposed model was presented as mathematical formulations. To be able to solve optimization problem and clarify the solutions for several cases of CLSC, analytical solution for Linear Programming methodology is decided

As s second step, we aim to represent changes on logistic constructions model in CLCS of auto industry regarding to several policy scenarios accordance with possible real case regulations of government. Effects of mutual interactions on International Regulations, Governments and Auto Industry.

In final step, there are two phases. First phase is to create general decision making model for general CLSC related to selection and evaluation decisions. According to the model, it is perceptible that end of life products can have still economic value and significant effects on companies to make total profit higher by managing forward and reverse flow of cycle. Model obviously presents that selections would be one of the main problem related to optimization of CLSC structure. (Figure 2.1)

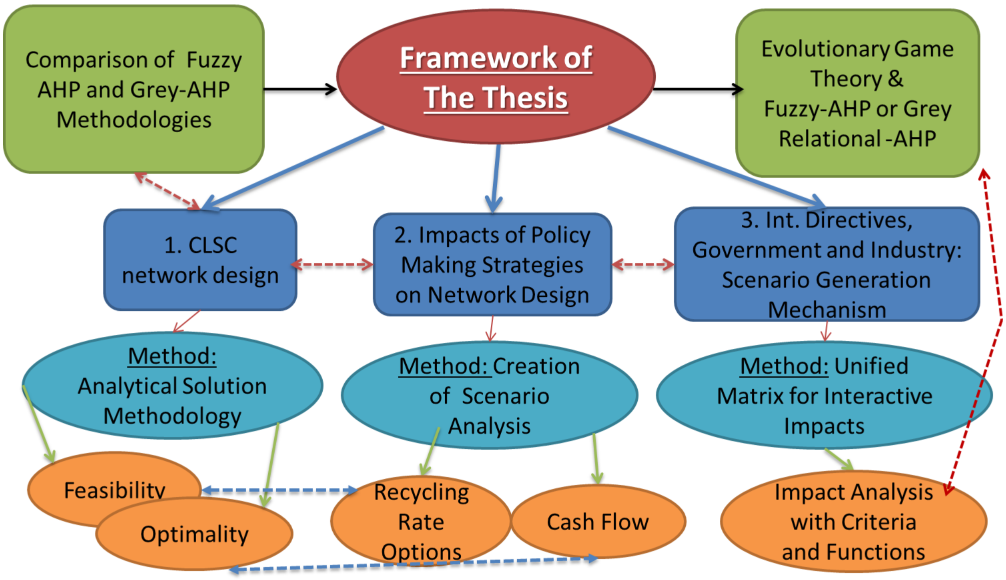

Figure 2.1: A framework for Objectives of the Thesis

This model was developed considering not only Japan's Recycling strategy for end of life products, but also international regulations, too. Getting approved solution methodology, these policy decision making strategies will be able to suggest as a robust selection strategy to create recycling centered CLSC take into account policies which can wield enormous influence on business world.

In this study, two major topics are mentioned to develop a new model to combine reverse logistics and forward supply chain management; Sustainability and Evaluations in CLCS.

Firstly, in the light of the sustainability, the projects, programs and supply chain of organizations' to be involved must be considered to have sustainable. Unlike the traditional supply chain models, which focus on only economic benefits for each member of the network, closed loop supply chain must consider economic, environmental and social aspects of sustainability. The term of Reverse Logistics is firstly defined by The Council of Logistics Management (CLM) in the early nineties [97] as “often used to refer to the role of logistics in recycling, waste disposal, and management of hazardous materials; a broader perspective includes all relating to logistics activities carried out in source reduction, recycling, substitution, reuse of materials and disposal.” This term could have some additions according to the types of organization such as business, industrial, government, commercial, and consumer organizations, but regardless of the type of organization, reverse logistics activities should be considered as an important percentage of sustainable development.

Secondly, Close loop supply chain includes forward supply chain and interdependent reverse logistics. This subject area which is focus on to combine and create reverse logistics and traditional supply chain approaches, still relatively new. If we need to make a definition, Closed loop supply chain system is , in which materials are returned and reused by the same originator, as the supplier or the manufacturer brings product back in, remanufactures it, refurbishes it then resells it (Kopicki, et al., 1993).

Most of the electronic equipment companies in the world are in the process of integrating sustainability factors into sourcing processes and decisions internally. Sustainability in general, has received much attention in the past few years, while sustainability in closed loop supply chain models has been attracting much attention within the last decade. This study aims to create a model to help evaluating suppliers by using hybrid grey relational analysis for a firm in cable industry. To be developed model is compared with hybrid fuzzy logic and AHP model. Output of the system will be a semi-annually or annually credit report for all suppliers to identify the current status to keep track on sustainability of outsourcing success of closed loop supply chain network.

As a solution case, this chapter also conducts a case study of supplier evaluation from the aspect of integrating sustainability factors into sourcing processes and decisions to be developed a general evaluation model of closed loop supply chain in a cable manufacturer which is a trading company in electronic components and energy sector. It is quite difficult to increase market share into cable market all over the world. The increasing raw materials price would affect the competition of the products and makes more difficult the first step of the selection approach and then for each phase of CLSC. Above all, there are three questions need to be answered in this study, which are; Which criteria and processes are used by company on the evaluation of suppliers? What are the selection and evaluation methods are recommended by the literatures? What the criteria and processes must be used by the company can be matched the aim of the project sustainability and CLSC approach?

2.3.2 Problem Statements

So, considering the given literature review and the explanation, it is possible to summarize the problems as given below;

Problem 1. Strategic policy making process to define possible future directions for all policy making stakeholders

Problem 2. Impact analysis of the political decision on the business sustainability and the affects on the objectives of companies

Problem 3. Construction of the reverse logistic side in CLSC by impact analysis of governmental policies.

Problem 4. Creation of scenario mechanism based on the possible political decisions and how to choose the appropriate one.

Problem 5. Micro level impacts of the policy making and the results of the rechecking of the CLSC structure and the evaluation of the suppliers

2.4 Outline of This Thesis

After the objectives of this thesis are stated in this chapter, this thesis is organized as follows; **Chapter 1** give brief information about the overall thesis and introduces the terms used in this thesis in general framework.

In **Chapter 2** an extensive literature review is represented topic by topic and according to the gaps the author defined, the objectives of the thesis and the problem statement are expressed. Solutions for each problem is published as a refereed papers and the list is given in this chapter.

In **Chapter 3**, the author will discuss a strategic policy making decisions for future direction by using evolutionary game theory. Macro level policy making can be clearly understood in this chapter and the impacts also in this process is represented. There are two conditions which are current and future situations of stakeholders and there are three main stakeholders which are international directives, government and industry. As a case study, mini car strategies including kei cars,current situation in Japan and the other possible implications of the other countries similar to mini car strategies is illustrated. Related works are also included as Appendix.

Chapter 4 deals with impact of political decisions on business sustainability. The main topic here is the generation of Unified Relation Matrix which defines the multiple dimensions of impact analysis. Firstly, it is possible to define the importance levels for criteria in trial bottom line of sustainability. Secondly the relation between the criteria and the functions of the CLSC is easy to express. Thirdly, the relation between the trial bottom line of sustainability and functions of CLSC is discussed. Finally, the overall impacts which are easily picked up for use in Analytic Solution method in LP. Related works are also included as Appendix.

Chapter 5 presents illustrative examples to explain clearly the impact of political decisions on construction of CLSC in the global auto industry as a case study. The main target here is expressing shifting for the flows in the network and the 3R activities in the reverse logistic side of CLSC by comparing the feasibility and optimality of different levels of policies. Related works are also included as Appendix.

Chapter 6 summarizes the major themes logical scenario generation mechanism based on possible political decision related to the cost of transportation, cost of 3R activities and the percentage of the recycling rates for engine parts of different class of cars as a case study. Related works are also included as Appendix.

Chapter 7 shows the impact of macro level political decision on the micro level decision making of a inner company by expressing the evlaution of key raw material suppliers to create a robust and sustainable CLSC. Related works are also included as Appendix.

Chapter 8 expresses the important and highlighted part of this thesis by the discussion of each chapters. Several results are representing the unique side of each research themes.

The final chapter **Chapter 9** summarizes the all research studies finalized through the thesis and conclude the results. For future recommendations, the author expressed several ideas and the way to develop this topic in future.

Chapter 3

Strategic Policy Making for Future Directions

In **Chapter 3**, the author will discuss a strategic policy making decisions for future direction by using evolutionary game theory. Macro level policy making can be clearly understood in this chapter and the impacts also in this process is represented. There are two conditions which are current and future situations of stakeholders and there are three main stakeholders which are international directives, government and industry. As a case study, mini car strategies including kei cars,current situation in Japan and the other possible implications of the other countries similar to mini car strategies is illustrated. Related works are also included as Appendix.

3.1 Introduction

Environmental centered sustainability is a major topic as in global-scale. While keeping the ongoing basis of the development with the balance of social and economic outputs, protecting the environment from all kind of pollutions is a great challenge for all policy making stakeholders. International directives are one of the major drivers to define macro level environmental standards as regulations. These regulations effect the decisions of government; which is second major driver on the process of policy making in their national strategies (Figure 3.1). Every government has their own aims to be able to be competitive; however, because of the commercial trades with other countries, international directives become an affecting part of national strategic decisions. They require several enforcements to maintain international trades. This creates a conflict in policy decision making process of governments. Governments need to define a development path by their own action plans and at the same time there should be a negotiation process between the global scale strategies including the environmental centered sustainability topic[1][29][52].

Governments should response the changes taken place in global world on time and with a competitive strategy. Furthermore, government is directly related to the industries' policies as well. So, it is said that a nation's strategies can lead firms to be successful or fail. National regulations and market dynamics may push many companies to consolidate, divest, or exit from some geographies or businesses sometimes. In Japan, automobile industry is one of the main drivers of the economy. So, automotive companies may have to recheck their product portfolio, manufacturing systems, management styles and supply chain strategies to remain competitive in the complex and changing global regulatory environment[15][53][65][64].

Governments and international regulations have been taking several imperative actions and pressure on automobile manufacturers to find innovative and effective solutions to deal with environmental centered sustainability problem. However, only creating technology policies are not enough to contribute drastic solution of environmental problems caused by automotive sector. Transportation policies can be one of the major problems in the solution of environmental problems. These policies may help transformations in the transportation demand and these changes are very essential for policy makers to define future scenarios. In considering such policies, it is necessary to consider that transportation demand is dependent on local characteristic. Hereby, it is the crucial point that preparing and applying appropriate transportation policies with due consideration of national characteristics and international directives' expectations, while monitoring the technological industrial innovations [3],[14]. In Japan, there are three main classification of automobiles based on body size. Government has regulations that support a type of vehicle named keijidousha (Kei car) which is light and Eco-friendly category of mini size vehicles and electric cars. The main purpose of the Japanese government's policy may be relevant to the aims of CO_2 reduction strategy of automobile sector in view of technological innovation and travel demand change. Travel demand change is related to the trends behind vehicle use. Vehicle preference indicates that mini cars are preferable by a great percentage of society [54]. Not only technological innovation, but also minimizing the car engine size and decreasing the gasoline usage may be a future option to seize the environmental burdens of international directives and the government's future strategies.

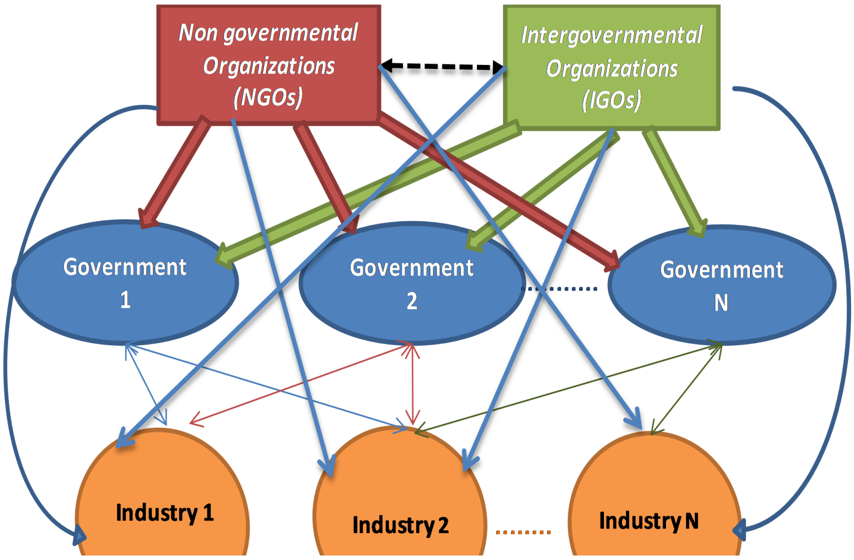

Figure 3.1: Influent key stakeholders in policy decision making and their relations (reproduced from ([13] p.5)

This part aimed to define the possible future directions of government's policies and international directives' related to the mini car strategies of auto industry considering Japan case [55]. Objective of this research is expressing strategic interaction between government, international directives and industry that depends on all agents' choices. These interactions create many conditions and each of them makes a significant impact on auto industry's future strategies related to the mini car regulations. As a solution methodology, evolutionary game theory is applied.

3.2 Problem Statement for Strategic Policy Making

Government and international directives has a great impact on automotive industry to make a decision for future strategies related to mini cars (Figure 3.2). In this situation, there are three main policy decision-makers which have interact with one another which are government, international directives and industry. The specific goal of each decision maker is different but however, they are dependent on each other to balance the satisfaction for the application of environmental centered sustainability expectations. Each of the strategic decisions is affected by how their behavior interacts with that of others [14]. So, all of the interaction has an impact on current and future conditions of their situations. Sometimes international directive can be dominant or government can be dominant. Especially in developed countries like Japan, generally industry has a power and one of the major social and economic drivers but recently, it is so relevant to the environmental problems, too. Hence, here is the solution methodology which is appropriate for this problem: Evolutionary Game Theory. Game theory is concerned with situations in which decision-makers interact with one another, and in which the happiness of each participant with the outcome depends not just on his or her own decisions but on the decisions made by everyone. The key insight of evolutionary game theory is that many behaviors involve the *interaction* of multiple organisms in a population, and the success of any one of these organisms depends on how its behavior interacts with that of others. So the fitness of an individual organism can't be measured in isolation; rather it has to be evaluated in the context of the full population in which it lives [58].

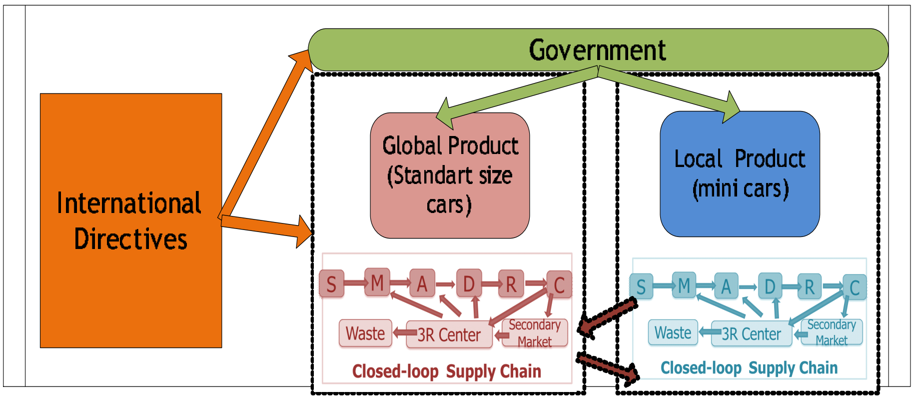

Figure 3.2: Policy Making and Automobile Industry

3.3 Methodology

3.3.1 Evolutionary Game Theory (EGT)

In general, game theory was primarily focused on cooperative game theory, which analyzes optimal strategies assuming that individuals stick to previous agreements. In the 1950's, the focus shifted to non-cooperative games in which individuals act selfish to get the most out of an interaction. At that time, game theory had matured from a theoretical concept to a scientific field influencing political decision making, mainly in the context of the arms race of the cold war [59]. Evolutionary games are the bandwidth choice game can be given a different interpretation where it applies to a large *population* of identical players. Equilibrium can then be viewed as the outcome of a *dynamic process* rather than of conscious rational analysis.[1]

Modern game theory goes back to a series of papers by the mathematician John von Neumann in the 1920s. This program started a completely new branch of social sciences and applied mathematics. Initially, game theory was primarily focused on cooperative game theory, which analyzes optimal strategies assuming that individuals stick to previous agreements. The basic assumption was that individuals act rationally and take into account that their interaction partners know that their decisions are rational and vice versa. Based on a common utility function that individuals maximize, the actions of others can be predicted and the optimal strategy can be chosen. However, the underlying assumption of rationality is often unrealistic. Even in simple interactions between two individuals A and B, it is difficult to imagine fully

[1]Please check [59] for the equations and mathematical expressions to calculate the evaluations expressed by pay off matrices in evolutionary game theory.

rational decision making, as this often leads to an infinite iteration: A thinks of B, who is thinking of A, who is thinking of B and so on. One way to avoid this situation in economy is the idea of bounded rationality. If the cost of acquiring and processing information is taken into account, individuals can no longer be assumed to do a fully rational analysis. unstructured populations.

3.3.2 Decision Making with EGT for Future Policy Directions

Evolutionary game theory can be adapted to the policy decision making model to set up future strategies because this method may support the distribution of each player's selection over time with a payoff matrix. Policy making directions especially for the sustainability can be uncertain for many cases. The general aims of the players, which are the international directives, government and the industry, always looks like they are in a different direction but the big picture related to the sustainability is generally similar; they all want to realize sustainable development.

Achievements and mostly all of the actions of each other can differ, for current situation and for the future situation. Each of the tactics have a great impact on each other's strategies. The Evolutionary Game Theory supplies to the players a significant direction and representing the dominant and the minor roles considering all of the possibilities.

The reason of the selection of EGT as an methodology for this part is; it is convenient for the visualization of the current situations, future circumstances and the interaction between the each problem. However, the fuzziness in this situation may be appropriate for the Quantum Game theory applications which can be considered as a future recommendation.

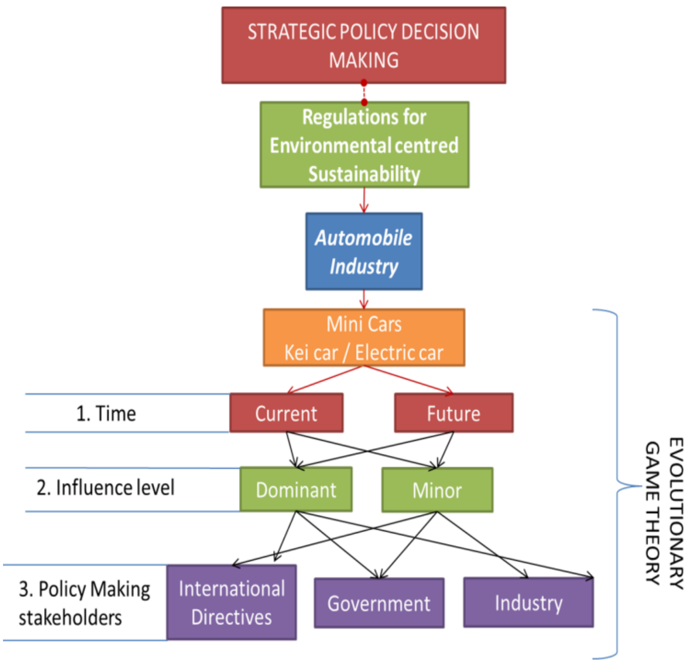

Figure 3.3: Defining Future Strategies with Strategic Policy Making

In this research, we considered the future situation and the current situation of these three players for their dominance cases. To be a dominant player in a strategic game means that a strategy dominates another strategy of all player if it always gives a better payoff to that player, even not considering what the other players do (Figure 3.3).

In dominance cases, one strategy is always a better choice, despite the action of the opponent. Either international directives dominates government (d1 >g1 and d2 >g2) or government dominates international directives (d1 <g1 and d2 <g2), and either government dominates industry (g1>i1 and g2>i2) or industry dominates government (g1<i1 and g2<i2) and as a third case, either international directives dominates industry (d1 >i1 and d2 >i2) or industry dominates international directives (d1 <i1 and d2 <i2) (Figure 3.4). However, the final case (industry dominates international directives) has almost any possibility to realize this strategy in real world.

	Directives	**Government**	**Industry**
Directives	d1	d2	d3
Government	g1	g2	g3
Industry	i1	i2	i3

Figure 3.4: Three strategies 3 x 3 pay off matrix

3.4 Illustrative Example

In order to express the interaction mechanism in policy making process by evolutionary game theory, dominance strategies of the player ‘directives’ on government’s future and current situation for developing regulations related to the mini car and industry’s future and current situation for seizing the regulations related to the mini car strategy is presented (Figure 3.3).

There are three different cases based on the consideration of the player in the intersection of four triangle is always dominant. In Figure 3.4, each triangle is the interactions and the influences of these elements’ on each player’s acts. In this example, an assumption is the international directives are the dominant element in all games. For instance, in combination 1, international directives are always considering the best strategy and become dominant to define the expressions and affect the decisions of government and industry in a sharp way. To be clearer, for example, international directives may have some drastic changes in their expectations from governments related to the environmental centered sustainability enforcement. Governments should define a path to meet the demands of these directives to stay competitive. Accordingly, government can see the path to follow according to the strength of the strategic dominance of international directives showed as pay off s in the game by evolutionary game theory. Finally, industry may have a chance to follow status of dominance for both of the other strategic policy decisions and create a countermeasure plan as a scenario path in time to seize the government’s and international directives’ aim sequentially.

In Table 3.1, there are eight combinations for three policy decision makers' game strategies considering the current time and the future. The aim of these combinations is to show all strategic games which have an influence on the time schedule of the players.

As an example; the current strategy of international directives may have a dominant impact on the future decisions of government and the result of the method 'evolutionary game theory' may show us the way of path of strategies. Based on a common utility function which is usually the payoff from the game that individuals maximize, the actions of others can be predicted and the optimal strategy can be chosen.

Table 3.1: Possible cases expressing the interaction of current and the future situation of three main policy decision making players

	CASES		
	Directive	***Government***	***Industry***
1	Current	Current	Current
2	Current	Current	Future
3	Current	Future	Current
4	Future	Current	Current
5	Future	Future	Current
6	Future	Current	Future
7	Current	Future	Future
8	Future	Future	Future

In evaluation step of evolutionary game theory, the payoff matrix should be created. Table 3.2 is the explanation of the status of being dominant in the game for all players. If the international directives are the main dominance player to define the strategy, then the evaluation value should be greater than the other two players. According to the Likert scale, we can use the evaluation values as 9,7,5,3 and 1. 9 is the highest point that shows the most dominant strategy is being held [64]. 1 is the lowest point which explains the less dominant strategy is being made by the player. For example, if the government has 9 degree dominance in a new policy definition game, the path of the future strategy is almost defined by government dominant regulations and there is less chance to create a different path for industry to follow the regulations.

The visualization of the all combinations in Figure 3.3 indicates the dominance status of each policy decision makers and the relation of the future condition and current condition of all players at the same time in strategic state. Strategic state is the explanation of the results of this evolutionary game in evolutionary game theory.

Considering the mini car strategies, current actions of each player have a decision but, they still interact another and this create a interaction that create a new dilemma such as the future strategies conflict of the each player.

In mini car strategies, industry is almost dependent on the consumer preferences and the government decision. If we consider that the consumer expectations are the key influencing issue for industry, they should keep an eye on their consumer relations strategies. However, only consumer preferences are not the only one issue to cope with. Government and accordingly

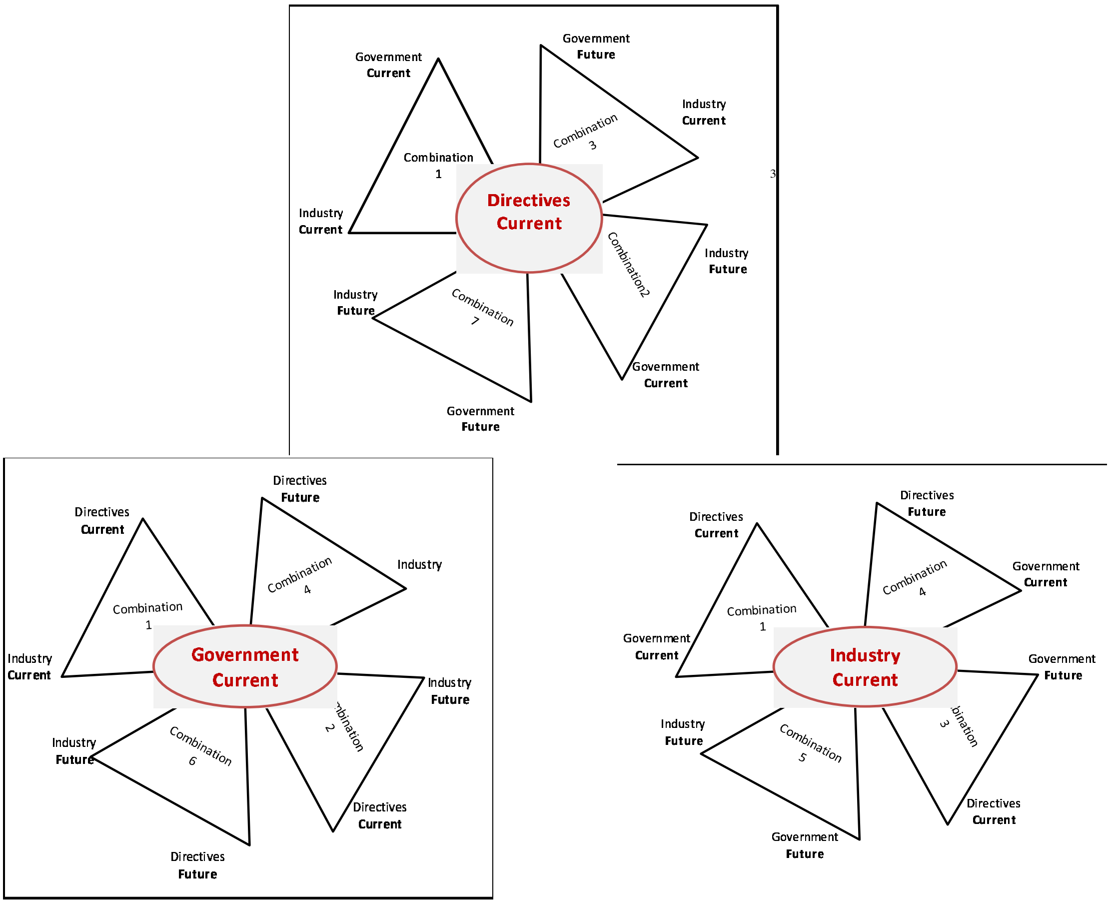

Figure 3.5: Possible cases with the dominant players' current and future situation and interactions of each other

Table 3.2: The Magnitude Order Of Evaluations To Define Most Dominant Player In Pay Off Matrix

DOMINANT STAKEHOLDER → ↓			Directives Government	
Directives	d1>g1≥i1 d2>g2≥i2 d3>g3≥i3	d1>i1≥g1 d2>i2≥g2 d3>i3≥g3	d1=i1>g2 d2=i2>g3 d3=i3>g4	d1>i1=g3 d2>i2=g4 d3>i3=g5
			Government Industry	
Government	g1>d1≥i1 g2>d2≥i2 g3>d3≥i3	g1>i1≥d1 g2>i2≥d2 g3>i3≥d3	g1=i1>d2 g2=i2>d3 g3=i3>d4	g1>i1=d3 g2>i2=d4 g3>i3=d5
			Industry Directives	
Industry	i1>g1≥d1 i2>g2≥d2 i3>g3≥d3	i1>d1≥g1 i2>d2≥g2 i3>d3≥g3	i1=d1>g2 i2=d2>g3 i3=d3>g4	i1>d1=g3 i2>d2=g4 i3>d3=g5

international directives ask for some changes that makes them dominant in current situation and future situation related to the decision making process.

These paths are described according to the payoff matrixes. Strategic state is given to specify the payoff value concretely. Dominance status of international directives and the current / future considerations of all players are main evaluation criteria. The path to strategic state is described with Dynamo notebooks [60] , created in Mathematica, -the mathematical software[61].

The arrows in Figure 3.5 mean that the movement amount per unit time. Colors mean the movement speed of the catching the strategy of the opposite player. The speed becomes faster when the color of the area gets red. The speed gets slower through the blue area. Black dots are showing the dominance status which is the stable fixed points and white dots are the unstable fixed points which is bistable o no dominance of the player. Arrows generally express the decision making path whether short term or long term with direction of the strategy selection.

Based on the Likert scale, 9 indicates the dominance of directives' strategy in current situation in pay off matrix.

In combination 1, the evaluation in pay off matrix is expressed in Figure 3.7

In this example, government's strategy in current time is less dominant than directives' strategies in current situation. Minor influent here is the industry's strategies for current situation. The black dot is on the exact coordinate of the international directives at current status. That shows that it is at the dominance status which is the stable fixed point. Hence, red area near industries presents that it should be faster than government to catch up the international

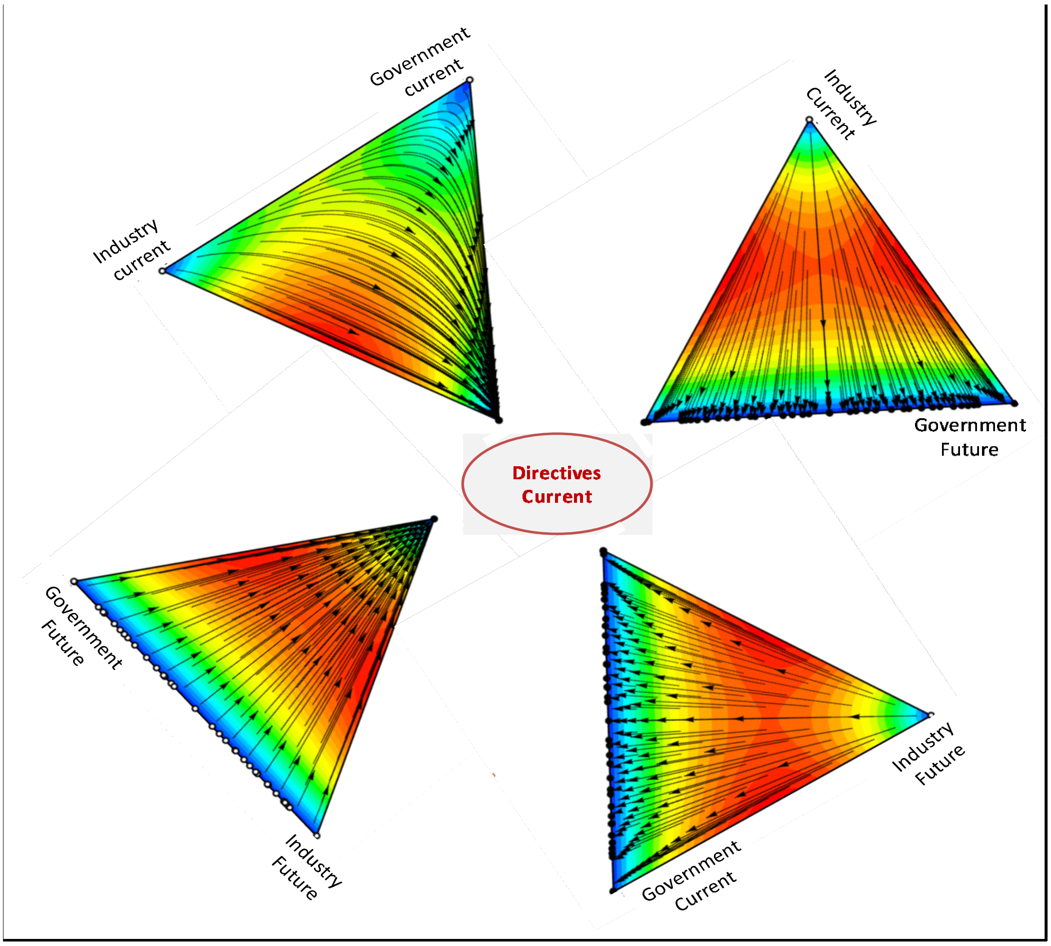

Figure 3.6: Illustrative example for the dominance situation for international directives for four combinations

d1>g1>i1
d2>g2>i2
d3>g3>i3

	Directives	Government	Industry
Directives	9	9	9
Government	7	7	7
Industry	5	5	5

Figure 3.7: An example of the payoff matrix and magnitude order of evaluations for Combination 1 in Illustrative Example

directives' strategic actions. Government is safer to be able to apply the strategies parallel to international directives.

In combination 3, the evaluation in pay off matrix is shown in Figure 3.8

d1=g1>i1
d2=g2>i2
d3=g3>i3

	Directives	Government	Industry
Directives	9	9	9
Government	9	9	9
Industry	5	5	5

Figure 3.8: An example of the payoff matrix and magnitude order of evaluations for Combination 3 in Illustrative Example

In this example, government's future plans are equally dominant with directives' current plans. Minor influent here is the industry's plans for current situation. The black dots are on the line between the international directives at current status and government future status. That shows that they are both at the dominance status and the stable fixed points are closer to them. Hence, red area near the center of triangle presents that industry can start to its strategies slower at the beginning but according to the time, mid-term decision making made them take fast actions to catch up the both international directives' strategic actions and government's actions. Government is safer to be able to apply the strategies parallel to international directives in this combination for near future and long term decision. Industry current is at the longest strategic path under these circumstances.

In combination 2, the evaluation in pay off matrix is shown in Figure 3.9

d1=g1>i1
d2=g2>i2
d3=g3>i3

	Directives	Government	Industry
Directives	9	9	9
Government	9	9	9
Industry	7	7	7

Figure 3.9: An example of the payoff matrix and magnitude order of evaluations for Combination 2 in Illustrative Example

In this example, government's current strategies and the directives' current strategies is equally dominate on industry's future situation. Minor influent here is the industry for future situation. The dots and the speed explanations are similar to combination 3 but only difference is the arrows. As said before, the arrows express the direction of the strategy selection. Here, direction is from industry future to the line between international directives current and government current. The similar strategies of government and international directives at current status made the industry at future status need more time to take the correct step; meaning it will need a long term decision making process to catch up with the main powerful policy making stakeholders.

In combination 7, the evaluation in pay off matrix is expressed in Figure 3.10

d1>g1=i1
d2>g2=i2
d3>g3=i3

	Directives	Government	Industry
Directives	9	9	9
Government	7	7	7
Industry	7	7	7

Figure 3.10: An example of the payoff matrix and magnitude order of evaluations for Combination 7 in Illustrative Example

In this example, government's future strategies and industry's future strategies are both less dominant than the directives' current situation. The black dot is on the exact coordinate of the international directives at current status. That shows that it is at the dominance status which is the stable fixed point. Hence, red area in the middle of the triangle presents that both government and industry at future status should start acts a little slower but in mid-term of the process, they need speed to act. All parallel arrows indicate that any strategy requires the similar direction of strategy decisions.

Set up Conditions an Application of EGT for Illustrative Example

In this illustrative example, we considered two main issues; the relation of current conditions with future expectations and the second issues is the dominant elements of policy directions. For this case, the author considered the directives are the main dominant element and the other elements should create a tactic according to the directives strategies as an answer.

There are numerous conditions which express the dominant case of directives to the other two elements. The author picked several cases which may show different expressions in the triangles to express unlike future cases. Some of the evaluation may have similar patterns in the result of EGT. First case directly represent the level of dominance, through most dominant to the minor influent for the current situation. Second case represent again a different dominance level but government's future strategies may be equally same with directives current strategies. Third case expresses the government?s current strategies and the directive's current strategies is equally dominate on industry?s future situation. The evaluations are created based on the Likert scale. 9 shows that most dominant effect, and 1 shows the most minor effect in current and future strategies.

3.5 Conclusion

In this research, the authors aimed to express strategic interaction between government, international directives and industry that depends on all agents' choices. These interactions create many conditions and each of them makes a significant impact on auto industry's future strategies related to the mini car regulations. As a solution methodology, evolutionary game theory is applied.

Results of the illustrative example and the literature reviews showed that these three stakeholders has all have their aims but at the same time, they have mutual interaction which is not easy to explain with rationalization or pure math only. Game theory fits the explain multi aim problems in the political strategic making both the optimum outputs for any players.

Illustrative example is only a little part to see the complexity and the difficulty to clearly explain of these interactions in big picture, however, that examples indicated that the international directives, government and industry are not the separate parts of policy making but they have together have a significant impact to create future strategies.

Chapter 4

Impact Analysis of Policy Decisions on Business Sustainability

Chapter 4 deals with impact of political decisions on business sustainability. The main topic here is the generation of Unified Relation Matrix which defines the multiple dimensions of impact analysis. Firstly, it is possible to define the importance levels for criteria in trial bottom line of sustainability. Secondly the relation between the criteria and the functions of the CLSC is easy to express. Thirdly, the relation between the trial bottom line of sustainability and functions of CLSC is discussed. Finally, the overall impacts which are easily picked up for use in Analytic Solution method in LP. Related works are also included as Appendix.

4.1 Introduction

Globalization made industries more affected from changes in political decisions and requirements of nongovernmental organizations that have power to make pressures on governmental laws. High-tech and multinational industries may be the most widely affected by the strategic changes and should be agile to adapt them to decrease cumulative effects of the pressures.[6] expresses that 'Cumulative effects can be expressed as are the total effects, including both direct and indirect effects, on a given resource, ecosystem, and human community of all actions taken, no matter who has taken the action'. Thus, all of the system or 'big picture' should be considered as whole to discuss how the influenced parts may take action towards the strategic changes as countermeasures.

Legislation mechanism of European Union and United States can be represented as an example to show relations between member national governments and top of the council in legislation decision making process (Figure 4.1)[1]. There are several actors from a particular country and the international committee that have direct influence on legislation making process. By this figure, manageable items of EU legislation mechanism are not easy to understand. The government of the United States of America (USA) is the federal government of fifty states that constitute the United States. Thus, in USA, there is a similar political system with EU but of course there are several changes in legislation making flow diagram.

The main actors are in multi elemental legislation making mechanism can be said that generally are similar. Legislation making includes negotiations, and negotiable factors are hidden in this flow. There is not a clear guide explains the decision making processes by factors and affected functions of industries. The main objective is to show the missing part of the multinational legislation mechanism and contributions that our research is dealing with. Political science issues related to the voting systems or elections are out of our scope.

First motivation of this research is to define multi-dimensional relations between stakeholders of policy making process. In literature there are very few studies to consider policy making process in terms of unified interrelation three bottom–lines of sustainability and important factors influence the business. Second motivation is political issues related to environmental concerns. Each stakeholder has their own objectives and criteria but recently, they cannot act alone in political decisions specifically based on end of life product life-cycle because especially multinational companies have to deal with several aspects; policies and nongovernmental institutions. Determining how to promote real equal opportunities for the main elements of law making process is the suffering part of this research. There were obstacles to define the overall picture including these elements that are affecting all industries. This is a newly arisen problem, which is to be solved by establishing a *Unified Matrix for Interactive Impacts*. We propose a methodology to define relations by factors and dividing them into smaller parts, for example; relation between functionality or relation between criteria affecting decision making strategy of the firms' CLSC (Closed loop supply chain) is one of the options.

[1]Adapted from `http://en.wikipedia.org/wiki/File:Politica_System_of_the_European_Union.svg`

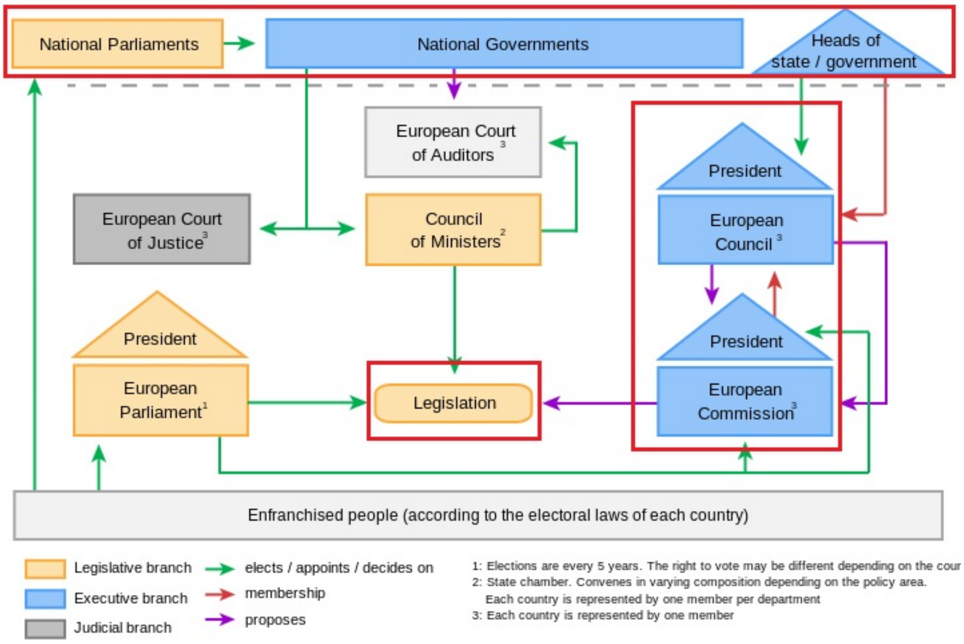

Figure 4.1: EU Legislation Mechanism: Organigram of the political system

4.2 Problem Statement for Global Policy Making Mechanism

Based on recent competitive trade rules, supply chain structures of firms have been transforming themselves into an upper level which is defined as 'closed-loop supply chain'. Furthermore, end of life products which have still economic value and re-usability in production, gain more importance. Companies have already found the secrets of not only recycling but also other 3R activities. Correspondingly, recycle management in their organization have been taking a significant place to decrease the several costs and to prove society that they are willing to increase environmental consciousness. These transformations are going on and more effective and dynamic changes are still required from industries by requirements of international organizations and governments' laws.

So, it is clear that environmental issues are one of the tools to apply sanctions on firms.

In literature, scenario analysis studies have been widely placed. However, scenarios are generally generated based on decision makers experiences and there is no clear guide to define scenario generation mechanism. Managing smooth transitions is an important topic for industries. However, global nongovernmental organizations and laws wait for fast changes in industrial actions according to the environmental awareness and managing the end of life products. International conflict creates significant pressures on industries. Making decisions and ability to see any effects on organizations are the main topic for maintaining sustainable business strategy. Managers make decision with the verbal and non-systematic expressions but the results of the decisions do not contribute the long term success of the company in default of systematic processes. This research's main topic is proposing a 'Unified Matrix for Interactive Impacts' methodology to fill a significant gap for decision makers how to create scenarios for future acting orders.

4.3 Methodology

In this part of this thesis, all of the general discussion in that research process can be said that are the cause of this part. The gap that the author realized is a huge gap which all of the policy making stakeholders have fuzzy strategies and there is no clear and certain directions. Actually even the current situation related to the sustainability and the environmental issues still in an ongoing process for the outputs of several countermeasures. So,if we need to answer the question "Why did we create the Unified Relation Matrix?", the first answer is : Because there is a need for simplifying and highlighting the hidden relations and visualization of the global policy making process in a matrix.

We assume all of the stakeholders have a significant impact on the process and the creation of the robust CLSC for industry which is the driver of the several important sustainability problems, so the hidden relation between the essential criteria which should be carefully discussed are shown here.

4.3.1 Unified Matrix for Interactive Impacts Structure

Process of policy making have been studied in literature and layers of this process were mentioned (Stone, 2011; [51] ; [25]; [12]). Substantial contributions of this research are clarifying the hidden elements by a newly developed *Unified Matrix for Interactive Impacts* and transforming the only verbally explained issues into a visualized and systematic interrelation mechanism by matrix. Table 4.1 is a generic framework of the matrix. In this matrix structure, main topics are given as follows;

- Functionality of CLSC
- Criteria affecting policy decision making
- Three main stakeholders of political processes
- Trial bottom-lines of Sustainability

Based on these main topics, critical comparisons and necessary definitions become possible.

At upper side of the matrix, decision makers start with the first step of influence definition mechanism. They should define importance level of each criterion based on the each element of trial bottom-line of sustainability. So it will be more organized and clear to see which criterion is more important to deliver what kind of sustainability principle. On the center of the matrix, functions are included as a row. Some of the function layer can be divided into several sub functions. Each layer of the function consists of the reflection of the influence three main policy making stakeholders Based on the level of function, the weights of each criterion are determined by reflecting each stake-holder's political decisions. Actually, this matrix is yet more flexible and may be used for defining any relational level and weights of criterion or the relation with sustainability issues given below;

- Criteria vs. Trial bottom-line of sustainability
- Criteria vs. Three stakeholders of Policy making
- Criteria vs. Functionality
- Functionality vs. Trial bottom-line of sustainability
- Functionality vs. Three stakeholders of Policy making
- Total policy impacts in a function and/or sub-function
- General weight of the criterion in each process
- Total impact of a specific criteria in a function

Effects and the relations in the matrix can be expressed by the impact of the three stakeholders in policy making process which may influence the each decision for all functions of CLSC of an organization. Criteria, on the other hand express the overall effects by the constraint of an organization and how each stakeholder may define this constraint is the explanation of "effect of criteria" in that matrix. Effect of the three stakeholders on sustainability issues can be expressed in the objectives of the organizations. In each function, to maintain the expectations of policies, the evaluation indicators are necessary. These criteria or with the other name criteria are the indicators of the measurement outputs.

4.3.1.1 Functionality in CLSC

In this chapter, five key functions of CLSC are mentioned to cope with the creation stage of a logical political decision system (Table 4.2). This is the core level to be able to define outputs centered sustainable business strategies. Evaluations express weights of criteria in each element of policy decision making in *Unified Matrix for Interactive Impacts*. Product planning function includes mainly the planning of 3R activities for end of life products. Product development stage in functionality divided into two sub-functions. First one is Design for Environment. This sub-function covers the topics related to design of the products centered environmental consciousness. Second sub-function is Eco Engineering & Management. This layer minds the ecologically aware engineering techniques and management styles in a closed loop structure of the company. Product implementation function divided into two sub-functions. Purchasing sub-function is related to the supplier relation and evaluation of them that are able to be concerned with ecological issues in CLSC. Second sub-function of implementation layer is Refurbish &

Production with used parts. This sub-function holds the key for main aims of CLSC strategy of firms. Product control function is related to the sales and marketing strategies connected with realization of objectives. End of life product functions is the core problematic part in the CLSC function because of the combination with the reverse logistic and the forward supply chain happens at this step. End of life products cannot be used directly in production as resource but they may still have economic value.

Table 4.1: Unified Matrix for Interactive Impacts

			X1 / Y1 / Z1	X2 / Y2 / Z2		Xn / Yn / Zn	Priority Level			
			Economical / Social / Environmental	Economical / Social / Environmental		Economical / Social / Environmental	Trial Bottom of Sustainability			
			Criterion 1	Criterion 2		Criterion N	Criteria			
								EFFECT		
FUNCTIONALTY	Function 1	1. International Directives	D11	D12	...	D1n	Economical	D1Eco=D11*X1+D12*X2+......+D1n*Xn	F1D1= (D1Eco+D1S+D1Env)/3	Total Impacts in FUNCTION 1 = F1D1+F1G1+F1I1
							Social	D1S =D11*Y1+D12*Y2+......+D1n*Yn		
							Environmental	D1Env=D11*Z1+D12*Z2+......+D1n*Zn		
		2. Government	G11	G12	...	G1n	Economical	G1Eco	F1G1	
							Social	G1S		
							Environmental	G1Env		
		3. Industry	I11	I12	...	I1n	Economical	I1Eco	F1I1	
							Social	I1S		
							Environmental	I1Env		
	Function 2	1. International Directives	D21	D22	...	D2n	Economical			
							Social			
							Environmental			
		2. Government	G21	G22	...	G2n	Economical			
							Social			
							Environmental			
		3. Industry	I21	I22	...	I2n	Economical			
							Social			
							Environmental			
	⋮	⋮	⋮	⋮		⋮	⋮	⋮	⋮	⋮
	Function M	1. International Directives	Dm1	Dm2	...	Dmn	Economical	DmEco=Dm1*X1+Dm2*X2+......+Dmn*	FmDm= (DmEco+DmS+DmEnv)/3	Total Impacts in FUNCTION M = FmDm+FmGm+FmIm
							Social	DmS =Dm1*Y1+Dm2*Y2+......+Dmn*Y		
							Environmental	DmEnv=Dm1*Z1+Dm2*Z2+......+Dmn*		
		2. Government	Gm1	Gm2	...	Gmn	Economical	GmEco	FmGm	
							Social	GmS		
							Environmental	GmEnv		
		3. Industry	Im1	Im2	...	Imn	Economical	ImEco	FmIm	
							Social	ImS		
							Environmental	ImEnv		
		EFFECT	Total Importance Level of Criteria 1 =(D11+G11+I11) +...+ (Dm1+Gm1+Im1) /m*3		...	Total Importance Level of Criteria N =(D1n+G1n+I1n) +...+ (Dmn+Gmn+Imn) /m*3				

For example; many parts of the end of life products can be used as a raw material in the production of new product. Recycled parts of the end of life products are used in manufacturing & assembly function or dealer can use those parts in a maintenance process. The product itself can be used as a reusable product in secondary market. After all applicable 3R processes realized, the leftovers can be used such as heating energy resource or for landfilling.

4.3.1.2 Criteria affecting policy decision making

In this thesis, based on the experiences of the authors and the fore mentioned literature reviews, 25 criteria which may have significant impacts on political decisions related to the functions of CLSC are decided to be used in this research (Figure 4.2). Criteria break down into 5 main

Table 4.2: Functions and Sub-Functions related to CLCS

Functions of a CLSC	PRODUCT PLANNING	1. 3R Planning
	PRODUCT DEVELOPMENT	2. Design for Environment
		3. Eco Engineering, Eco Management
	PRODUCT IMPLEMENTATION	4. Purchasing
		5. Refurbish & Production with used Parts
	PRODUCT CONTROL	6. Sales / Marketing
	END OF LIFE PRODUCT	7. End of Life Use

sub-classes which could make easier to understand the relational process in unified matrix. Main sub-classes are;

Cost: *Cost* sub-class includes five criteria; Total cost, cost of labor, logistics cost, remanufacturing cost, price of new product.

Environment: *Environment* sub-class includes two criteria; Environmental impact and Hazardous material usage.

Performance: *Performance* sub-class covers ten criteria; Sale rate, Production rate, Quality, Material selection, Inspection, Stakeholder evaluation on a period of time, Product lifespan, product return rate, demand, rate of innovation.

3R Activities: *3R Activities* sub-class includes three criteria; recycling rate, product design for reuse, recycling fee.

Organization: Organizational structure, economic development, wide product range, network design and strategic planning are the elements of *Organization* sub-classes.

As a further explanation, environmental impact exists as a sub-criterion of environment, so we need to mention that it has several angles discussed by global business world and legislation makers such as CO emissions, pollution prevention, prevent ecosystems etc. [5] Price of new product actually is not only related to the *Cost*. To create a simplified structure this sub-criterion expressed under the *Cost* sub-class.

4.3.1.3 Three main stakeholders of political processes

In order that authors realized that International directives, governments and industries should be expressed as main stakeholders of the political decision making processes (Figure 4.3). Therefore, it is significant that the members have been influencing each other in their decisions, and they should create an negotiation mechanism within this influence circle. In Figure 4.3, general

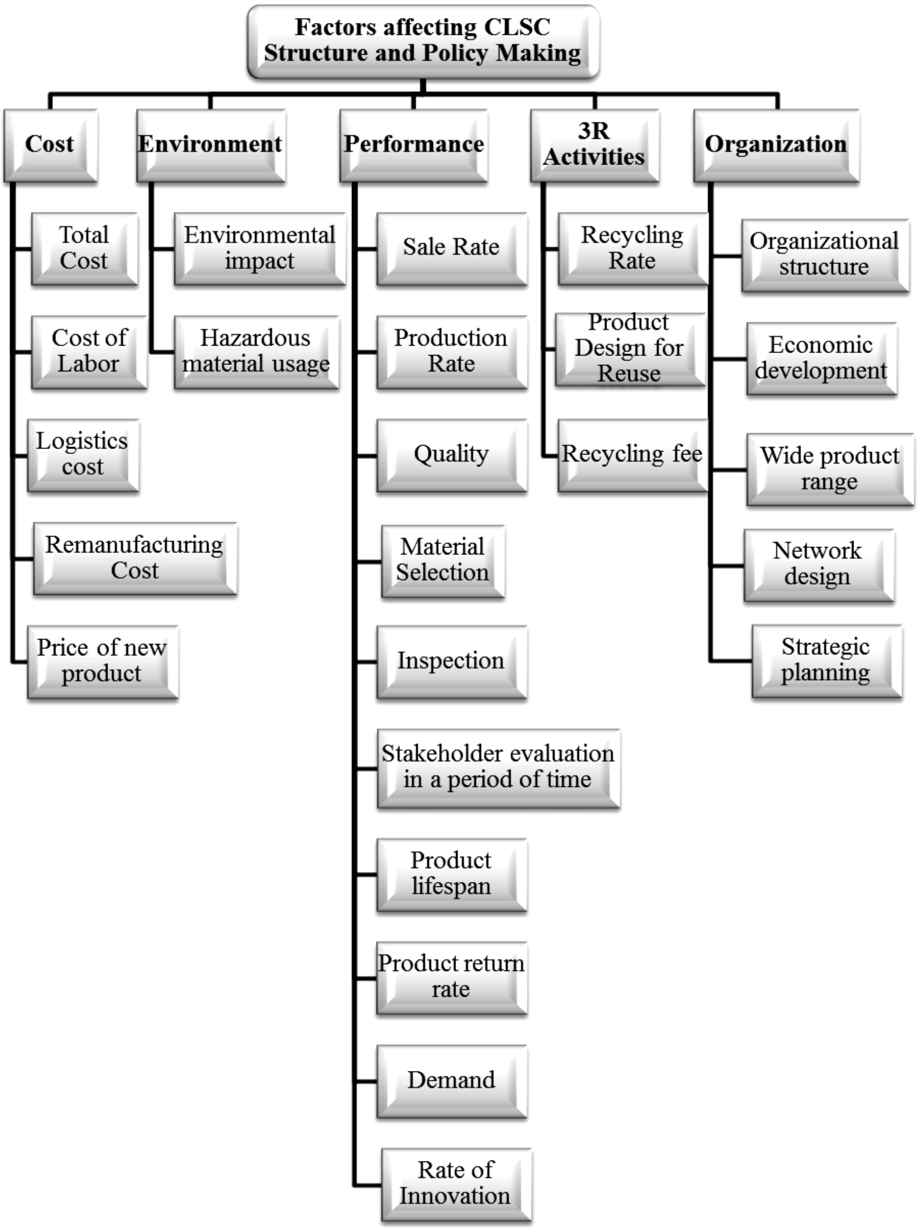

Figure 4.2: Factors Affecting Sustainable Business Structure and Policy Making Process

mechanism of influences on the political processes and the way of making strategic decisions are introduced all together as a clarifying explanation of the 'big picture'. Impacts of international legislations are determined through the calculations expressed by Unified Relation Matrix. Determination of priority of functions and determination of weights of criteria shape the general requirements. Then, these requirements are transformed into the *legislation* itself.

Governments are in the center of this policy making system. Based on our proposed mechanism, governments have greater powers to affect industries but also at the same time themselves are affected by global discussions and sanctions of international directive mechanisms. This is actually a clear conflict for especially developing countries. Objectives of governments are cannot only economic but also the y have to consider social and environmental development.. Staying sustainable in global world depends on coping with conflicts in light of carefully prepared scenarios that can optimize the economic, environmental and social outputs. So, importance levels of these outputs are decided according to the proposed relation matrix.

4.3.1.4 Trial bottom-lines of Sustainability

The term of sustainability could be misunderstood by society. Society generally considers that term only as a single topic which the businesses / industries are concern about and find an appropriate direction to handle realizing the sustainability aims. This term can be defined according to the Brutland Commission (1989) "providing human being needs without endangering the ability of meeting future generations' needs". In business perspective, term of sustainability can be defined by three main bottom-lines which are Social concern, Environmental issues, Economical continuance [1]

These bottom-lines notices that only profit centered strategies and point of view are not acceptable in recent times. Global trade rules and conscious society desires more than that ability from the industries. Thus, in the unified relation matrix, authors aimed to show determination of the relations and importance levels between key issues of sustainability and topics explained above.

4.3.2 Impacts on Network Design in CLSC

Although the government and international regulations make pressure on companies and create complex conflicts, this research part's solution proposal develops a generic decision making mechanism that includes scenario generation system. Crucial point is to develop a scenario generation mechanism besides to see all network changes and results of each predefined network design in name of industries' objectives in the further step of those evaluations. As an essential aim of this research, make global businesses' strategic decision makers to realize that there is an important need to express the direction of changing network design in CLSC structure.

In [10], a scenario analysis expressed the network shifting through several policies as a basic example and dealing with the scenarios based on the feasible and the optimum results for each cost functions result range for different tax options and expected recycling rates of several

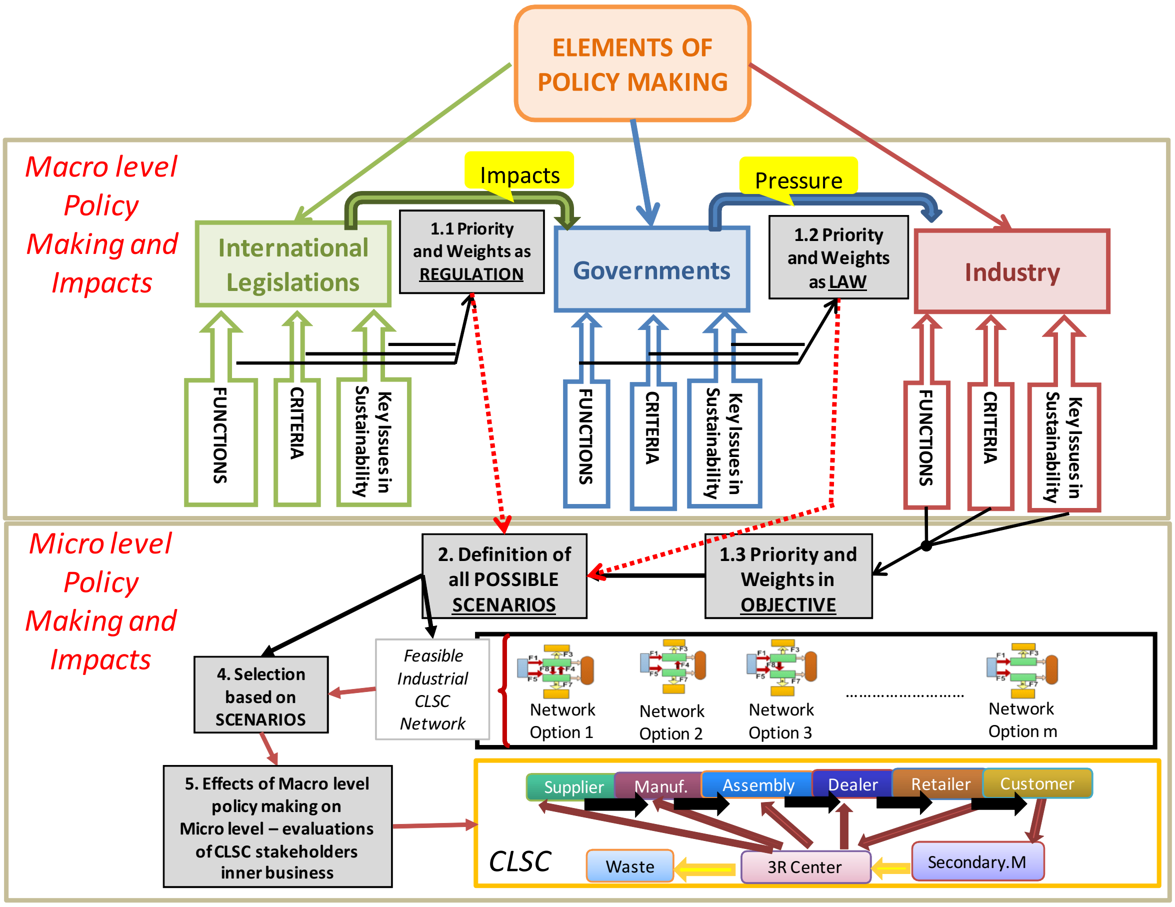

Figure 4.3: Effects of Political Decisions and Scenario Generation Mechanism

reusable parts. As a result, that showed regulations and policies of government have great impact on industries' strategic decisions such as supply chain structure and the organizational transformation.

4.4 Illustrative Example

In a function layer, 5 different subjects can be expressed at the same time. First subject is related to priority evaluation of criteria in each elements of bottom-line of sustainability. Second subject is related to *impact weights of three main stakeholders* on each *criterion* in each function. Third subject defines the impact and relation between sustainability issues and stakeholders of policy making. Fourth subject explains the total impact on each layer and finally fifth subject is used for comparison of impacts on functions. In this chapter, an implication of the mentioned methodology is discussed with the exemplified results of the relations between criteria, functions and trial bottom-line of sustainability as an input of the definition of coefficients and the weights of parameters and constraints in a mathematical modeling in end of life product function of CLSC is discussed. (Figure 4.4)

4.4.1 Model of Closed Loop Supply Chain with Decision Making Structure

In end of life cycle function, the organization should manage the flows from the final owners through the last step that is crushing centers. There should be three main objectives in all functions in end of life function as well. Firstly, in economic point of view, to effectively use the end of life products as much as possible to maintain them as reusable parts or recovered parts, and then make it available to use in the production cycle as raw materials. Secondly, the organization should keep the expectations related to the environmental considerations into their end of life mechanism. Finally, they have to keep the social sustainability issues on the requested level.

Following discussions expresses the authors' opinion and adaptation of a simple analytical mathematical model to illustrate how the results can be used as a scenario generation mechanism to find the feasible and then the optimum network design for predefined conditions. In order to obtain the business sustainability, the organization should set three objectives for each function level. Hence, in end of life product function, there should be three objectives;

1. Realize the expected Economic outputs
2. Catch up the Environmental expectations
3. Improve the expected level in Social indicators

First objective will be the maximization of profit in the trades of end of life flows. Second objective will be the minimization of total environmental impacts of end of life flows. Final objective should be set up as the maximization of the social outputs such as labor satisfaction.

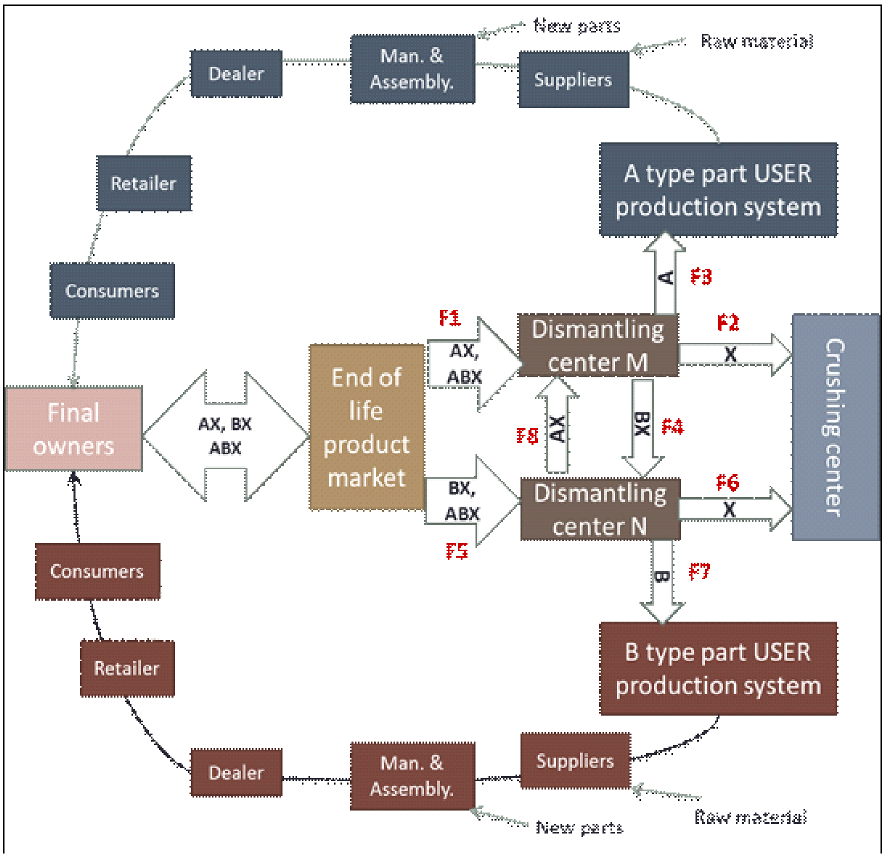

Figure 4.4: Illustrative Example of End of life function of a CLSC (Reproduced from [20])

1. Maximize Profit→

$$Z_1(Eco) = [(I_3F_3 + I_4F_4) - ((C_{AX}(1-\eta_A)F_1 + C_{ABX}\eta_AF_1) + C_8F_8 + C_XF_2)]$$
$$+[(I_7F_7 + I_8F_8) - ((C_{BX}(1-\eta_B)F_5 + C_{ABX}\eta_BF_5) + C_4F_4 + C_XF_6)]$$

1. Minimize Environmental Impact

$$Z_2(E) = E_3F_3 + E_4F_4 + (E_{AX}(1-\eta_A)F_1 + E_{ABX}\eta_AF_1) + E_8F_8 + E_DF_2)$$
$$+E_7F_7 + E_8F_8 + (E_{BX}(1-\eta_B)F_5 + E_{ABX}\eta_BF_5) + E_4F_4 + E_XF_6)$$

1. Maximize Social Outputs

$$Z_3(S) = S_3F_3 + S_4F_4 + (S_{AX}(1-\eta_A)F_1 + S_{ABX}\eta_AF_1) + S_8F_8 + S_XF_2)$$
$$+S_7F_7 + S_8F_8 + (S_{BX}(1-\eta_B)F_5 + S_{ABX}\eta_BF_5) + S_4F_4 + S_XF_6)$$

Subject to

1. Demand and supply balance of Dismantling Center M

$$m_1F_1 - F_4 + m_2F_8 = F_2$$

$$m_3F_1 + m_4F_8 = F_3$$

$$m_5F_1 \geq F_4$$

1. Demand and supply balance of Dismantling Center N

$$n_1F_5 - F_8 + n_2F_4 = F_6$$

$$n_3F_5 + n_4F_4 = F_7$$

$$n_5F_5 \geq F_8$$

4.4.2 How to Use the Unified Relation Matrix Results as Input in Analytical Solution Method

In the end of life product function, D5Eco, G1Eco and I1Eco results will affect the weight of the objective 1. D5Env, G5Env and I5Env results will affect the weight of the objective 2. Finally, D5Soc, G5Soc and I5Soc results will affect the weight of the objective 3.

D5Eco is reflecting the result for importance level of production rate in end of life function considering economical sustainability for the international directives. G1Eco is reflecting the importance level of production rate in end of life function considering economical sustainability for government and I1Eco is reflecting the importance level of production rate in end of life function considering economical sustainability for industry. Hence, in end of life product function, D5Eco, G1Eco and I1Eco results will affect the weight of the "Objectives 1". D5Env is reflecting the result for importance level of production rate in end of life function considering environmental sustainability for the international directives. G5Env is reflecting the result for importance level of production rate in end of life function considering environmental sustainability for government and I5Env is reflecting the result for importance level of production rate in end of life function considering environmental sustainability for the industry.. D5Env, G5Env and I5Env results will affect the weight of the "Objective 2". Finally, D5Soc, G5Soc and I5Soc results will affect the weight of the "Objective 3". D5Soc is reflecting the result for importance level of production rate in end of life function considering social sustainability for the international directives. G5Soc is reflecting the result for importance level of production rate in end of life function considering social sustainability for the government. I5Soc is reflecting the result for importance level of production rate in end of life function considering social sustainability for the international directives. (Table 4.3) Possible result ranges of D5-1, D5-2,...,D5-25 will be used as definition of constraints in name of criteria. Possible result ranges of G5-1, G5 2,...,G5-25 will be used as definition of constraints in name of criteria. Possible result ranges of I5-1, I5-2,...,I5-25 will be used as definition of constraints in name of criteria as shown in Table 4.3.

The main aim is not to describe the model itself but express the relation of the unified matrix results and coefficients and the parameters in the model here

Coefficients of the parameters in objective functions represent the relation of the impact of each flow in model and the outcome of each sustainability issue. Coefficients in the constraints (m_i and n_i, i: 1...5) define the probability of obtaining of the different parts from the flows (F_i, i: 1,...,8) and existence rate in each flow (F_1, F_4, F_5, F_8) in the end of life products . Notations in the objective functions are the reflection of the total impact value as a range of three stakeholders in the end of life product level. The coefficient in the demand and the supply balance in constraints are influenced by the evaluation range in the unified relation matrix. Effects of criteria given in the matrix will create several conditions to represent the constraints. The effects of the stakeholders in function will represent the weight of each objective function.

To generalize the overall structure, following steps can be emphasized;

1. The criteria are defined based on the global scale trade rules.

Table 4.3: Illustrative Example of End of life function of a CLSC in Unified Relation Matrix

			X1	Y1	Z1	X2	Y2	Z2		X25	Y25	Z25	Priority Level		
			Economical	Social	Environmental	Economical	Social	Environmental		Economical	Social	Environmental	Trial Bottom of Sustainability		
			1. Production Rate			2. Recycling Rate				25. Remanufacturing Cost			Criteria	EFFECT		
FUNCTIONALITY	Function 5 End of Life Use	1. International Directives	D5,1			D5,2			...	D5,25			Economical	D5Eco	F5D5	Total Impacts in FUNCTION 5
													Social	D5S		
													Environmental	D5Env		
		2. Government	G5,1			G5,2			...	G5,25			Economical	GmEco	F5G5	
													Social	GmS		
													Environmental	GmEnv		
		3. Industry	I5,1			I5,2			...	I5,25			Economical	ImEco	F5I5	
													Social	ImS		
													Environmental	ImEnv		
		EFFECT	Total Importance Level of Production Rate			Total Importance Level of Recycling Rate			...	Total Importance Level of Remanufacturing Cost						

2. The functions of CLSC are defined to make simple to seize and monitor the objectives.

3. The main stakeholders of policy making are expressed by three main actors.

4. In order to keep tracks of the results of three pillars of sustainability, economic, social and environmental indicators are defined as the main objectives.

5. The influences of these stakeholders in each function can be presented in case of different evaluation and the range as possible results.

6. The relation between the possibilities in criteria which returns to the constraints are reflected by the model as the coefficient of variables.

7. As objectives, the organization should set three objectives to reflect each sustainability goal to define feasible and optimum network in end of life function.

8. Weight of the objective functions should be defined according to the total impacts calculations for three stakeholders in predefined functions. Industry is the final point to decide how much they will reflect that effects on the network design strategies.

4.5 Conclusion

This chapter aimed to represent the way to reflect the impacts of macro policy making issues on micro policy making issues. The organizational transformations are influenced by not only the decision of industries in name of the predefined criteria but also the how government and the international directives see the importance and the relations between the CLSC functions matters.

To sum up, major topics discussed in this research can be divided into three subtopics;

- Definition of hidden factors by a unified relation matrix as a systematic approach in global political decision making process
- Scenario Generation Mechanism
- Shifting in Network design as a consequence of revisions in global regulations and government's sanctions
- Show the way how to reflect the result range of the evaluation in the analytical approach in mathematical modelling

Since admitting that complexity is a critical point of global policy making process, to be able to see the 'big picture', issues should be divided into several subtopics. In this thesis, functionality, criteria, main stakeholders of policy decisions and sustainability key issues are the subtopics. Scenario generation mechanism aims to develop a systematic guide how to decide the factors which can create different scenarios. In this mechanism, factors are predefined and relations between the elements of the decision matrix (for example; importance rate of three main stakeholders vs. function) are determined by a unified relation matrix. Since the network design of businesses has been mentioned as one of the crucial strategic decisions in literature expressed above, all possible factors, subjects which have direct or indirect impact should be clearly presented in a process. If this decision would be based on managers' experiences and unsystematic verbal way, fast changes in global world can destroy the businesses which cannot compete with the new era's trade rules anymore. So that, overall aim of the research proposing a decision process includes many main unsolved subjects in policy making and relation of impacts on the industries' network strategies. This matrix has many advantages such as flexibility and being easy to understand, it is not enough to solve the conflicts itself. Struggling part of the proposed methodology is developing connections between the decision matrix results and the network design creation mechanism which is studied in [20]. Main suffering part is verbally defining the direction of real impacts of regulations on multiple governments.

In this thesis, there is a static argument but for further researches this topic may need to be argued in dynamic approaches. Strategic states of elements in game theory may express the smooth transitions of structural changes. Due to being innovative, authors realized that the evolutionary approach based on the game theory is appropriate to describe future movements of industries decisions. Secondly, the overall survey study is a great opportunity to understand the overall but close to the real evaluation of the policy makers' expectations and their view in the relation analysis of the criteria and functions of the organization.

Chapter 5

Impact of Policy Decisions on Construction of Auto Industry CLSC

Chapter 5 presents illustrative examples to explain clearly the impact of political decisions on construction of CLSC in the global auto industry as a case study. The main target here is expressing shifting for the flows in the network and the 3R activities in the reverse logistic side of CLSC by comparing the feasibility and optimality of different levels of policies.

5.1 Introduction

Today, the environment and energy issues have been paid more and more attention. As the public becomes more aware of the above problems, companies will have to expect questions about how green their manufacturing processes and supply chains are, and how they recycle. Developed green supply chain includes not only traditional forward supply-chain but also the additional reverse logistics.

As a pioneer work of reverse logistics, the European Commission has shown interest in the development of the field of reverse logistics by sponsoring international scientific projects through the European working group on reverse logistics, ([68]; [69]). This group has focused much of its efforts on issues such as inventory management, particularly in a remanufacturing context. ([70]; [71]; [72]).

Consideration of Global Automobile Recycling

European Union: The European Union (EU) wishes to limit the production of waste arising from end-of-life vehicles and to increase re-use, recycling and other forms of recovery of end-of-life vehicles and their components. In order to achieve these two objectives, the EU establishes new requirements for European vehicle manufacturers, who should design vehicles which are easy to recycle.

Based on this background, Directive 2000/53/EC aims not only to decrease the quantity of waste arising from vehicles, but also to increase the rate of re-use and recovery. By this directive, priority must be given to the re-use and recovery (recycling, regeneration, etc.) of vehicle components.

In this Directive, the rate of re-use and recovery (in average weight per vehicle and year) should reach 85% no later than 1 January 2006; 95% no later than 1 January 2015. Also the rate of re-use and recycling (in average weight per vehicle per year) should reach 80% no later than 1 January 2006; and 85 % no later than 1 January 2015. For vehicles produced before 1980, the targets are lower.

United States of America (USA): There is no federal law governing EPR Extended Producer Responsibility the United States. In the United States, End of Life Vehicle Solutions (ELVS), a national not-for-profit corporation formed by automobile manufacturers, provides educational materials and collects and recycles automotive switches at no cost to dismantlement and recyclers. Policy makers at all levels of government have paid particular attention to issues associated with vehicle tires and have taken actions to support tire recycling and reuse. At a national level, these programs include the application of both comprehensive procurement guidelines for recycled content products (e.g., retread tires) and environmentally preferable purchasing practices. A number of States have taken specific actions to prevent pollution associated with mercury in vehicles scrap tires, and lead-acid batteries.

The automobile industry's Vehicle Recycling Partnership, formed in 1992 by Ford, Chrysler, and General Motors, is charged with collaborative research and pilot programs to promote integrated and sustainable vehicle recycling practices in North America and globally. Ford has teamed with auto manufacturers in Europe and Japan to establish the International Materials Data System, which facilitates reuse and recycling through shared information on materials in vehicles (U. S. Environmental protection Agency, 2008).

Japan: Under the 2002 ELV (End of Life Vehicle) Recycling Law, which is based on a ”shared responsibility” principle, consumers in Japan pay a fee when they purchase a new car or, for cars sold before the enforcement of the law, at the time of mandated regular inspection. The fee is managed by a third party, the Japan Automobile Recycling Promotion Center (JARC). The fee is managed by a third party, the Japan Automobile Recycling Promotion Center (JARC).

On January 1st 2005, the Japanese automobile recycling law went into effect. Under the law, auto manufacturers are obliged to recycle air-bags and crushed parts from disused automobiles. The used car are processed well by obligating appropriate roles to auto recycling parties compared to the situation before. However, in recent years, illegal dumping has become such a serious problem that a new policy was enacted to promote recycling.

China: In this session, China, who is a representative of developing countries, is analyzed. Today, vehicles have become a consumable industrial product for the average Chinese family. The volume of in-use vehicles in China, which is increasing dramatically, reached 70 million in 2009. The annual sales of new cars in China were about 18 million in 2010. The Chinese annual sales of new cars in recent years are shown in Figure 5.1. As a consequence, the annual volume of end-of-life vehicles (ELVs) in China has been more than 270 million since 2010. In 2001, China passed a law regulating the disposal and recycling of ELVs. Progress has been slow, with the rate of ELV dismantling at just 10% at the beginning of 2004. However, a pilot industrial demonstration of ELV dismantling and disposal was established in Shanghai in 2005

In addition, Shanghai Volkswagen established a modern engine remanufacturing plant aimed at its after-sales market. In response to the EU ELV directive, the Chinese National Development and Reform Commission (NDRC) released its “Automotive Products Recycling Technology Policy” in 2006.

In the global supply chain, the amount of new cars demand in the world has increased in the most recent 10 years. Although the demand of vehicles in developed countries is depressed, the demand is still large. On the other hand, the demand in developing countries has expanded greatly such as India, Brazil and China (Figure 5.1). Therefore, ELVs recycling is a significant part of global industry strategy in both today and the future.

5.2 Problem Statement for Logistics Model of Used Part Traders

The consideration of Japan’s current situation for the reverse logistic scheme as an example for the creation of the CLSC’s recycling part for automobile industry is expressed here. Reverse logistic is essential for the competitiveness of the traders in the end of life products section

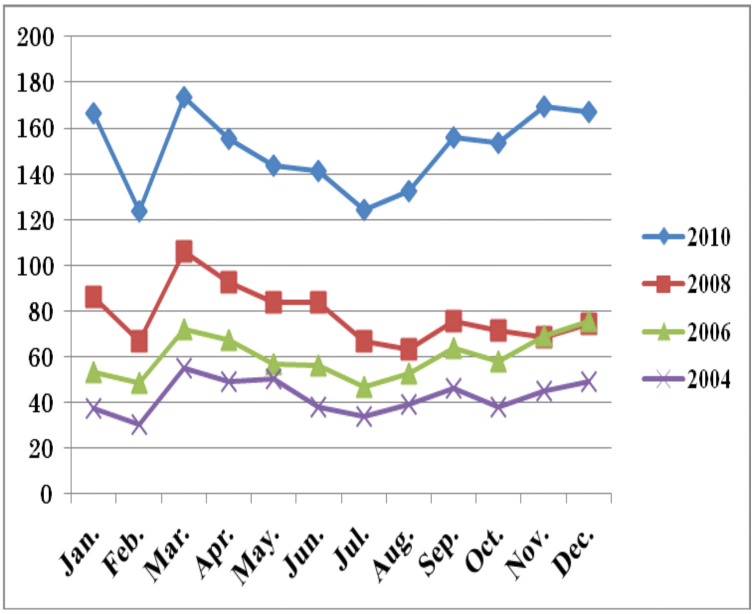

Figure 5.1: Transition of new cars sales in China (10,000 units)

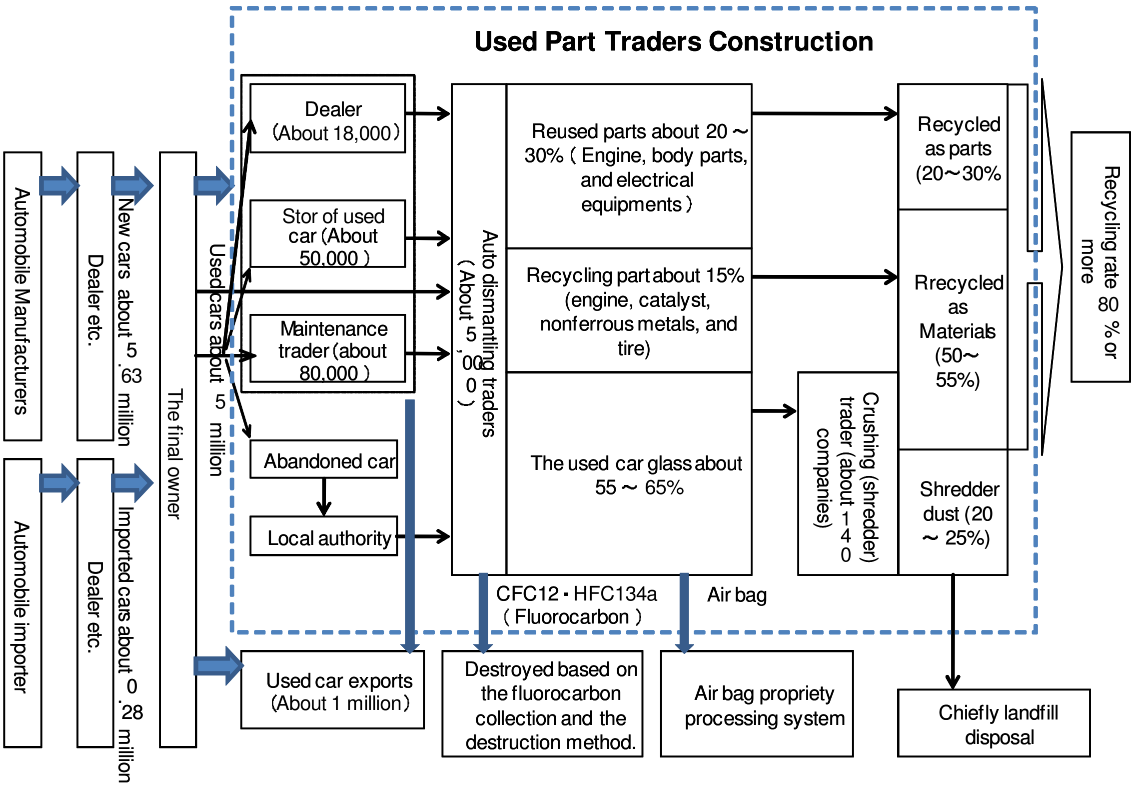

Figure 5.2: Recycle trader construction in supply chain of Japanese auto-industry

and it is a high priority problem for closing the flow in an appropriate way. Regarding to the issue which shows that automobile industry is one of the significant cause of the several urgent environmental problems in global world, this research have become more of an issue. Figure 5.3 shows the supply chain including reverse logistic in the Japanese auto-industry, in which the used part traders' construction is expressed in detail.

From Figure 5.3, we can see the recycling rate and flow of used cars in Japan, which was compiled with the data of 2006. Also we can see that about 5.52 million new cars and 0.28 million imported cars are sold every year; and there are about 5,000 auto dismantling traders and about 140 crushing traders in Japan [95].

From Figure 5.3, it also can be noted that there are four levels in car recycling.

1. Product level: used cars as products are sold.
2. Used part level: used parts of cars as products are sold.
3. Material recycle level: used parts as materials are recycled.
4. Thermal recycling level: recycling as heat source (e.g. the remaining abandoned parts are burned to obtain a heat source.)

In recent years, environmental burdens and user cost reduction have attracted attention. Customers are buying more used or rebuilt parts taken from ELVs, in order to minimize repair costs. Therefore, it has become more important to consider the construction problem of reverse logistics in terms of marketing strategy and policy decision.

In this chapter, based on the used part traders construction in Figure 5.3, we consider the logistics model (Figure 5.4) centered around dismantling traders. Figure 5.4 shows the detail relation between used car markets, dismantling traders, used part users and crushing traders, where the used car markets include dealer, used car store, maintenance trader, and local authority of Figure 5.3.

The model of Figure 5.4 is set based on the following assumptions.

(1) Three types of used cars are dealt by dismantling traders M and N.

Used car AD	The disused car including parts A and waste D.
Used car BD	The disused car including parts B and waste D.
Used car ABD	The disused car including parts A, part B and waste D.
Used car D	The disused car including only waste D.

(2) Used parts A and B are taken out by dismantling traders M and N, respectively.

(3) Used parts AD and BD are traded between M and N companies.

The notations used are as follows:

εA1	Probability of A obtained from $F1$
εA2	Probability of A obtained from $F8$
εB1	Probability of B obtained from $F5$
εB2	Probability of B obtained from $F4$
rA	Existence rate of AD in $F8$
rB	Existence rate of BD in $F4$
ηA	Probability of ABD in $F1$
ηB	Probability of ABD in $F5$
CAD	Cost of single AD
CBD	Cost of single BD
CABD	Cost of single ABD
Ci	Profit of single reusable part in Fi, where i =3, 4, 7, 8.
CJ	Cost of single waste D.
$F1$	Number of used parts AD and ABD from market of used cars to dismantling trader M per unit time.
$F2$	Number of used part D from dismantling trader M to crushing trader per unit time.
$F3$	Number of used part A from dismantling trader M to A reused part user per unit time.
$F4$	Number of BD used parts from dismantling trader M to trader N per unit time.
$F5$	Number of used parts BD and ABD from market of used cars to dismantling trader N per unit time.
$F6$	Number of used part D from dismantling trader N to crushing trader per unit time.
$F7$	Number of used part B from dismantling trader N to B reused part user per unit time.
$F8$	Number of AD used parts from dismantling trader N to trader M per unit time.

The evaluation function of the proposed model is the expected total profit $Z(F_i)$of dismantling traders. From assumptions (1)-(3) and the win-win point of view, the mathematic formulations are shown as follows:

Max $\rightarrow$

$$\begin{aligned} Z(F_i) = E\left[(C_3F_3 + C_4F_4) - ((C_{AD}(1-\eta_A)F_1 + C_{ABD}\eta_AF_1) + C_8F_8 + C_JF_2)\right] \\ +E\left[(C_7F_7 + C_8F_8) - ((C_{BD}(1-\eta_B)F_5 + C_{ABD}\eta_BF_5) + C_4F_4 + C_JF_6)\right] \end{aligned} \quad (5.1)$$

where i=1...8.

Subject to

(i) Demand and supply balance of M company

$$(1-\varepsilon_{A1})(1-\eta_A)F_1 + (1-\varepsilon_{A1})\eta_AF_1 - F_4 + (1-\varepsilon_{A2})F_8 = F_2 \quad (5.2)$$

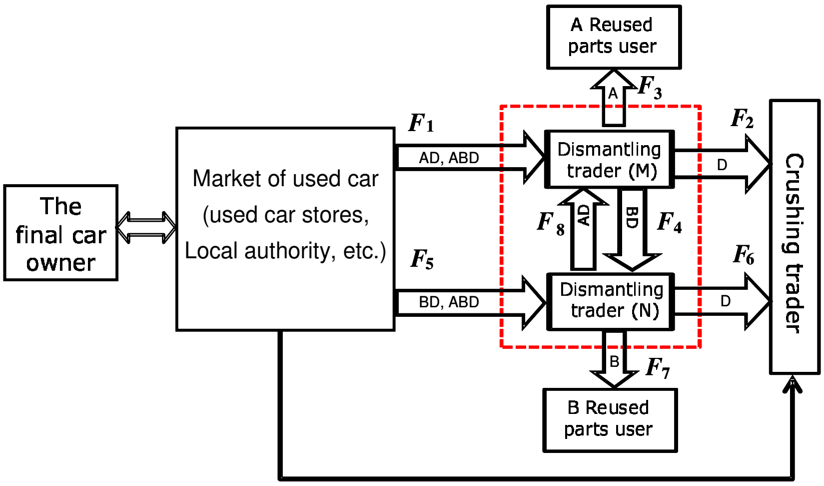

Figure 5.3: Logistics model of used parts traders

$$\varepsilon_{A1}F_1 + \varepsilon_{A2}F_8 = F_3 \quad (5.3)$$

$$\gamma_A\eta_A F_1 \geq F_4 \quad (5.4)$$

$$(5.5)$$

(ii) Demand and supply balance of N company

$$(1-\varepsilon_{B1})(1-\eta_B)F_5 + (1-\varepsilon_{B1})\eta_B F_5 - F_8 + (1-\varepsilon_{B1})F_4 = F_6 \quad (5.6)$$

$$\varepsilon_{B1}F_5 + \varepsilon_{B2}F_4 = F_7 \quad (5.7)$$

$$\gamma_B\eta_B F_5 \geq F_8 \quad (5.8)$$

$$(5.9)$$

In eq. 1, $(C_3F_3+C_4F_4)$and$(C_7F_7+C_8F_8)$are the sales profits, $(C_{AD}(1-\eta_A)F_1+C_{ABD}\eta_AF_1)+C_8F_8)$and $(C_{BD}(1-\eta_B)F_5+C_{ABD}\eta_BF_5)+C_4F)$are the total used parts cost, $(C_JF_2)$and$(C_JF_6)$are the crushing waste costs of M and N dismantling traders, respectively.

Based on assumptions (1)-(3), demand and supply relation of waste D, used parts A and BD of company M are defined by eq. 2, 3 and 4, respectively.

Similarly, demand and supply relation of waste D, used parts B and AD of company N are defined by eq. 5, 6 and 7, respectively.

5.3 Methodology for Logistics Construction Analysis

In this research, we use a LP (Linear Programming) solution method [96], which is useful to deeply study the reverse logistics construction. Before describing the procedure for analytical solution of logistics construction, we first show the theoretical basis of the method as follows:

5.3.1 Theoretical basis of Analytical Solution Methodology (ASM)

The linear programming problem may be stated as follows using matrix notation [42]

Maximize $P = c^T x$
Subject $A\,x = b$

$$x \geq 0 \tag{5.10}$$

where variables x include so-called "slack variables" introduced when inequality constraints are made into equality constraints. A is an $m \times n$matrix with $n > m$in eq. 9, where n is the number of variables and m is the number of constraints. Now consider solving m simultaneous eq. 9. By partitioning $x$into basic variables X_B and non-basic variables X_N and A into sub-matrices B and N, we can get

$$A\ = (B\ N) \tag{5.11}$$

$$x = \begin{bmatrix} X_B \\ X_N \end{bmatrix} \tag{5.12}$$

and

$$A\,x = BX_B + NX_N = b \tag{5.13}$$

Also by partitioning the cost vector c into c_B and c_N, the objective function P can be written as follows:

$$P = [c_B^T\ c_N^T] \begin{bmatrix} X_B \\ X_N \end{bmatrix} = c_B^T X_B + c_N^T X_N$$

By substituting eq. 13 into eq. 14, we can get $P = c_B^T B^{-1} b - (c_B^T B^{-1} N - c_N^T) X_N$

Accordingly, the LP problem stated in eq. 8 ˜10 can be rewritten in the following from.

Maximize $P = c_B^T B^{-1} b - (c_B^T B^{-1} N - c_N^T) X_N$

Subject to $X_B = B^{-1} b - B^{-1} N X_N$

$$x = \begin{bmatrix} X_B \\ X_N \end{bmatrix} \geq 0$$

Therefore, we can obtain the conditions for feasibility of basic solutions and optimality of basic solutions, which are shown as follows:

(i) Conditions for Feasibility of Basic Solutions

Non-basic variables are set to be zero in eq. 16 in order to get basic solutions. Using eq. 17, the condition for the basic solution to be feasible is as follows:

$$X_B = B^{-1}b \geq 0$$

(ii) Conditions for Optimality of Basic Solutions

Coefficient vector $(c_B^T B^{-1} N - c_N^T)$in the objective function 15 is called the vector of reduced costs. According to eq. 15, the reduced costs must be positive in order that basic solutions are optimal. Otherwise, the objective function will increase as non-basic variables become positive. Therefore, the condition for the basic solution to be optimal is as follows:

$$c_B^T B^{-1} N - c_N^T \geq 0$$

Equations 18 and 19 are basic conditions in the Simplex method as well. The Simplex method gives in a step-by-step manner the optimal solution which satisfies the condition for optimality while renewing by a pivoting operation a combination of basic variables which satisfies the condition for feasibility [41]

As a traditional mathematical programming method, LP technique has been used widely. In 1940's, George Dantzig created a Simplex Algorithm to solve linear programs for planning and decision-making in large-scale enterprises. As the main difference from Simplex Method, using the above method, specific numerical values are not given to A, $b$and $c$to get the general solutions. Therefore, it is possible to obtain the condition for feasibility, the condition for optimality, and the general solutions by deriving the inverse matrix of B when a combination of basic variables composing a solution is arbitrarily specified. Namely, relationship among$A$, $b$and c satisfying eq. 18 and 19 is derived by assuming possible combinations of basic variables.

5.3.2 Application of ASM for Logistic Model

This part represent the logistic model for reverse logistic in CLSC of auto industry related to the management of traders relation for the recyclable, recoverable and reusable end of life parts. We aimed to minimize the waste and at the same time maximizing the profit from these trades.

In real world, the set up conditions of the several policies may not be clear, and the author would like to simplify in a group of all possible results to see any kind of structure and show how to select the convenient one easily. ASM is selected to represent changes in the flows, and according to the changes, the profit is th key point for sensitivity analysis of each structure.

Deleting one flow may cause great impact on over all CLSC structure, o the analysis not only by dta, also on analytical way is a opportunity for the decision makers.

5.4 Illustrative Example

Step 1: Obtain feasibility sets of combinations of basic variables. Table 5.1 shows the logistics constructions with all possibilities of this research. In Figure 5.5, the feasibility logistic constructions of recycle traders are considered. From Figure 5.5, it can be noted that solutions 3, 6, 8, 10, 13, 14 and 15 are not adopted, because of the realistic business rule.

Step 2: Derive the inverse matrix of the coefficient matrix corresponding to the basic variable.

Step 3: Derive the conditions of feasibility and optimality for the basic solution.

Step 4: Arrange the feasibility area of solutions. By steps 2˜4, the feasibility logistic constructions of recycle traders are considered. In Figure 5.5, solutions 3, 6, 8, 10, 13, 14 and 15 are not adopted, because of the realistic business rule.

By steps1˜4, $B, b, c_B^T, N$and$c_N^T$of the solution 1 for the reverse logistics (Table 5.1) are expressed as follows:

Table 5.1: Set of combination of basic variables

Sol. No.	F_1	F_4	F_5	F_8	λ_1	λ_2
1	1	1	1	1	0	0
2	1	1	1	0	1	0
3	1	1	0	1	1	0
4	1	0	1	1	1	0
5	1	0	1	1	0	1
6	1	1	0	1	0	1
7	1	1	1	0	0	1
8	0	1	1	1	0	1
9	1	1	0	0	1	1
10	1	0	0	1	1	1
11	0	0	1	1	1	1
12	1	0	1	0	1	1
13	0	1	1	0	1	1
14	0	1	0	1	1	1
15	0	1	1	1	1	0

$$B = \begin{bmatrix} \varepsilon_{A1} & 0 & 0 & \varepsilon_{A2} \\ 0 & \varepsilon_{B2} & \varepsilon_{B1} & 0 \\ \gamma_A\eta_A & -1 & 0 & 0 \\ 0 & 0 & \gamma_B\eta_B & -1 \end{bmatrix}, \tag{5.14}$$

$$b = \begin{bmatrix} F_3 \\ F_7 \\ 0 \\ 0 \end{bmatrix}, \tag{5.15}$$

$$c_B^T = \begin{bmatrix} -C_1 & \varepsilon_{B2}C_J & -C_5 & \varepsilon_{A2}C_J \end{bmatrix}, \tag{5.16}$$

$$N = \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ -1 & 0 \\ 0 & -1 \end{bmatrix}, \tag{5.17}$$

$$c_N^T = \begin{bmatrix} 0 & 0 \end{bmatrix}. \tag{5.18}$$

Therefore, by using $X_B = B^{-1}b \geq 0$, we can obtain the conditions for feasibility of basic solutions of the solution 1 as follows:

(i) $\varepsilon_{A1}\varepsilon_{B1}$-$\varepsilon_{A2}\gamma_{\mathrm{A}}\eta_{\mathrm{A}}\varepsilon_{B2}\gamma_{\mathrm{B}}\eta_{\mathrm{B}} \geq 0$; $(\varepsilon_{A1}/\varepsilon_{B2}\gamma_{\mathrm{A}}\eta_{\mathrm{A}}) \geq (F_3/F_7) \geq (\varepsilon_{A2}\gamma_{\mathrm{B}}\eta_{\mathrm{B}}/\varepsilon_{B1})$

(ii) $\varepsilon_{A1}\varepsilon_{B1}$-$\varepsilon_{A2}\gamma_{\mathrm{A}}\eta_{\mathrm{A}}\varepsilon_{B2}\gamma_{\mathrm{B}}\eta_{\mathrm{B}} \prec 0$; $(\varepsilon_{A2}\gamma_{\mathrm{B}}\eta_{\mathrm{B}}/\varepsilon_{B1}) \prec (F_3/F_7) \prec (\varepsilon_{A1}/\varepsilon_{B2}\gamma_{\mathrm{A}}\eta_{\mathrm{A}})$

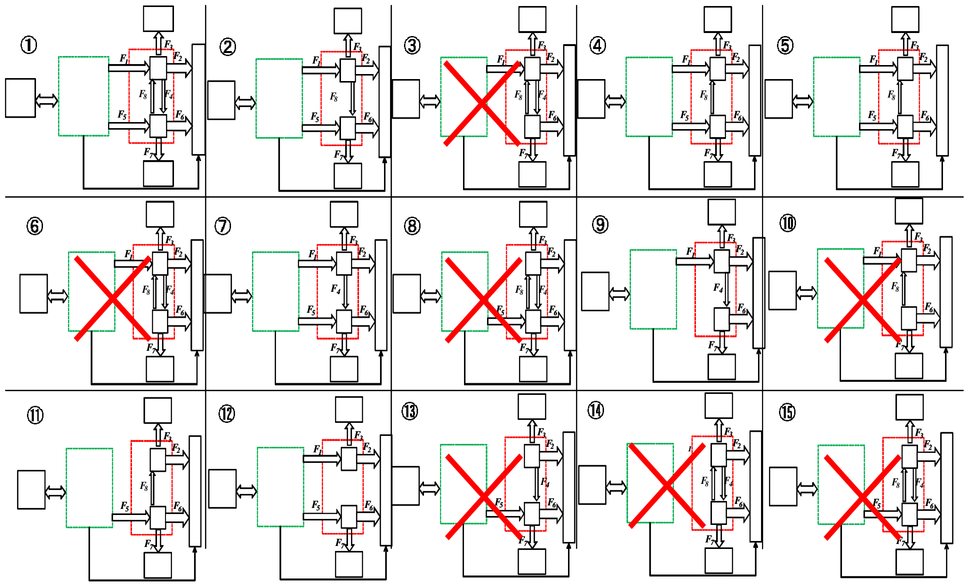

Figure 5.4: Taking out the feasibility logistic constructions solutions

Also, by using $c_B^T B^{-1} N - c_N^T \geq 0$, we can obtain the optimality conditions of the solution 1 as follows:

(i) $\varepsilon_{A2}\gamma_{\mathrm{A}}\eta_{\mathrm{A}}\varepsilon_{B2}\gamma_{\mathrm{B}}\eta_{\mathrm{B}} - \varepsilon_{A1}\varepsilon_{B1} \geq 0$; $\frac{\varepsilon_{B2}\gamma_{\mathrm{A}}\eta_{\mathrm{A}}}{\varepsilon_{B1}} \geq \frac{C_1+\varepsilon_{A1}C_J}{C_5+\varepsilon_{B1}C_J} \geq \frac{\varepsilon_{A1}}{\varepsilon_{A2}\gamma_{\mathrm{B}}\eta_{\mathrm{B}}}$

(ii) $\varepsilon_{A2}\gamma_{\mathrm{A}}\eta_{\mathrm{A}}\varepsilon_{B2}\gamma_{\mathrm{B}}\eta_{\mathrm{B}} - \varepsilon_{A1}\varepsilon_{B1} \prec 0$; $\frac{\varepsilon_{B2}\gamma_{\mathrm{A}}\eta_{\mathrm{A}}}{\varepsilon_{B1}} \prec \frac{C_1+\varepsilon_{A1}C_J}{C_5+\varepsilon_{B1}C_J} \prec \frac{\varepsilon_{A1}}{\varepsilon_{A2}\gamma_{\mathrm{B}}\eta_{\mathrm{B}}}$

where,

$C_1 = C_{AD}(1-\eta_A)+C_{ABD}\eta_A+C_J(1-\varepsilon_{A1})$ and $C_5 = C_{BD}(1-\eta_B)+C_{ABD}\eta_B+C_J(1-\varepsilon_{B1})$.

By the same way, we can get the feasibility and optimality conditions of the solution 2~15, respectively.

Step 5: Rearrange the feasible regions for all basic solution with increasing order of of extreme points from left to right. The rearranged extreme points on a sequence are called cut-points hereinafter.

By step 5, the following two cut-points $k1$ and $k2$ are obtained.

$$k_1 = \frac{\varepsilon_{A2}\gamma_{\mathrm{B}}\eta_{\mathrm{B}}}{\varepsilon_{B1}}$$

$$k_2 = \frac{\varepsilon_{A1}}{\varepsilon_{B2}\gamma_{\mathrm{A}}\eta_{\mathrm{A}}}$$

Step 6: Line up all basic solutions based on the feasible region on the cut-point sequence. One of the solutions in a feasible region may be an optimal solution, and the remaining solutions correspond to alternative feasible solutions.

By step 6, feasible regions of all logistic constructions are obtained. There are two cases of $k1>k2$ and $k2>k1$. Figure 5.6 and Figure 5.7 show the feasible regions of the two cases, respectively.

Step 7: Assume one of the basic solutions to be optimal in the feasible region on the cut-point sequence from left to right; proceed one-by-one in sequence to the next region and obtain the optimal solution space as a result of successive assumption of optimality.

How to Extract the Results from ASM methodology for logistic construction

By step 7, optimal solution structures and optimal conditions for logistic constructions are obtained which are shown in Figure 5.8 and Table 5.2.

Therefore, according to the above seven steps, the following policies are obtained which are useful to find the optimal solution of logistics construction corresponding to the demand of reused parts.

The basic variables indicate the logistics constructions with all possibilities.

The feasibility conditions of basic solution indicate the feasibility conditions of logistics constructions.

The optimality conditions of basic solution indicate the optimality conditions of logistics constructions. From →→, →, → of Figure 5.6 and → of Figure 5.7, it can be noted that with the accompanying rising of demand rate A of trader M, the distribution structure centered M becomes the optimal logistics constructions.

From of Figure 5.6 and Figure 5.7, it can be noted that when the demand rate of the two companies is well-balanced, the cooperate distribution structure is the optimal logistics constructions

From of Figure 5.6 and Figure 5.8, and from the condition 4 of phase I in Table 5.2, it can be noted that when the internal sourcing costs of related traders are zero ($C1= C5= C$J=0), then the no

cooperate distribution structure is the optimal logistics constructions in all the demand rate states of the companies. This indicates cases with the subsidy from the government.

The most highlighted result here is, visualizing all logically acceptable and unacceptable structure is useful for the decision of selections. The data can be applied whenever it is possible. The main opportunity is possible to see all of the general structuring methodology is useful here.

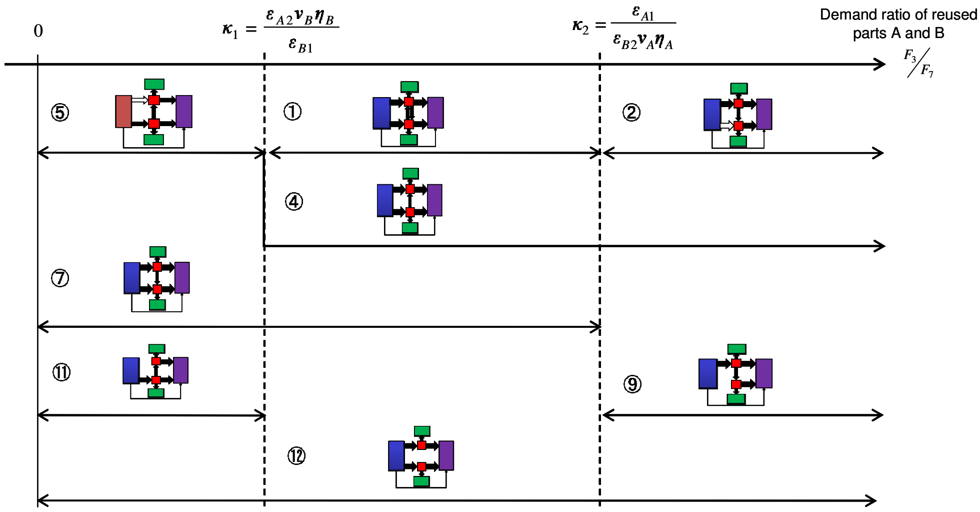

Figure 5.5: Line-up of feasibility solutions for logistic constructions ($k2>k1$))

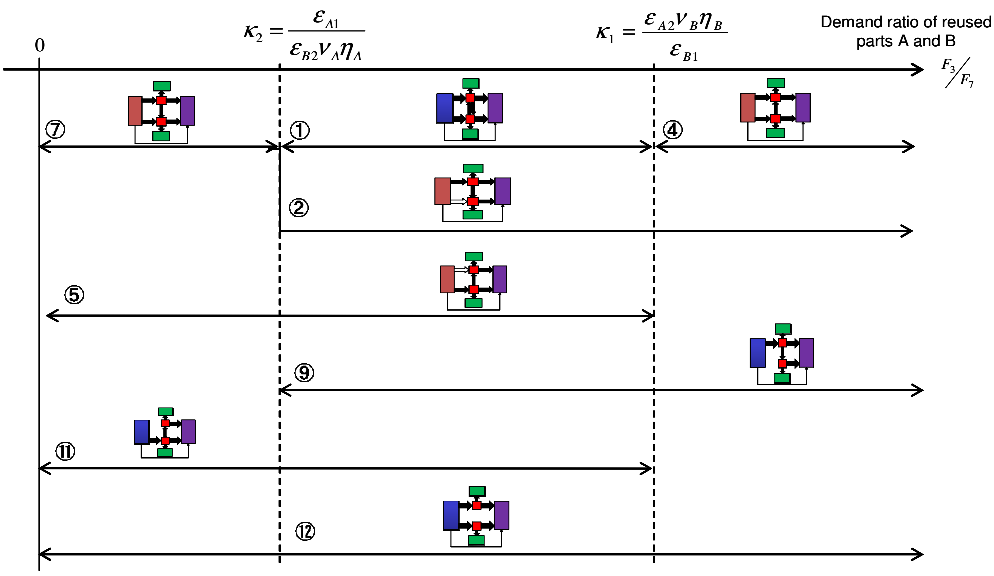

Figure 5.6: Line-up of feasibility solutions for logistic constructions ($k1>k2$)

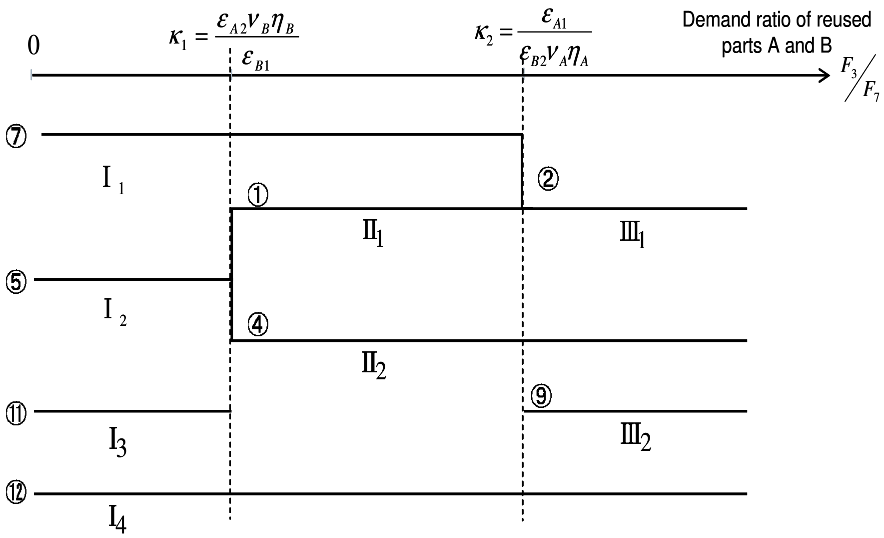

Figure 5.7: Structure of optimal solution space for logistic constructions

Table 5.2: Condition for optimality

Phase		Optimality Condition
I	1	$\varepsilon_{B1}(C_1+\varepsilon_{A1}C_J)-\varepsilon_{B2}\gamma_A\eta_A(C_5+\varepsilon_{B1}C_J)\le 0$
	2	$\varepsilon_{B1}(C_1+\varepsilon_{A1}C_J)-\varepsilon_{B2}\gamma_A\eta_A(C_5+\varepsilon_{B1}C_J)\ge 0$
	3	$C_5=0, C_J=0$
	4	$C_1=C_5=C_J=0$
II	1	$\varepsilon_{A1}\varepsilon_{B1}-\varepsilon_{A2}\gamma_B\eta_B\varepsilon_{B2}\gamma_A\eta_A\ge 0, \varepsilon_{B1}(C_1+\varepsilon_{A1}C_J)-\varepsilon_{B2}\gamma_A\eta_A(C_5+\varepsilon_{B1}C_J)\ge 0, \varepsilon_{A1}(C_5+\varepsilon_{B1}C_J)-\varepsilon_{A2}\gamma_B\eta_B(C_1+\varepsilon_{A1}C_J)\ge 0$
	2	$\varepsilon_{A2}\gamma_B\eta_B(C_1+\varepsilon_{A1}C_J)-\varepsilon_{A1}(C_5+\varepsilon_{B1}C_J)\ge 0$
III	1	$\varepsilon_{A2}\gamma_B\eta_B(C_1+\varepsilon_{A1}C_J)-\varepsilon_{A1}(C_5+\varepsilon_{B1}C_J)\le 0$
	2	$C_1=0, C_J=0$

5.5 Conclusion

This research considers the optimal reverse logistics structure of the automobile-industry to maximize the total profit of side traders from a win-win point of view.

In this problem, the optimal and feasible reverse logistics structure can be clarified based on the demand of reused parts and internal costs of related traders. In this study, first, the reverse logistics problem of the auto-industry is analyzed based on the current global state including developed and developing countries of car recycling. Next, based on the current Japanese state of vehicle recycling, the mathematic formulation of the reverse logistics is proposed for improving reuse rate. Finally, by using the analytical solution method of the Linear Programming the optimal and feasible reverse logistics structure can be clarified based on the reused parts demand and internal costs of related traders, and the following policies of recycling logistics from a win-win point of view are identified.

1. When the demand rate of the two companies is well-balanced, the cooperative distribution structure is the optimal logistics construction.
2. When the internal sourcing costs of related traders are zero (e.g. receiving the subsidy from the government), the no cooperation distribution structure is the optimal logistics constructions.
3. Accompanying the rising of the reuse part demand rate of a trader company, the distribution structure centered around this trader becomes the optimal logistics constructions.

Chapter 6

Scenario Generation Mechanism Based on Possible Policies

Chapter 6 summarizes the major themes logical scenario generation mechanism based on possible political decision related to the cost of transportation, cost of 3R activities and the percentage of the recycling rates for engine parts of different class of cars as a case study. Related works are also included as Appendix.

6.1 Introduction

As a consequence of globalization, any development and revision in international regulations and governmental policies are affecting especially most type of large-scale production industry. Regarding to creation of several political scenarios, these mutual interactions challenge to set up interconnections between law makers, users, producers and 3R providers through to determine all acceptable inputs and outcomes or, deal with uncertain outcomes.

Firstly, in order to introduce legislations, the intervention of government without mutual communication with other influenced stakeholders does not help to solve any part of policy decision making problem. In literature, it can be noted that most discussions for the efficiency of practical issues of industrial production with supply chain and reverse logistics can show up one main topic; which completely connects to legislations to manage and control take-back, recycling, dismantling and waste decisions ([35], [49]).

There are several active and effective policy options served to aim to solve this problem in USA, EU and Japan. Extended producer responsibility (EPR) approach is one of the alternatives which demonstrate the concept that producers should be made physically and / or financially responsible for environmental impacts of their products This approach is mostly applied in several states of USA. European Union (EU) wishes to limit the production of waste arising from end-of-life vehicles and to increase re-use, recycling and other forms of recovery of end-of-life vehicles and their components. In order to achieve these two objectives, the EU establishes new requirements for European vehicle manufacturers, who should design vehicles which are easy to recycle [20].Based on this background, Directive 2000/53/EC would like not only decrease the quantity of waste arising from vehicles, but also increase the rate of re-use and recovery. By this directive, it can be recognized that priority in policies must be re-use, recycle and then recovery of vehicle components (Directive 2000/53/Ec). In Japan, under the 2002 ELV (End of Life Vehicle) Recycling Law, which is based on a "shared responsibility" principle, consumers should pay a fee when they purchase a new car or, for cars sold before the enforcement of the law, should pay a fee at the time of mandated regular inspection. The fee is managed by a third party, the Japan Automobile Recycling Promotion Center (JARC).

6.2 Problem Statement for Logical Scenario Generation Mechanism

In a general scenario, the expected results sometimes can be highlighted. In this part of this research, the author realzied that the definition ot all possible results are important for selection of the tactics. To have ful knowledge of the expected conditions are more important than the result generation. The process itself have to highlighted.So, in that angle, the scenario generation mechanism depending on the possible regulations from te governments pressure and the also from the international expectations are creating the conditions, and then set up the logistic construction for all condition with analytical logic is our problem here. Based on the real world situation, simplification of all trades, flows, system and then creating the simple model to clarify he problem is significant consideration for this part.

6.3 Methodology

6.3.1 Decision Making in Scheme of Tactics and Analysis

Combination of ASM results and the scheme of tactics and analysis creates a totally different method from the ordinary Scenario Analysis methodology. In ordinary Scenario Analysis, the set up conditions may be dependent on the expectations of scenario creator's results, however, in our methodology, we create all of the possible results and then according to the expected conditions, we pick the appropriate structure. So, overall discussion differs from the simple heuristics. In our scenarios, the possibility of the conditions are important and the problem is the definition of the possibilities, the results are obvious for each condition.

In decision making process, scenarios provide big opportunity as a decisional support in many areas for decision makers to anticipate potential strategies. This method fits to analytical research methodologies where structured data are not implied. As a beginning, scenario analysis provide inputs such as recycling rates or payment options for transaction cost as well as a guidance to long-term policy strategies. However, scenario analysis can be expressed as a heuristic, so; it does not mean that the scenarios and their model or data can predict the future totally true, they can only show possibilities if it will exist or not.

Instead, they are idea pieces expressing reflections about future developments into illustrations of possible actions in future. If regarded as such, they can provide a valuable basis for reflecting on long-term oriented policy alternatives [48].

6.3.2 Analytic Solution Methodology in Linear Programming and Theoretical basis

In previous researches, generally, options of modeling CLSC and numerical solutions have been presented ([47],[45], [44]) but to be able to see all possible CLSC structures as visualized model, is one of the key success point to take precaution against expected uncertainties. To fill gap in solution methodologies presented in literature, [38] proposed Analytic Solution Methodology.(Chapter 5 describes the mathematical model.)

According to this mathematical model given in Chapter 5, Steps of Analytic solution Methodology was applied in [20]. Eight feasible logistic constructions were defined because only these were appropriate for realistic business rules (Figure 6.3).To define cut points, as a result of calculations in the way of proposed and applied solution methodology, Demand Rates of F3 and F7 are found as a sequence line.

In this research, scenarios are set up based on these assumptions; F3 includes recycled and reusable Battery (A) and F7 includes recycled and reusable Engine (B). Cut points (k_1 and

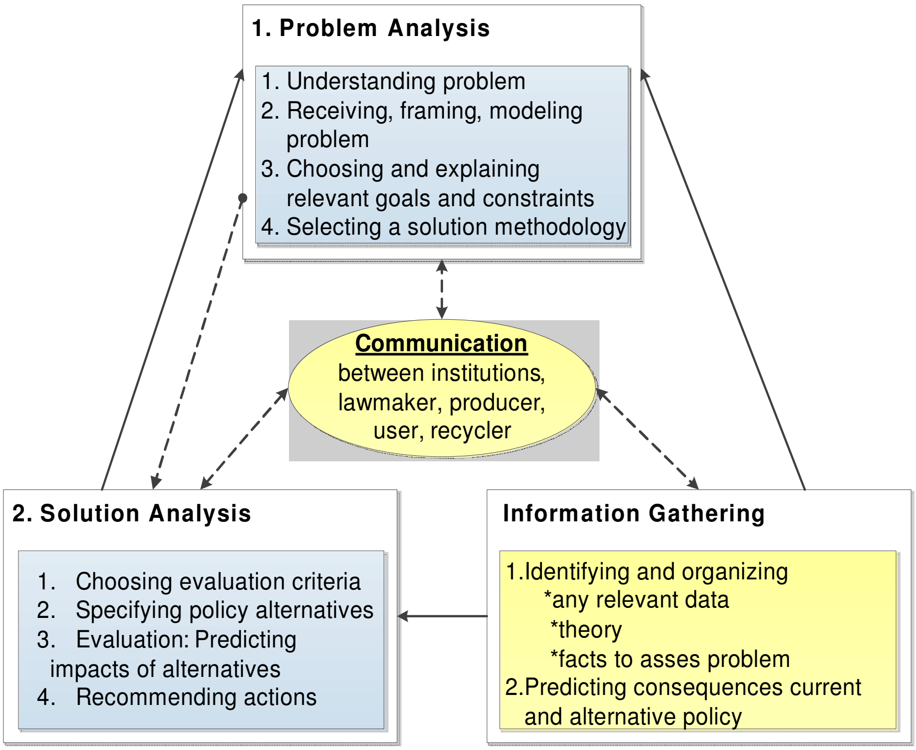

Figure 6.1: Policy Analysis Process [4]

k_2) which define scalar relation between demand rates of A and B, and quantitative changes in increasing order of magnitude of extreme points from left to right. There are two possible 'Line-up of feasible Structure' in order of scalar size of k_1 and k_2 are $k_2>k_1$ and $k_1>k_2$. Feasible logistic constructions for any scenario can be determined in light of several mathematical conditions of k_1 and k_2 (Figure 6.3). Optimal model of recycling structure could be defined by objective function. Line-up through demand rate between flow of Recycled Part 'A' and flow of Recycled part of 'B' and cut points named k_1 and k_2 come from calculations according to the steps of Analytic Solution Methodology. Under particular conditions and rates of particular parts of ELVs scenarios are created according to the model includes flows and demands are come from production side of CLSC.

6.4 Illustrative Example

There are many type of policy options assessed in practice related to ELV recycling but it is not possible to define one of them is the best for all conditions. This approach has a big opportunity against to the techniques show only optimal condition numerically.

In nature of definition of 'selection', more than one alternative of feasible structure must exist and comparison is an essential requirement under pre-defined circumstances. Logistic construction selection is very close to heuristics to settle short cut logical results. So, upper level in decision making of selection appropriate reverse logistic construction in CLCS, might be expressing all feasible candidates as a model and create scenario analysis which can have ability to describe effects on each components.

Generic CLSC Structure for Scheme of Tactics and Analysis

In [20]showed all possible models and optimality conditions for each of them through order relation between cut points in sequence line of demand rates recycled part ‘A’ and recycled part ‘B’. In real world, many options as a cash flow are in use for several regulations (Figure 6.2), and mostly, some of them may be applied at the same time. As can be seen in Figure 6.2, User, Industry, Government and Recyclers are main actors to select responsible and to define cost policy of recycle transactions. Price is the fixed cost plus profit of stakeholders who is an element of production and handing after production processes. Recycling requires additional costs hence decision of responsible of this cost is a problem needs a solution for each aspect of CLSC.

From user to industry, there are two possible flow options; Price and Deposit. Price is fixed and explained below, in additionally, industry request the amount of price from end users, hereafter, other plausible flow, deposit, is money paid from end user to industry for recycling costs of ELV and rules are managed by government but when end user does not want to use car anymore and sells to second hand market or recyclers, they can get their deposit back from a responsibility organization or directly from designated government offices. Among other issues, assignment of the management responsibility is one of the main decision making problem.

From industry to government, there are two possible methods to meet the recycling costs; Government subsidy, Recycling Fee or Deposit / Refund system. As a one possible method, if government wants to encourage recycling activities, it can support ELV recycling transactions by a subsidy directly to industry. These subsidies can be paid from taxes that citizens have to pay in time periods or government can allocate designated percentage of total money reserves in a year. Government may set up a direct way such as paying recycling fee without a refund system, too. In deposit / refund system, industry can have a responsibility to pay a designated amount of money related to calculations from its production rate or selling rates in a year. Government is again the responsible to set laws to manage cash flow between industry and government if they select either. From end user to government, there are two possible methods to cover all recycling costs; Government subsidy, Recycling Fee or Deposit / Refund system. As a one possible method, if government wants to encourage users to join recycling activities or to lead users to buy cars designed concerning environmental hazard effects such as the cars have very low CO emission and produced by high and new technological improvements, it can support ELV recycling transactions by a subsidy directly to end user by decreasing tax rates, or deleting all taxes and added payments. In deposit / refund system, end user is responsible to pay fees directly to a responsibility organization or directly to pre-set government offices. Government has to manage cash flow between end user and itself. For recycle site, there are directly several subsidies to support recycling, reuse and recovery of ELVs or particular parts of ELV. Subsidy can occur as a tax reduction or elimination of all taxes for dismantlement. In this research, several scenario analyses are generated according to the governments’ pressure on to increase

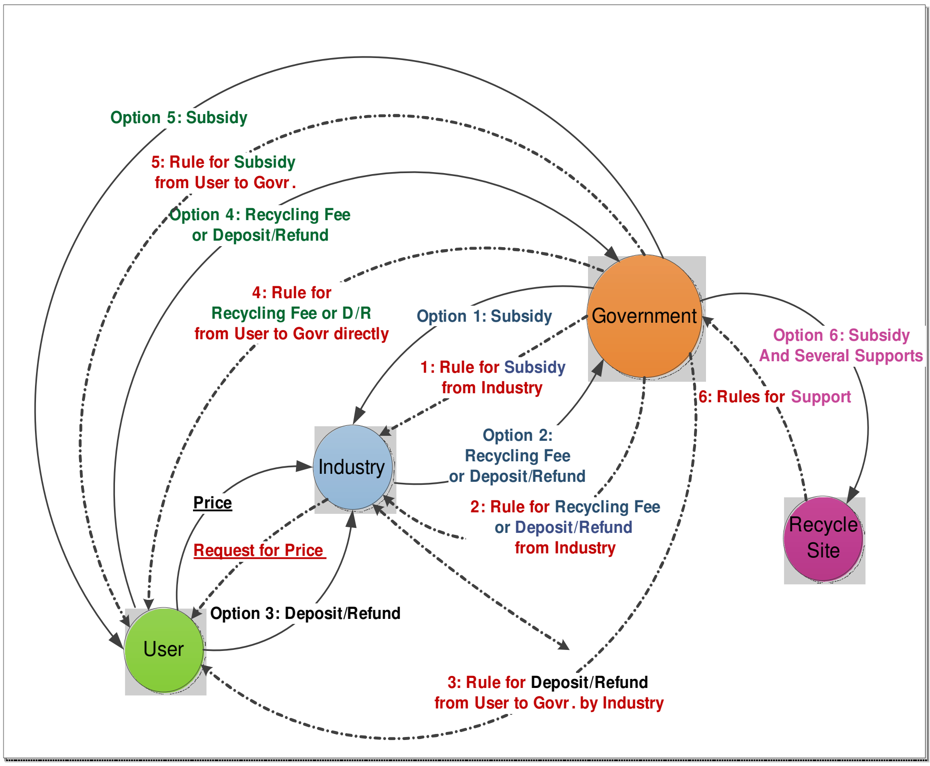

Figure 6.2: Possible Regulations concerning ELV Recycling

recycling rates of defined parts of ELVs and are a proposal to answers this question: Who will take financial responsibility for transportation and 3R processes' costs from appropriate cash flow options.

Selection strategy includes policy options (Figure 6.5), which are being defined by cash flow legislation options, can be determined by cut-point sequence, expression of cut point equations and objective function itself by decision makers for supply chain and reverse logistic structure. Feasible logistic constructions for any scenario can be determined in light of several mathematical conditions of k_1 and k_2 (Figure 6.3). Optimal model of recycling structure could be defined by objective function. Line-up through demand rate between flow of Recycled Part 'A' and flow of Recycled part of 'B' and cut points named k_1 and k_2 come from calculations according to the steps of Analytic Solution Methodology .

Under particular conditions and rates of particular parts of ELVs scenarios are created according to the model includes flows and demands are come from production side of CLSC.

In reverse logistic decision of CLSC in auto industry, each stakeholder would like to consider transportation and recycling costs (fee). Main problem is the expressing changes in benefits and cost in different plausible scenarios can occur sooner or later. Today government may have a regulation to deal with problems but in global world, rules might be affected by any changes. Costs can increase according to possible and unexpected trouble. An economic crisis or exogenous reasons such as broken relations between the countries of supplier of raw material

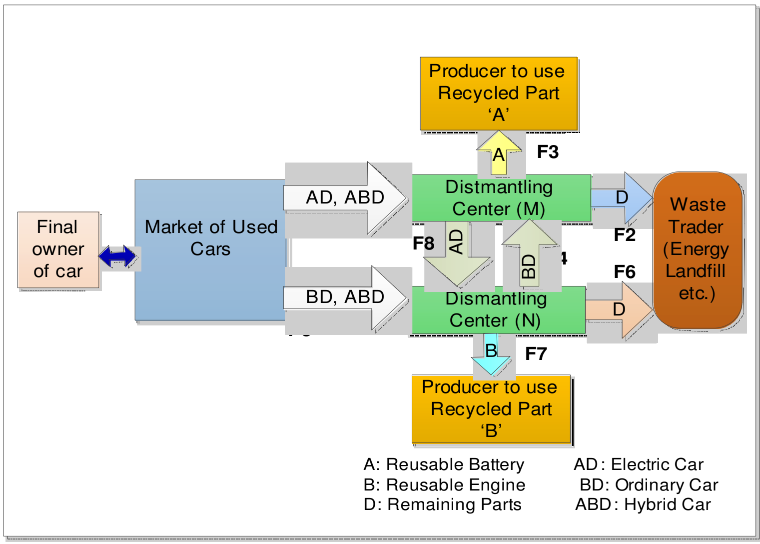

Figure 6.3: Reverse Logistic Side of CLSC Structure (adapted from [2])

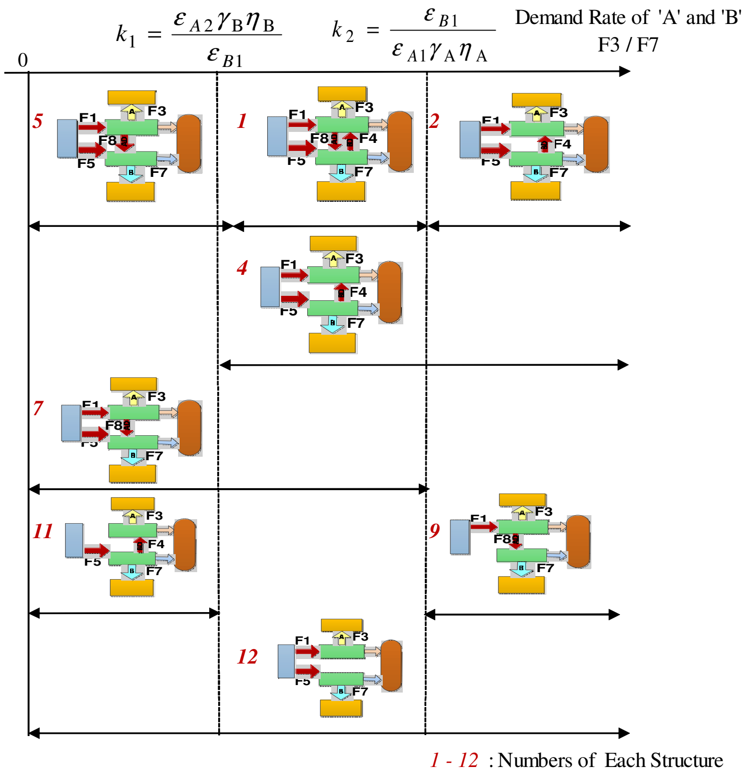

Figure 6.4: Line-up of feasibility solutions for logistic constructions (k2 >k1))

might have a result to make governments and companies necessary to know any scenario has a possibility to exist in real world. Government has an important role which includes being a leader to establish 3R (Reuse, Recovery, and Recycle) activities all over the country, but surely this might be a consequence of having interactions between international regulations and global companies as a business partnership. Nowadays, to save our planet and help to minimize production and raw material costs, technological improvements on auto industry have been directing to support hybrid and electric cars.

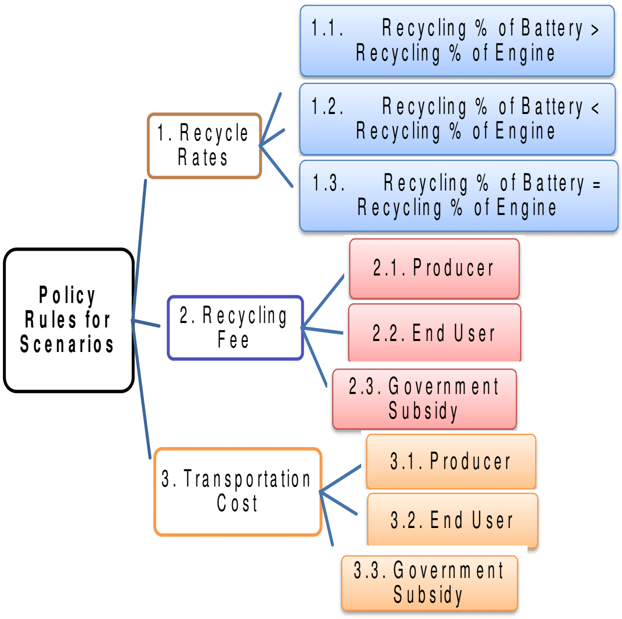

Figure 6.5: Possible Policy Alternatives for Generic CLSC

In this research, theoretically, F3 includes recycled battery and F7 includes recycled engine. Three policy options are predicated; Recycling rate of Battery = Recycling Rate of Engine, Recycling rate of Battery >Rate of Engine and Recycling rate of Battery <Rate of Engine. Recycling rate of Battery = Recycling Rate of Engine has the same meaning with F3=F7 and other two policies are the same meaning with relation of F3 and F7 like this explanation. In aspect of reason to show 'Recycling rate of Battery = Recycling Rate of Engine' as a policy option can be explained such that: government might have a particular support for hybrid and / or ordinary cars. Reason to show 'Recycling rate of Battery >Rate of Engine' as a policy option is, government and / or associations related to auto industry obviously would like to support Electric car in society. Reason to show 'Recycling rate of Battery <Rate of Engine' as a policy option is, government and / or associations related to auto industry does not have a specific support for Hybrid, Electric or Ordinary cars in society.

To sum up, as an illustrative example, we studied previous paper [20] to continue the research study to be able to present decision making problem related to scenarios created based on three different relations of demand rates and three plausible occurrences of transportation cost and recycling fee will be paid by either from end user, producer or subsidy from government.

The foremost addition to the research is definition of effects by scenarios based on realistic policies and presented and proposed feasible and then optimum structure to industry. Managers and decision makers can clearly see the whole picture of their CLSC model in a specific policy condition and shifts in model one scenario to another one.

First step is, to find critic points to define feasible structure. As a consequence of mathematical model and calculations of Analytic Solution Methodology, k_1 and k_2 are expressed as cut points. Equations of k_1 and k_2 are given below.

$$k_1 = \frac{\varepsilon_{A2}\gamma_{\mathrm{B}}\eta_{\mathrm{B}}}{\varepsilon_{B1}}$$

$$k_2 = \frac{\varepsilon_{A1}}{\varepsilon_{B2}\gamma_{\mathrm{A}}\eta_{\mathrm{A}}}$$

It is recognized that to meet the requirements of demand rates in policy options, equation and lining up orders of $k_1$and k_2 on ‘x’ axis are the key points in solution steps. They exist in solution as a fraction. So numerators and denominators of k_1 and k_2 and scalar relations of them are set up as shown in Figure 6.6.

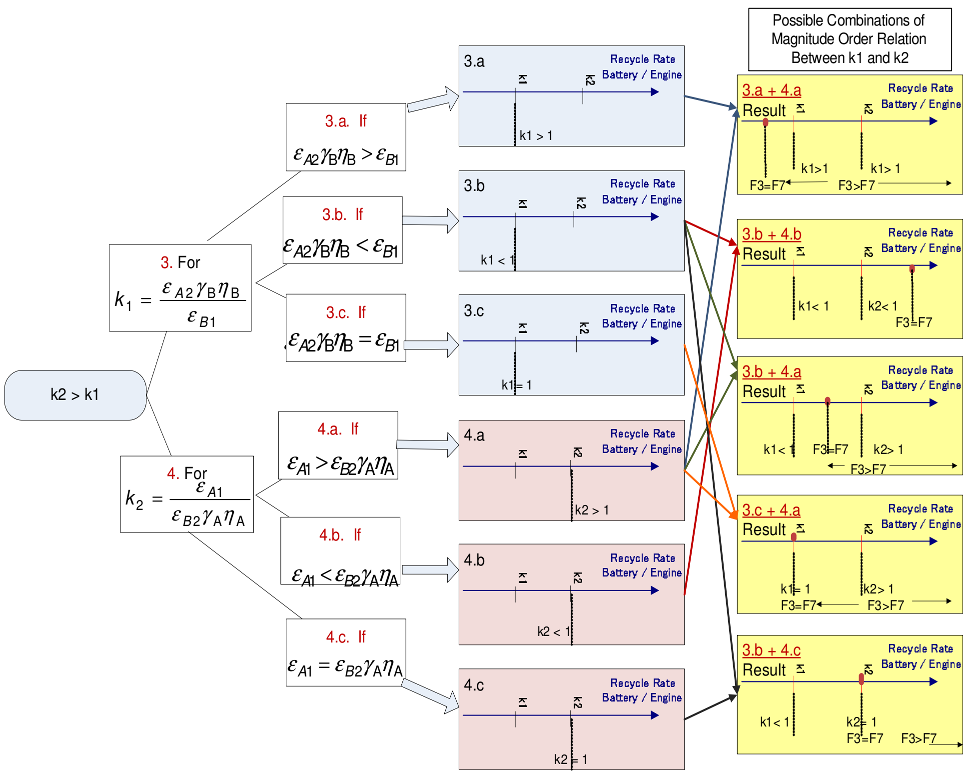

Figure 6.6: Breakdown Structure for Possible Line-up Order Relation of $k_2 > k_1$

Firstly, as a result of each expression, magnitude relation for k1 and k_2 are set up separately and then as a logical result, possible combinations of magnitude relation between them are defined.

We can find where demand rates of F3 and F7 are greater than 1, equal 1 and less than 1 in line-up so each combination stands as an option of policy in generic example. As the same way is expressed in Figure 6.6 , breakdown structure of possible conditions for $k_1 > k_2$ which can be occurred in line up order as a line-up set up and according to combinations of relation between magnitude order of demand rates of Battery (A) and Engine (B) .

To be an example, for structure of $k_2 > k_1$, 3a + 4a can be explained like that; if numerator of k_1 is greater than denominator of it and if numerator of k_2 is greater than denominator of it, to find where recycling rate of Battery (A) is equal to recycling rate of Engine (B), line-up order is checked in result of 3a + 4a. As it is seen, CLSC structures which exist between 0 and k1 in cut point sequence become feasible options because k_1 is greater than 1 and k_2 is greater than 1 in this combination. If policy requires that the recycling rate of Battery (A) should be larger than recycling rate of Engine (B), reverse logistic constructions which exist in the area between k1 to infinite towards right become feasible solutions.

On the other hand, if policy requires that the recycling rate of Battery (A) should be less than recycling rate of Engine (B), there is no feasible reverse logistic constructions which exist in the area between 0 to infinite towards right side on x axis.

$$C_1 = C_{AD}(1 - \eta_A) + C_{ABD}\eta_A + C_J(1 - \varepsilon_{A1})$$

$$C_5 = C_{BD}(1 - \eta_B) + C_{ABD}\eta_B + C_J(1 - \varepsilon_{B1})$$

To decide optimal construction(s), we need a guide to show structures' magnitude order for total costs. This guide is redefined and some shifting of notations in equations are made. For example in equation 23, $C_{AD}(1 - \eta_A) + C_{ABD}\eta_A$is equal to C_{F1}, and in equation 24, $C_{BD}(1 - \eta_B) + C_{ABD}\eta_B$is equal to C_{F5}.

To be an example, scenario alternatives created based on several possible policy rules (Figure 6.5) as a result of feasibility and optimality conditions for each structure are given in Table 6.2.

Firstly, we considered scenario alternative A, the aims are;

- Balanced recycling rates of battery and engine
- Full producer responsibility for all costs related to recycling transactions.

Balanced recycling rates of battery and engine might have the same meaning with 'no government support for new generation automobiles'.

In order to define Scenario A, political policy rules will exist in such exact definition:

- Recycling % of A= Recycling % of B (F3 = F7)
- Cost of Transportation of ELV and Parts PAID by Producer
- Recycling Fee PAID by Producer (Table 6.2)

Table 6.1: Optimal Conditions and Order Results

Case		$k_1 = \frac{\varepsilon_{A2}\gamma_B\eta_B}{\varepsilon_{B1}} < k_2 = \frac{\varepsilon_{A1}}{\varepsilon_{B2}\gamma_A\eta_A}$ can be shifted to	$\frac{\varepsilon_{A2}\gamma_B\eta_B}{\varepsilon_{A1}} < \frac{\varepsilon_{B1}}{\varepsilon_{B2}\gamma_A\eta_A}$	Results
Feasible Structure **1**	**Condition 1**	$\varepsilon_{A1}\varepsilon_{B1} - \varepsilon_{A1}\gamma_B\eta_B\varepsilon_{B1}\gamma_A\eta_A \ge 0$ can be shifted to	$\frac{\varepsilon_{A2}\gamma_B\eta_B}{\varepsilon_{A1}} \le \frac{\varepsilon_{B1}}{\varepsilon_{B2}\gamma_A\eta_A}$	$\frac{\varepsilon_{B1}}{\varepsilon_{B2}\gamma_A\eta_A} \ge \frac{\varepsilon_{A2}\gamma_B\eta_B}{\varepsilon_{A1}} \ge \frac{C_{F_5}+C_J}{C_{F1}+C_J}$
	Condition 2	$\frac{\varepsilon_{B1}}{\varepsilon_{B2}\gamma_A\eta_A} \ge \frac{C_5+\varepsilon_{B1}C_J}{C_1+\varepsilon_{A1}C_J}$	$\frac{\varepsilon_{B1}}{\varepsilon_{B2}\gamma_A\eta_A} \ge \frac{C_{F_5}+C_J}{C_{F1}+C_J}$	
	Condition 3	$\frac{\varepsilon_{A2}\gamma_B\eta_B}{\varepsilon_{A1}} \ge \frac{C_5+\varepsilon_{B1}C_J}{C_1+\varepsilon_{A1}C_J}$	$\frac{\varepsilon_{A2}\gamma_B\eta_B}{\varepsilon_{A1}} \ge \frac{C_{F5}+C_J}{C_{F1}+C_J}$	
Feasible Structure **2**	**Condition**	$\frac{\varepsilon_{A2}\gamma_B\eta_B}{\varepsilon_{A1}} \le \frac{C_5+\varepsilon_{B1}C_J}{C_1+\varepsilon_{A1}C_J}$	$\frac{\varepsilon_{A2}\gamma_B\eta_B}{\varepsilon_{A1}} \le \frac{C_{F5}+C_J}{C_{F1}+C_J}$	Total Cost for Structure 2 > 4
Feasible Structure **4**	**Condition**	$\frac{\varepsilon_{A2}\gamma_B\eta_B}{\varepsilon_{A1}} \ge \frac{C_5+\varepsilon_{B1}C_J}{C_1+\varepsilon_{A1}C_J}$	$\frac{\varepsilon_{A2}\gamma_B\eta_B}{\varepsilon_{A1}} \ge \frac{C_{F5}+C_J}{C_{F1}+C_J}$	
Feasible Structure **5**	**Condition**	$\frac{\varepsilon_{B1}}{\varepsilon_{B2}\gamma_A\eta_A} \ge \frac{C_5+\varepsilon_{B1}C_J}{C_1+\varepsilon_{A1}C_J}$	$\frac{\varepsilon_{B1}}{\varepsilon_{B2}\gamma_A\eta_A} \ge \frac{C_{F5}+C_J}{C_{F1}+C_J}$	Total Cost for Structure 7 > 5
Feasible Structure **7**	**Condition**	$\frac{\varepsilon_{B1}}{\varepsilon_{B2}\gamma_A\eta_A} \le \frac{C_5+\varepsilon_{B1}C_J}{C_1+\varepsilon_{A1}C_J}$	$\frac{\varepsilon_{B1}}{\varepsilon_{B2}\gamma_A\eta_A} \le \frac{C_{F5}+C_J}{C_{F1}+C_J}$	
Feasible Structure **9**	**Condition**	$C_1 = 0$ and $C_J = 0$		Costs are '0'
Feasible Structure **11**	**Condition**	$C_5 = 0$ and $C_J = 0$		
Feasible Structure **12**	**Condition**	$C_1 = 0$ and $C_5 = 0$ and $C_J = 0$		
				Magnitude order of Total costs 7 > 2 > (4 ▪1) > 5

There are three plausible combination magnitude relation of order such as '3a + 4a', '3b + 4b' and '3b + 4a' based on breakdown structure for line-up order relation of k_2 >k_1 where F3 = F7 exists. Constructions 5 and 11 are defined as feasible structures for 3a + 4a, 2 and 9 for 3b +4b and finally structure 1 for 3b + 4b (see Figure 6.6 and Table 6.2), these decision were expressed regarding to recycling rates, in other words, magnitude relation of k_1 and k_2 .Optimality is being decided throughout the criteria used in objective function and equation of objective function itself. In previous research [2], optimality conditions were calculated according to the Analytical Solution methodology in LP. There has been a shifting between notations ε_{B1} and ε_{B2} in equations of k_1 and k_2 because, as a result of calculations for optimality of structures, order of total costs should be presented in light of these shifted equations. In our case, for the first magnitude order (3a + 4a), 5 and 11 was expressed as feasible solutions. To define optimal structure Optimal Conditions and Order Results (Table 6.1) should be checked for these ones. As a comparison of total cost of 5 and 11, 5 is picked up as optimal solution. 11 cannot be picked by as an optimal solution because in optimality condition of 11, C_5 and C_J are zero. It is clear that actual costs are impossibly can be zero so there should be a subsidy from government but in Scenario A, no support exists. For the second magnitude order (3b + 4b), 2 and 9 was expressed as feasible solutions. To define optimal structure, optimal conditions and order results (Table 6.1) should be checked for these ones.

As a comparison of total cost of 2 and 9, 2 is picked up as optimal solution. 9 cannot be picked by as an optimal solution because in optimality condition of 9, C_1 and C_J are zero. It is clear that actual costs are impossibly can be zero so there should be a subsidy from government however in Scenario A, no support exists. Finally for last magnitude order (3b + 4a), only 1 was expressed as feasible solution. When we check optimal conditions and order results (Table 6.1) for structure 1, it is clear that actual costs are greater than zero, so there is no subsidy from government in Scenario A, producer has to be responsible all costs without any support.

In Scenario B, aims are, giving priority to increase recycling rate of battery and full producer responsibility.

In order to define Scenario B, political policy rules will exist in such exact definition:

- Recycling % of A >Recycling % of B (F3>F7)
- Cost of Transportation of ELV and Parts paid by Producer
- Recycling Fee paid by Producer (Table 6.2)

Under condition of magnitude orders 3a + 4a, 3b + 4a and 3c + 4a, feasible structures are defined as 1, 2, 4, 9 and 12. According to the optimality condition and order rules (Table 6.1), it can be said that model 1 and model 4 have similar total costs hence, 1 or 4 can be selected as optimal solution. In model 4, all flows exist except trade flow dismantler M to N. In model 1, all flows exist. In Scenario C, aims are, giving priority to increase recycling rate of battery, government support and pay as you used / throw. As a requirement of Scenario C, policy rules are defined:

Table 6.2: Scenario Alternatives and Policy Rules

	Defined by Rules	Defined by Recycling Rates	Defined by Costs
SCENARIO ALTERNATIVES	**POLICIES**	**FEASIBLE LOGISTIC CONSTRUCTIONS**	**OPTIMUM LOGISTIC CONTRUCTION(S)**
A) Balanced Recycling Rates of Battery and Engine & Full Producer Responsibility	**1.** Recycling % of A = Recycling % of B (F3=F7) **2.** *Cost of Transportation of ELV and Parts paid by Producer* **3.** Recycling Fee paid by Producer	**If k2 > k1** 3a + 4a **feasible logistic constructions are 5, 11** 3b + 4b **feasible logistic constructions are 2, 9** 3b + 4a **feasible logistic constructions is 1**	→ 5 → 2 → 1
B) Priority to Increase Recycling Rate of Battery & Full Producer Responsibility	**1.** Recycling % of A > Recycling % of B (F3>F7) **2.** *Cost of Transportation of ELV and Parts PAID by Producer* **3.** Recycling Fee PAID by Producer	If **k2 > k1** 3a+4a 3b + 4a 3c + 4a **feasible logistic constructions are 1, 2, 4, 9, 12**	**1 and 4**
C) Priority to Increase Recycling Rate of Battery & Government support & Pay-as-you used/throw	**1.** Recycling % of A > Recycling % of B (F3>F7) **2.** *Cost of Transportation of ELV and Parts PAID by End User* **3.** Recycling Fee Subsidy from Government	If **k2 > k1** 3a+5a 3b + 4a 3c + 4a **feasible logistic constructions are 1, 2, 4, 9, 12**	**4 and 2*** *2 End users because of psychological impacts, may have a tendency to accept paying a little more.
D) Priority to Increase Recycling Rate of Battery & Full Government support for Costs	**1.** Recycling % of A > Recycling % of B (F3>F7) **2.** Cost of Transportation of ELV and Parts PAID Subsidy from Government **3.** Recycling Fee Subsidy from Government	If **k2 > k1** 3a+6a 3b + 4a 3c + 4a **feasible logistic constructions are 1, 2, 4, 9, 12**	**9 and 12*** *12 is not acceptable under competitional trade conditions because competition might be appropriate in aspect of win-win in CLSC structure
E) Priority to Increase Recycling Rate of Engine & Full Government support for Costs	**1.** Recycling % of A < Recycling % of B (F3<F7) **2.** *Cost of Transportation of ELV and Parts PAIDSubsidy from Government* **3.** Recycling Fee Subsidy from Government	If **k2 > k1** 3a + 4a 3b+4b 3b+4a 3c + 4a 3b+4c **feasible logistic constructions are 1, 5, 7, 11,12**	**11 and 12*** *12 is not acceptable under competitional trade conditions because competition might be appropriate in aspect of win-win in CLSC structure

- Recycling % of A >Recycling % of B (F3>F7)
- Cost of Transportation of ELV and Parts paid by End User
- Recycling Fee paid by Subsidies from Government (Table 6.2)

Under condition of magnitude orders 3a + 4a, 3b + 4a and 3c + 4a, feasible structures are defined as 1, 2, 4, 9 and 12. According to the optimality condition and order rules (Table 6.1), it can be said that model 4 has the lowest cost but they can select model 2, because end user psychologically can be ready to accept more cost to pay. Government support might have an influence such making them encourage to select greater cost. In Scenario D, aims are, giving priority to increase recycling rate of battery, full government support.

As a result of requirements of Scenario D, policy rules are defined given below:

- Recycling % of A >Recycling % of B (F3>F7)
- Cost of Transportation of ELV and Parts paid by Subsidies from Government
- Recycling Fee paid by Subsidies from Government (Table 6.2)

Under condition of magnitude orders 3a + 4a, 3b + 4a and 3c + 4a, feasible structures are defined as 1, 2, 4, 9 and 12. According to the optimality condition and order rules (Table 6.1), it can be said that model 9 and 12 both has 'zero' costs. However, structure 12 does not cover trade flows between dismantlers M to N vice versa. This might not be acceptable under competitive trade conditions. In Scenario E, aims are, giving priority to increase recycling rate of engine, full government support. As a result of requirements of Scenario E, policy rules are defined as given below:

- Recycling % of A <Recycling % of B (F3<F7)
- Cost of Transportation of ELV and Parts paid by Subsidies from Government
- Recycling Fee paid by Subsidies from Government (Table 6.2)

Under condition of magnitude orders 3a + 4a, 3b + 4a and 3c + 4a, 3b + 4b and 3b + 4c feasible structures are defined as 1, 5, 7, 11 and 12. According to the optimality condition and order rules (Table 6.1), it can be said that model 11 and 12 both has 'zero' costs. However, as same as previous scenario, structure 12 does not cover trade flows dismantlement M to N and N to M. This might not be acceptable under competition rules.

6.5 Conclusion

This research expresses the general idea of connection between policy issues, production systems and production management in decision making approaches.

To sum up entire ideas of the research, proposed steps of Scenario analysis by analytical solution methodology are defined as given below:

1. Flow diagram of reverse logistics structure of CLSC should be created.
2. According to the expressed flows and balance of inputs and outputs of elements of structure, mathematical LP model and notations should be defined.
3. Analytical Solution methodology should be applied to defined mathematical expressions.
4. As a result of analysis, to get feasibility conditions based on constraints, line up order of feasible structures should be created.
5. Optimality conditions are calculated as a set of equations for each structure based on objective function(s).
6. Possible scenarios might have a chance to occur in future should defined by general explanations related to expected outcomes.
   (a) According to the aims of each scenario, define political policy rules in exact words to be a guideline for industry and society.
7. Referring to line - up order cases created in step 4, to define specific location of structure and to meet related policy rules, possible magnitude orders of cut points should be visualised as a breakdown structure.
8. Based on optimality conditions calculated in step 5, define orders of total costs of each structure.
9. Feasible structures should be decided according to the concerned particular policy rules related to cut points. It should be remembered that cut points are calculated as a result of constraints.
10. After defining feasible structures, based on orders of total costs expressed in step 9 and concerned particular policy rule, select appropriate structure(s).

Step 1-5 express Analytic Solution Methodology as well. Step 6 -11 express policy making approach by using scenario analysis on results of Analytic Solution methodology used in reverse logistic construction problem in auto industry. If there are more than one optimal solution depends on one criteria considered in objective function, addition of new criterion to be able to considered, might decrease number of optimal structure.

In this thesis, as a generic model, five scenarios are analysed to show different conditions and possibilities that can be faced in future. Three main policy layers are defined as;

- Order of recycling rates of ‘battery’ and ‘engine’
- Cost of transportation,

- Cost of 3R (Reuse, Recycle, Recovery) activities,

based on expressed cash flow options (Figure 6.2). Each layer has three policy alternatives (Figure 6.5). So, according to the possible policy alternative options which can be pushed by government and international regulations are studies as scenario analysis to find out feasible and then optimal reverse logistics structure of in auto industry CLSC.

Another important part of this research is, any numerical analysis can be applied through selected feasible and optimal solutions because all result and requirement conditions are explained mathematically, particularly for each scenario. Furthermore, businesses are able to see whole picture of their supply chain and reverse logistics model in particular policy conditions. As a comment, it is obvious that, decisions in policy making should have a interrelation of stakeholders from international units, government(s), industries and society. Government also have a unique role to be the leader supporting industries to change their SC models for a more sustainable world.

Chapter 7

Policy Impacts on Supplier Evaluation in Sustainable CLSC

Chapter 7 shows the impact of macro level political decision on the micro level decision making of a inner company by expressing the evaluation of key raw material suppliers to create a robust and sustainable CLSC. Related works are also included as Appendix.

7.1 Introduction

Any organizations, today, which wants to stay competitive, must satisfy customers' demand and obey the environmental legislation and follow a sustainable approach. Sustainability includes not only economic side of a project but also environmental and earth issues. It is a fact that environmental issues and then protection and enhancement of the human and natural resources will be needed in near future are cross-boundaries ranging from companies to customers, suppliers, competitors, the community. REACH and RoHS environmental legislation issued by EU are prevailing all over the world related to sustainability problem of companies. When considered from this point of view, supplier selection and evaluation is recognized as a critical decision phase of project management related to closed loop supply chain (CLSC), which is a long term project for companies. Because reliable vendors can help their manufacturer partners to reduce approximately 70% of total costs and to design, produce products having regard to environmental issues, it is perceptible that firstly selection and then evaluation of appropriate suppliers in a certain time period are key factors in raising satisfaction of each part of the closed loop supply chain, so it affects the competitiveness and the sustainability of the companies.

7.2 Problem Statement for Policy Impacts on Supplier Evaluation

The major policy making issues have two dimensional effects; first dimension is the impact on the overall CLSC decisions such as tactical and strategic steps of the organizations. Second dimension is related to the impact on minor policies related to the inner side of organizations such as some of the key business partnerships are still available or convenient for the evolving conditions. The discussion creates a new issue; evaluation of the stakeholders in CLSC to keep up with conditions of the policy changes. Suppliers of raw / recycled, reusable material are the strat point of the success in the CLSC which is the first step of CLSC. Thus, in this part, the evaluation related to the uncertain environment for business in a still evolving condition , the suppliers situation are described as a must- check topic. The uncertainty make the author to use Fuzzy Logic and the author would like to compare the new methodology named Grey Relational Analysis which takes place in literature lately. It has a similar usage but the nature of data may be different.

7.3 Methodology

7.3.1 Hybrid Grey Relational Analysis (HGRA)

Grey relational analysis (GRA) is a part of Grey System Theory, which is suitable for solving problems with complicated interrelationships between multiple factors and variables (Moran et al., 2006). It uses the Grey relational grade to measure the relational degree of criteria. GRA possesses the merit of point set topology and such as the global comparison between two sets of data is undertaken instead of local comparison by measuring the distance between two point. The steps of GRA are shown in Figure 7.2.

1. Referential series and compared series: If there are m alternatives and n criteria, the i th alternative can be expressed as $Y_i = (y_{i1}, y_{i2}, \ldots, y_{ij}, \ldots, y_{in})$ where y_{ij} is the performance value of criteria j of alternative i.

   Y_2 =(1,01,01,5,5,9,5,15,6,10,10,7,5,7,7,5,1.5,5,9,7,9)
   Y_3 =(5,5,5,5,5,7,7,15,6,5,5,7,10,7,7,10,2.5,10,7,7,7)
   Y_4 =(5,10,5,5,15,7,5,15,5,5,5,7,5,7,5,7,7,5,1.5,10,7,7,7)
   Y_5 =(5,5,5,5,10,9,10,15,6,10,10,9,10,9,9,10,0.5,10,9,7,7)
   Y_6 =(1,5,5,1,5,9,10,15,6,10,10,9,10,9,9,10,0.5,10,9,7,7)

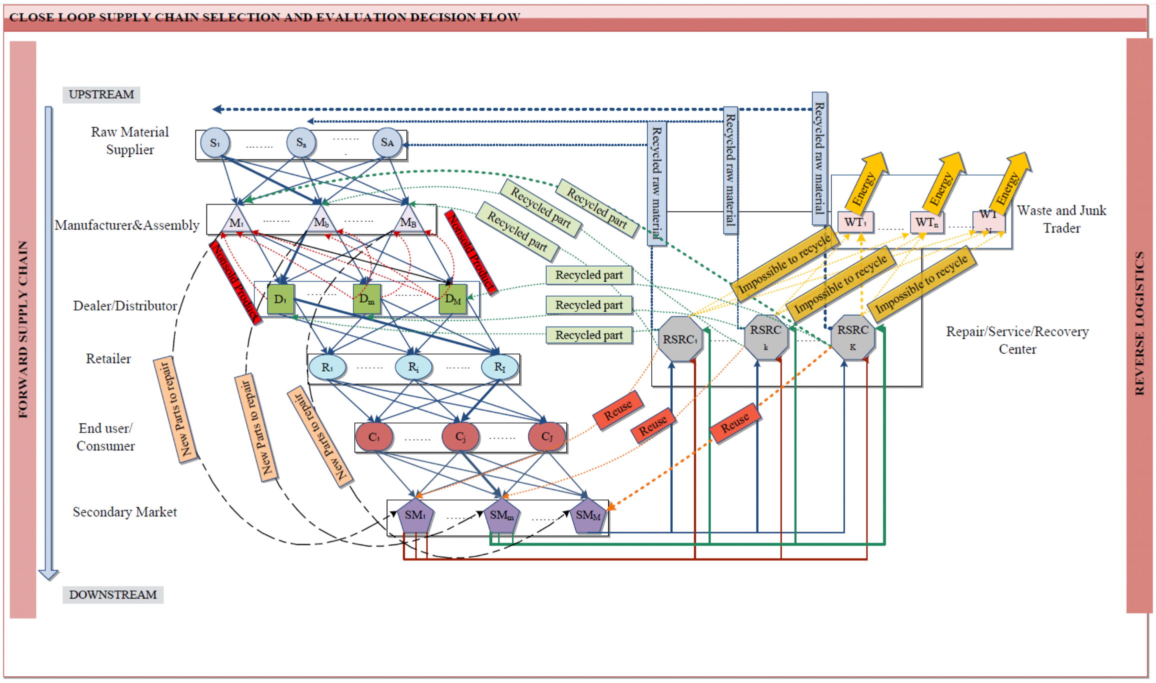

Figure 7.1: A General Decision Model for Closed Loop Supply Chain

And then to normalize the data, referential series

Y_{min} =(1,5,1,1,5,5,3,1,2,1,5,3,1,3,5,1,0.5,5,3,3,3)

and

Y_{max} =(10,10,10,10,10,15,9,10,6,10,15,7,10,9,9,10,6,10,9,5,9) should be used.

For other two raw materials' supplier evaluation procedure, referential series other raw can be written at the same way. The term of Y_i can be translated into the comparability sequence $X_i = (x_{i1}, x_{i2}, \ldots, x_{ij}, \ldots\ldots, x_{in})$ by using one of the formulas given is Step 2 according to the characteristics of the critera. Referential serie X_0 is defined as $X_0 = (x_{01}, x_{02}, \ldots, x_{0j}, \ldots, x_{0n})$.

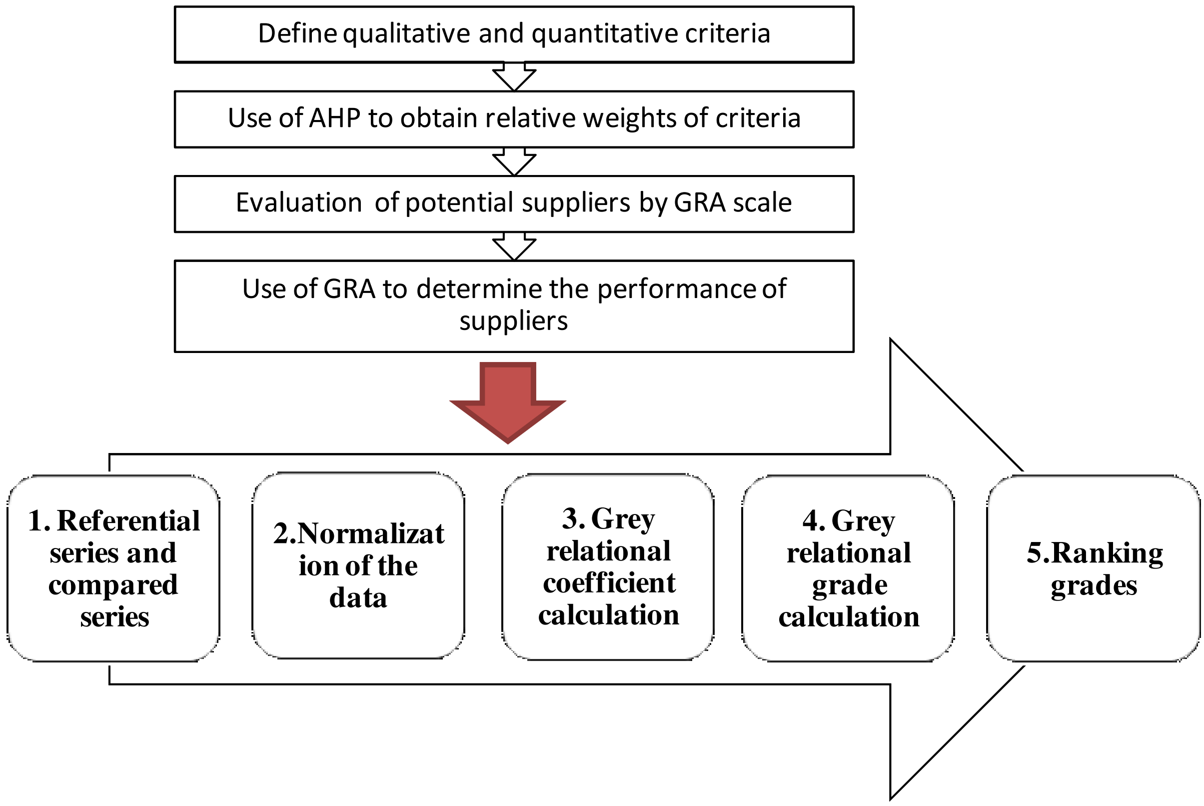

Figure 7.2: Steps of Grey Relational Analysis

2. Normalization of the data: Processing all criteria values for every alternative into a comparability sequence in a process analogous to normalization, is necessary. This processing is called Grey relational generating in GRA.

   If the expectancy for the criteria is larger-the-better, it can be calculated by the following formula:

$$x_{ij}=\frac{y_{ij}-\min y_{ij}}{\max y_{ij}-\min y_{ij}} \tag{7.1}$$
$$i=1,2,3\ldots,m \quad j=1,2,3,\ldots,n$$

   If the expectancy for the criteria is smaller-the-better, it can be calculated by the following formula:

$$x_{ij}=\frac{y_{ij}-\min y_{ij}}{\max y_{ij}-\min y_{ij}} \tag{7.2}$$
$$i=1,2,3\ldots,m \quad j=1,2,3,\ldots,n$$

   If the expectancy for the criteria is the closer –to-the-desired-value (y_j^*)-the-better, it can be calculated by the following formula:

$$x_{ij}=\frac{\left|y_{ij}-y_j^*\right|}{\max\{\max y_{ij}-y_{ij}^*;y_{ij}^*-\min y_{ij}\}} \tag{7.3}$$
$$i=1,2,3\ldots,m \quad j=1,2,3,\ldots,n$$

   The series data in this study, can be treated using two approaches: larger better and smaller better. It is explained completely which criterion's characteristic is larger better and which one's smaller better. The calculations of normalization should be done according to equation which fits to the characteristics of criterion x_{ij}^* means that characteristic of criterion is smaller better and equation (1) is used for normalization x_{ij} that characteristic of criterion is larger better and equation (2) is used for normalization.

   Normalization calculations are given below for raw material Cooper as an example:

$$\begin{array}{lll}
x_{1\,1}^*=\frac{5-1}{5-1}=1 & x_{1\,2}=\frac{10-5}{10-5}=1 & x_{1\,3}^*=\frac{10-10}{10-5}=0\\
x_{1\,4}=\frac{10-10}{15-10}=0 & x_{1\,5}=\frac{9-7}{9-7}=1 & x_{1\,6}=\frac{10-5}{10-5}=1\\
x_{1\,7}=\frac{5-1}{6-1}=0.8 & x_{1\,8}^*=\frac{9-7}{9-1}=0.25 & x_{1\,9}=\frac{2.5-0.5}{6-0.5}=0.36\\
x_{1\,10}=\frac{5-1}{9-1}=0.5 & x_{1\,11}=\frac{7-1}{9-1}=0.75 & x_{1\,12}=\frac{9-7}{9-7}=1
\end{array}$$

   The calculations show that the referential series X_0 = (1,1,1,1,1,1,1,1,1,1,1,1).

3. Grey relational coefficient calculation: Grey relational coefficient is used for determining how close x_{ij} is to x_{0j}. The larger the grey relational coefficient, the closer x_{ij} and x_{oj} are. The grey relational coefficient can be expressed as $\gamma(x_{0j},x_{ij})$ between x_{ij} and x_{oj} and calculated by using the formula given below.

$$\gamma(x_{oj}, x_{ij}) = \frac{\Delta_{min} + \varphi\Delta_{max}}{\Delta_{ij} + \varphi\Delta_{max}} \tag{7.4}$$
$$i = 1, 2, 3 \ldots, m \quad j = 1, 2, 3, \ldots, n$$

$$\Delta_{ij} = |x_{oj} - x_{ij}|, \Delta_{min} = \min \Delta_{ij}, \Delta_{max} = \max \Delta_{ij}$$

ψ is the distinguishing coefficient, $\psi \in [0, 1]$ the value of distinguishing coefficient can be adjusted by the decision maker but in literature $\psi = 0,5$ is commonly used, so in this study value of coefficient $= 0,5$ is used. For Copper suppliers the Grey relational coefficient calculation solutions are given below,

$$\gamma(x_{o1}, x_{1\,1}) = \frac{0 + 0.5 \times 1}{1 + 0.5 \times 1} = 0.33$$
$$\gamma(x_{o12}, x_{1\,11}) = \frac{0 + 0.5 \times 1}{0 + 0.5 \times 1} = 1.00$$
$$\gamma(x_{o12}, x_{1\,21}) = \frac{0 + 0.5 \times 1}{0 + 0.5 \times 1} = 1.00$$

4. Grey relational grade calculation: The final step to calculate the grade of the grey relational coefficient Γ_{0i} by using the equation below.

$$\Gamma_{0i} = \sum_{k=1}^{n} w_i(k) \times \gamma_{0i}(k)$$

In this equation, $w_i(k)$ is the weight of each criterion, which can be assigned by experts or which can be calculated by using some approaches such as AHP, ANP and other weight computable approaches?

In hybrid grey relational analysis, all of the procedure and the formulas are the same with grey relational analysis. But only at final step; in equation of grey relational grade calculation, $w_i(k)$ values which are the weights of criteria are calculated in procedure of Analytic Hierarchy Process or by using other weight computable approaches.

For example, Copper suppliers the Grey relational grade calculation is given below;

$$\Gamma_{01} = (0.077 \times 0.33 + 0.041 \times 1 + 0.03 \times 1 + 0.016 \times 1 + \ldots + 0.0189 \times 1) = 065$$
$$\Gamma_{06} = (0.077 \times 0.33 + 0.041 \times 0.33 + 0.0301 \times 0.33 + 0.0106 \times 0.33 + \ldots + 0.0189 \times 0.33) = 083$$

According to GRA, the alternative with the highest Grey relational grade is the most important (or optimal) alternative. Therefore, in this study, the priorities of potential suppliers can be ranked in accordance with the grey relational grade values because the relative weights (W_i) of evaluative criteria are determined by using AHP.

The priority of the six supplier for copper, in accordance with their grey relational grades is $CS1 = 0.65$, $CS2 = 0.60$, $CS3 = 0.56$, $CS4 = 0.47$, $CS5 = 0.68$ and the last one $CS6 = 0.83$,so the ranking order is $CS6 > CS5 > CS1 > CS2 > CS3 > CS4$.

7.3.2 Fuzzy Logic Integrated AHP (FLI AHP)

The procedure for determining weights of the evaluation criteria and performance values for alternatives is shown in Figure 7.3

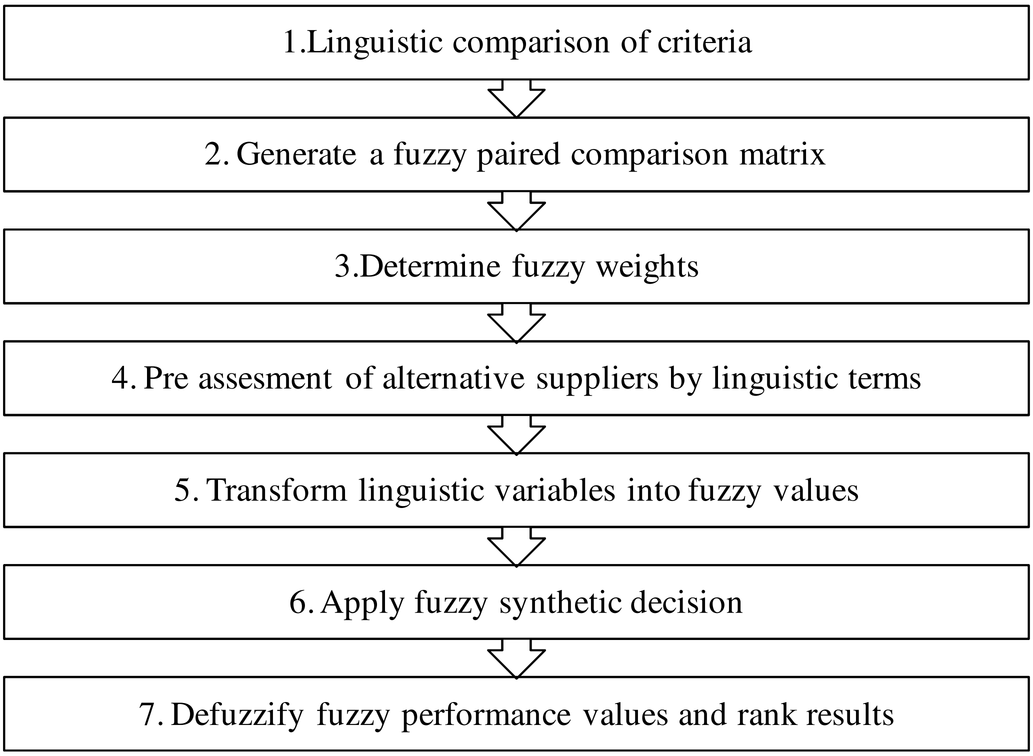

Figure 7.3: The procedure of Fuzzy Logic integrated AHP adapted from (Sun, 2010)

These steps can be summarized as follows:

Step 1: It is used to compare evaluation criteria by five basic linguistic terms, as “absolutely important,” “very strongly important”, “essentially important,” “weakly important” and “equally important” with respect to a fuzzy five level scale (Table 7.1). According to the formulated structure of suppliers’ evaluation, the weights of the criterion hierarchy can be analyzed. Decision making group contains two manager; purchasing department manager and quality management manager and two assistant expert. Weights were obtained by using the Fuzzy Logic Integrated AHP method, then the weights of each decision maker and average weights were derived by geometric mean method (Buckley, 1985).

Step 2: Generate a fuzzy paired comparison matrix for all criteria: Construct pairwise comparison matrices among all criteria in the dimensions of the hierarchy system. Assign linguistic terms to the pair wise comparisons by asking which one is the more important of each two criteria.After applying fuzzy numbers to see each decision makers’ evaluations, the elements of synthetic pair wise comparison matrix can be computed by using the geometric mean method by using equation;

Table 7.1: Scale of fuzzy numbers of linguistic scale for measuring weights of criteria

Fuzzy Number	Linguistic Scales	Scale of Fuzzy Number	Reciprocal
$\tilde{1}$	Equally important	(1 1 3)	(0.33, 1 ,1)
$\tilde{3}$	Weakly important	(1 3 5)	(0.2, 0.33, 1)
$\tilde{5}$	Essentially important	(3 5 7)	(0.14, 0.2, 0.33)
$\tilde{7}$	Very strongly important	(5 7 9)	(0.11, 0.14, 0.2)
$\tilde{9}$	Absolutely important	(7 9 9)	(0.14, 0.11, 0.11)

$$\tilde{a}_{ij} = \left(\tilde{a}^1_{ij} \otimes \tilde{a}^2_{ij} \otimes \tilde{a}^3_{ij} \otimes \tilde{a}^4_{ij}\right)^{\frac{1}{4}} \tag{7.5}$$

For $\tilde{a}_{1\,2}$ as an example;

$$\tilde{a}_{12} = \left((1,1,3) \otimes \left(\frac{1}{9},\frac{1}{9},\frac{1}{7}\right) \otimes \left(\frac{1}{9},\frac{1}{9},\frac{1}{7}\right) \otimes \left(\frac{1}{9},\frac{1}{9},\frac{1}{7}\right)\right)^{1/4} = (19,23,39)$$

It can be obtained for the other matrix elements by the same computational procedure, therefore, the synthetic pair wise comparison matric of the four representatives can be constructed.

Step 3: Determine fuzzy weights of each criterion: Geometric mean is one of the techniques is used to define the fuzzy geometric mean and fuzzy weights of each criterion by using the equation shown below;

$$\tilde{r}_i = \left(\tilde{a}_{i1} \otimes \tilde{a}_{i2} \otimes \ldots\ldots \otimes \tilde{a}_{in}\right)^{1/n} \tag{7.6}$$

$$\tilde{w}_i = \tilde{r}_i \otimes \left(\tilde{r}_1 \otimes \tilde{r}_2 \otimes \ldots\ldots \otimes \tilde{r}_n\right)^{-1} \tag{7.7}$$

where $\tilde{a}_{in}$ is fuzzy comparison value of criterion i to criterion n and $\tilde{r}_i$ is geometric mean of fuzzy comparison value, $\tilde{w}_i$ is the fuzzy weight of criterion i. $\tilde{w}_i = (Lw_i, Mw_i, Uw_i)$. So here Lw_i, Mw_i, Uw_i stand for the lower, middle and upper values of the fuzzy weight of criterion i.

To use (7) to obtain the fuzzy weights of main evaluation criteria $\tilde{r}_1$ as an example that calculation is shown;

$$\tilde{r}_1 = \left(\tilde{a}_{11} \otimes \tilde{a}_{12} \otimes \tilde{a}_{13}\right)^{\frac{1}{3}} = (0.589,\ 0.721,\ 1.302)$$

$$\tilde{r}_2 = \left(\tilde{a}_{21} \otimes \tilde{a}_{22} \otimes \tilde{a}_{23}\right)^{1/3} = (1.916, 2.510, 3.232)$$

$$\tilde{r}_3 = (\tilde{a}_{31} \otimes \tilde{a}_{32} \otimes \tilde{a}_{33})^{1/3} = (0.511, 0.748, 1.027)$$

$$\tilde{r}_4 = (\tilde{a}_{41} \otimes \tilde{a}_{42} \otimes \tilde{a}_{43})^{1/3} = (0.403, 0.740, 0.995)$$

For the weight of each main criteria, calculations as follow can be done by using (8);

$$\tilde{w}_1 = \tilde{r}_1 \otimes (\tilde{r}_1 \otimes \tilde{r}_2 \otimes \tilde{r}_3 \otimes \tilde{r}_4)^{-1} = (0.09, 0.153, 0.381)$$

$$\tilde{w}_2 = \tilde{r}_2 \otimes (\tilde{r}_1 \otimes \tilde{r}_2 \otimes \tilde{r}_3 \otimes \tilde{r}_4)^{-1} = (0.292, 0.532, 0.945)$$

$$\tilde{w}_3 = \tilde{r}_3 \otimes (\tilde{r}_1 \otimes \tilde{r}_2 \otimes \tilde{r}_3 \otimes \tilde{r}_4)^{-1} = (0.078, 0.158, 0.300)$$

$$\tilde{w}_4 = \tilde{r}_4 \otimes (\tilde{r}_1 \otimes \tilde{r}_2 \otimes \tilde{r}_3 \otimes \tilde{r}_4)^{-1} = (0.61, 0.157, 0.291)$$

To employ the Center of Area method to compute the Deffuzified Performance Value (DPV) of the fuzzy weights of each criteria, , the calculation process is as follows, As an example, the calculation of the fuzzy weights for main criteria process for Copper suppliers is shown below.

$$DPV_{w_i} = \frac{[(U_{w_i} - LR_{w_i}) + (MR_{w_i} - LR_{w_i})]}{3} + LR_{w_i}$$

$$DPV_{w_1} = \frac{[(U_{w_1} - LR_{w_1}) + (MR_{w_1} - LR_{w_1})]}{3} + LR_{w_1}$$

$$= \frac{[(0.166 - 0.075) + (0.094 - 0.075)]}{3} + 075 = 208$$

Similarly, the weights for the remaining criteria and the final DPV_{wi} values can be found as shown below:

$$DPV_{w_2} = 0.590$$

$$DPV_{w_3} = 0.179$$

$$DPV_{w_4} = 0.170$$

Step 4: Evaluate alternatives by linguistic terms: By using the measurement of linguistic variables decision makers demonstrate the criteria performance for each alternative by expressions such as very good, good, fair, poor, very poor. (Table 7.2)

Step 5: Transform linguistic variables into fuzzy values: Each linguistic variable can be defined by a triangular fuzzy number within a scale of [0,100].Fuzzy performance evaluation for a decision maker can be shown by $\tilde{E}^k_{ij} = (LE^k_{ij} ME^k_{ij} UE^k_{ij})$. If there is more than one evaluator (m evaluator), fuzzy performance value $\tilde{E}_{ij}$ is calculated by using the equations given below;

Table 7.2:Scale of fuzzy numbers of linguistic scale for measuring performance of alternatives

Table 7.2: Scale of fuzzy numbers of linguistic scale for measuring performance of alternatives

Very poor	(0 0 10)
Poor	(10 25 40)
Fair	(30 50 70)
Good	(60 75 90)
Very Good	(80 100 100)

$$\tilde{E}_{ij} = {}^{1}\!/_{m} \otimes (\tilde{E}_{ij}^{1} \oplus \tilde{E}_{ij}^{2} \oplus \ldots\ldots \oplus \tilde{E}_{ij}^{m}) \tag{7.8}$$

$$\tilde{E}_{ij} = (LE_{ij}, ME_{ij}, UE_{ij})$$

$$LE_{ij} = \left(\sum_{k=1}^{m} LE_{ij}^{k}\right) \Big/ m$$

$$ME_{ij} = \left(\sum_{k=1}^{m} ME_{ij}^{k}\right) \Big/ m$$

$$UE_{ij} = \left(\sum_{k=1}^{m} UE_{ij}^{k}\right) \Big/ m$$

where $k = 1, 2, \ldots, m$

As an example, for Copper suppliers' transformation of linguistic variables to fuzzy values is given. These expressions can obtained to the fuzzy performance matrix by using equation

$$LE_{11} = \left(\sum_{k=1}^{2} LE_{11}^{k}\right) \Big/ 2 = \frac{30+30}{2} = 30$$

$$ME_{11} = \left(\sum_{k=1}^{2} ME_{11}^{k}\right) \Big/ 2 = \frac{50+50}{2} = 50$$

$$UE_{11} = \left(\sum_{k=1}^{2} UE_{11}^{k}\right) \Big/ 2 = \frac{70+70}{2} = 70$$

Average fuzzy performance value for copper can be shown as $\tilde{E}_{11} = (E_{11}, ME_{11}, UE_{11}) = (30, 50, 70)$.

Step 6: Apply fuzzy synthetic decision: The weights of each criterion to find the performance evaluation values of alternatives', weight vectors of criteria $\tilde{w}_j = (\tilde{w}_1, \tilde{w}_2, \ldots, \tilde{w}_n)$ which is derived by Fuzzy integrated AHP and the fuzzy performance matrix of alternatives under n criteria $\tilde{E} = (\tilde{E}_{ij})$ must be conducted to find fuzzy synthetic decision matrix $\tilde{R}_I$ of alternatives. This calculation can be done by using equation $\tilde{R}_i = \tilde{w}_j \odot \tilde{E}_{ij}$ where $\odot$

indicates operation of fuzzy addition and fuzzy multiplication. After calculation, fuzzy synthetic decision value as a fuzzy number of each alternative matrix is composed.

$$\tilde{R}_i = (LR_I, MR_I, UR_I) \tag{7.9}$$

$$LR_i = \sum_{i=1}^{n} LE_{ij} \times Lw_j \tag{7.10}$$

$$MR_i = \sum_{i=1}^{n} ME_{ij} \times Mw_j \tag{7.11}$$

$$UR_i = \sum_{i=1}^{n} UE_{ij} \times Uw_j \tag{7.12}$$

$$i = 1, 2, \ldots, t; j = 1, 2, \ldots, n$$

where $\tilde{E}_j = (Lw_j, Mw_j, Uw_j)$ and $\tilde{E}_{ij} = (LE_{ij}, ME_{ij}, UE_{ij})$ are given above.

From the criteria weights obtained by FAHP and the average fuzzy performance values of each criterion of experts for each alternative, the final fuzzy synthetic decision step can then be processed. To take the fuzzy synthetic decision value of alternative for copper as an example, equation (11) and (12),(13) and (14) is used to obtain this value as follows:

$$\tilde{R}_1 = ((80{\times}03{+}\ldots\ldots{+}50{\times}016), (100{\times}068{+}\ldots\ldots{+}667{\times}064), (100{\times}2{+}\ldots\ldots{+}833{\times}143))$$

$$\tilde{R}_1 = (11.718, 70.028, 385.624)$$

Similarly, the final fuzzy synthetic decision step then can be processed as illustrated below:

$$\tilde{R}_2 = (11.62, 67.35, 377.57)$$

$$\tilde{R}_3 = (8.95, 58.53, 345.355)$$

$$\tilde{R}_4 = (10.266, 63.19, 363.411)$$

$$\tilde{R}_5 = (13.36, 79.75, 410.38)$$

$$\tilde{R}_6 = (14.99, 85.76, 424.318)$$

Step 7: Rank fuzzy performance values and defuzzify results of each alternative: The result of the fuzzy synthetic decision step, reached by each alternative is a fuzzy number. A defuzzify ranking method is necessary for fuzzy numbers to be employed for comparison of each alternative. At this last step, main idea is to apply procedure of defuzzification to locate the defuzzified performance value of alternatives. Methods of such defuzzified fuzzy ranking generally include mean of maximal, center of area and α-cut. To utilize the Center of Area method to find out the defuzzified performance score (DPV) a simple and practical method, and there is no need to bring in the preferences of any evaluators which in α-cut method there is a need to consider preferences, so it is used in this study. The DPV value of the fuzzy number $\tilde{R}_i$, can be found by the following equation:

$$DPV_i = \frac{[(UR_i - LR_i\,) + (MR_i - LR_i)]}{3} + LR_i \tag{7.13}$$

According to the value of the derived DPV for each of the alternatives, the ranking of each alternative can then be proceeded. Next, the process is shown to find out each suppliers' DPV value as follows and as an example for copper suppliers' DPV value is calculated by using equation (15)

$$DPV_1 = \frac{[(UR_1 - LR_1\,) + (MR_1 - LR_1)]}{3} + LR_1$$

$$= \frac{((256.51 - 19.12\,) + (84.62 - 19.12))}{3} + 1912 = 15578$$

At the final step, ranking fuzzy performance values and to defuzzified results of each alternative can be processed as illustrated below:

$$DPV_2 = 15218$$

$$DPV_3 = 13761$$

$$DPV_4 = 145627$$

$$DPV_5 = 16783$$

$$DPV_6 = 175023$$

7.4 Illustrative Example

To realize sustainable project management in supply chain, a general methodology is improved for supplier evaluation problem of the company. This evaluation methodology should be extended and applied to all phase of the developed decision model for close loop supply chain to reach expected results. To keep track of performance level of the ERP project and the results for the developed supply chain model, each layer should evaluate performances of former one which could provide raw material, parts, service or logistic .The company produces halogen free cables, medium voltage cables, high voltage cables, copper conductor.

To be able to manufacture these products there are many raw materials need to be bought from various suppliers. Three main raw materials is very crucial for production in cable manufacturing industry; Copper, PVC and DOP chemical. Copper is the vital point of cable industry in whole companies so there is a great competition among suppliers and producers. PVC, DOP chemical and especially copper market is so non-stable and suppliers must be checked too often to be able to lower raw material costs. For supplying copper, the company makes business partnership with six suppliers. (CS1, CS2, CS3, CS4, CS5, CS6).For supplying PVC, the company makes a business partnership with seven suppliers. (PS1, PS2, PS3, PS4, PS5, PS6, PS7)For supplying DOP chemical, the company makes a business partnership with five suppliers. (sDS5, DS2, DS3, DS4, DS5).

In supply chain of the company, purchasing department and quality management department is responsible for selecting and evaluating suppliers which provides raw materials to use in production. The current procurement system cannot respond the whole needs of the company. According to the ERP project aims, purchasing department is supposed to monitor their suppliers closely to keep their aims alive and applicable. To make the company goals applicable and sustainable, in current procurement system of the company, three main and twelve performance sub criteria were used. After a literature review about which supplier evaluation criteria can be used in cable, telecommunication, electronic component industry and brainstorming with two responsible department manager ,one new main criteria, plus with three sub criteria and nine new criteria addition to current main criteria is decided to be added in as a performance evaluation criteria for new evaluation model.

To demonstrate the hybrid GRA model in this supplier evaluation problem, the suppliers were considered as alternatives i, whereas evaluative factors were viewed as criteria j for each alternative. According to the grey information principle in Grey system theory, to calculate suppliers performance value for each criterion, a scale that is special to each criterion, is developed by searching literature and brainstorming with department managers. The sub criteria that had the characteristic of "larger better" are frequency of price increase requirement from price performance main criteria , Sending order confirmation, On time delivery, Appropriate packing, Meeting requirements of delivery contract from delivery performance main criteria and Product development, Process development, Quality planning, Inspection and experimental studies, Quality audit results, Environmental audit results, After sales support, Success in R&D tests and approval for new material from quality performance main criteria, and the last one, all of the sub criteria in company profile main criteria. Then the sub criteria that had the characteristic of "smaller better" are price afford-ability, Room for negotiation from price performance main criteria, Meeting requirements of order quantity, Sending order confirmation from delivery performance main criteria and the last one Raw material entrance quality return rate from quality performance main criteria.

How to Use HGRA and FLI AHP

According to the relation between the impact of policies on supplier evaluation and the methods, the predefined methodologies are discussed.The application of these methods are useful for such discussion. Fuzziness will help to deal with uncertainty for the future expectations of policy making stakeholders. Grey relational analysis also The Grey theory can provide a solution of a system in which the model is unsure or the information is incomplete. It also provides an efficient solution to the uncertainty,multi-input and discrete data problem. A fuzzy number is defined on the universe as a convex and normalized fuzzy set. Its membership function is piecewise continuous and it is defined in the real numbers. Also a fuzzy number may be considered with a flat in the set of integers. Fuzzy numbers can be named according to their different membership function types. In this study triangular fuzzy number is used to solve supplier evaluation problem.

To demonstrate the hybrid GRA model in this supplier evaluation problem, the suppliers were considered as alternatives i, whereas evaluative factors were viewed as criteria j for each

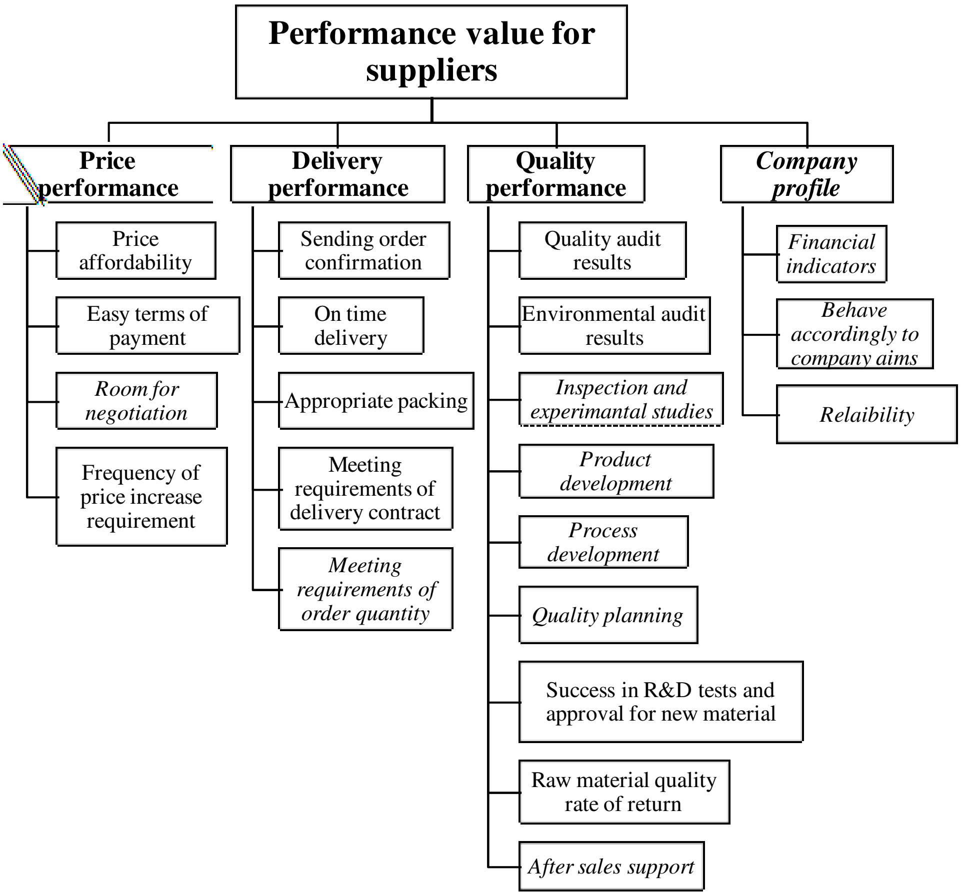

Figure 7.4: Criteria used in the evaluation process

alternative. According to the grey information principle in Grey system theory, to calculate suppliers performance value for each criterion, a scale that is special to each criterion, is developed by searching literature and brainstorming with department managers. The scale is shown in Appendix A. The sub criteria that had the characteristic of ?larger better? are frequency of price increase requirement from price performance main criteria , Sending order confirmation, On time delivery, Appropriate packing, Meeting requirements of delivery contract from delivery performance main criteria and Product development, Process development, Quality planning, Inspection and experimental studies, Quality audit results, Environmental audit results, After sales support, Success in R&D tests and approval for new material from quality performance main criteria, and the last one, all of the sub criteria in company profile main criteria. Then the sub criteria that had the characteristic of ?smaller better? are price affordability, Room for negotiation from price performance main criteria, Meeting requirements of order quantity, Sending order confirmation from delivery performance main criteria and the last one Raw material entrance quality return rate from quality performance main criteria.

AHP approach?s results found by using new proposed system with new nine sub criteria and one main criterion. The FAHP approach ranks the importance to raw material suppliers of the various criteria used to compare desirability of them. For proposed evaluation framework, four main criteria and twenty one sub criteria are used. According to the overall ranking calculations depends on AHP, Quality planning ranks first, Quality audit results ranks second, Environmental audit results ranks third. Criterion which has the lowest importance weight is Sending order confirmation.

7.5 Conclusion

In this chapter, two integrated approaches has been formulated and applied to a energy sector company to examine its feasibility in evaluating the three absolute must and causing most percent of cost raw material (Copper, DOP, PVC) suppliers' performance in aspect of project management. First method is Hybrid Grey Relational Analysis and this integrated model is very flexible and more mathematical analysis of the decision making systems, for example; using the AHP can reflect weights of criteria, it is suitable to deal with take account into both qualitative and quantitative factors and adding new criteria and changing weight of them can be included to the easily to the suggested model and examines the analysis if there are discrete and insufficient input data.. Second approach is Fuzzy Logic integrated AHP. This integrated model uses linguistic expressions to determine performance scores. FAHP is very suitable and easy to apply for experts' assessments in fuzzy and complex decision making processes like MCDM problems. The Hybrid GRA approach ranks the importance to raw material suppliers of the various criteria used to compare desirability of them by using AHP method.

FAHP approach ranks the importance to raw material suppliers of the various criteria by using FAHP criteria weighting method. For proposed evaluation framework for Hybrid GRA model, four main criteria and 21 sub criteria are used. According to the overall ranking calculations depends on AHP, Financial indicators ranks first, Environmental audit results ranks second, Quality planning ranks third. Criterion which has the lowest importance weight is Sending order confirmation. For proposed evaluation framework for FAHP, four main criteria and twenty one sub criteria are used as the same like previous method. According to the overall ranking calculations, Quality planning ranks first, Quality audit results ranks second, Environmental audit results ranks third. Criterion which has the lowest importance weight is Sending order confirmation. It is obvious that ranking orders and importance level of evaluation criteria are nearly the same for both approaches.

According the performance score results for Copper suppliers, first, second, third and fourth supplier is the same with Hybrid GRA results but fifth supplier in Hybrid GRA is sixth in FAHP and sixth supplier is fifth in FAHP results ranking. In light of the results, total performance score of DOP chemical suppliers ranking is same with Hybrid GRA results DS5 is the first, then DS4, DS1, DS2 and the last supplier is DS3 which has the lowest performance score. For PVC suppliers, total performance score ranking is same with Hybrid GRA results. PS6 is the first, and then PS5, PS1, PS4, PS7, PS2 and the last supplier is PS3 which has the lowest performance score. In this study it is clear that performance score results of three raw materials' supplier for two approaches are nearly the same.

It is not easy to say which MCDM approach is more suitable, satisfactory and desirable for supplier selection and evaluation problem. The best thing is to apply several MCDM methods to the same problem, comparing the results and then making the final decision. Except Hybrid GRA and FAHP, other MCDM approaches can be applied for this study and it is better to see which differences occur. In order to follow sustainability goal for newly improved general closed loop supply chain model, this study could be taken as a reference to be able to evaluate performances of material, part, logistics or reuse and recycled component provider for each member of the CLSC.

Chapter 8

Discussion

Chapter 8 expresses the important and highlighted part of this thesis by the discussion of each chapters. Several results are representing the unique side of each research themes.

8.1 Motivation of This Thesis

The motivation to represent the studies in this thesis is firstly dealing with the sustainability issues especially considering the policy making part of the environmental problems. The author herself has found a gap between the problems discussed in literature and the logical solutions proposed. Those gaps makes her push to meet the needs of additional combinational research. Huge gap is generally related to the topic of the industry's situation in policy making both in macro level and micro level. Secondly, industry is generally considered the ruler but the author believe that it should not be separately considered and business is not the only one to be in the center of application of problem solution and stand to the pressure, but also it should be the element of the policy making as a stakeholder.

So, beginning from the sustainability argument, policy making is necessary to be discussed. The sustainability goals are requiring the mutual interaction and furthermore there is significant need for collaboration between any stakeholders. Thinking the each elements are separate and are not responsible from the others' decisions can not be considered in global world. Hence problems of interaction and considering that they are alone to find a solution does not work because the especially environmental side of the sustainability issues is still full of uncertain parts, undefined impacts, unclear problem solutions and there is not any perfectly successful implications in policy making side and the applicant side.

Considering all of the arguments and the problems which are expressed in the beginning of the thesis, following discussion is appropriate to express by the list given below;

1. Focus on policy making issues both macro level and micro level;

2. Explore the gap for the solution of environmental problems in industry by social and economic considerations to keep up the international and governmental laws pressure

3. Decision making for the reverse logistics side of the CLSC in the new business models which can be profitable through recycle management and the sustainable development

4. How to be ready for the future expectations of directives and the changes in national policies and be able to represent scenario generation mechanism

5. Defining the hidden details by criteria , sustainability and the functions of the CLSC

6. Promote sustainable procurement for rechecking the CLSC stakeholders in the new structure for the industry's own supply chain models

8.2 Discussion of Each Main Chapter

8.2.1 Defining Future Directions by Strategic Policy Making

Chapter 3 is the top of the research topic which explains the macro level discussions in strategic policy making. In global trade world, it is necessary to be ready for any move from all stakeholders which has impact on realization of their own goals. That is a problem which requires to understand each stakeholders tactics and their own steps against that tactic. In Chapter 3, the methodology "Evolutionary game theory" helped the visualize any kind of the possible strategies by into triangles and the colors and arrows in the triangle expresses that three stakeholders importance level for any criteria and the sustainability level can be understood clearly. As a result of that chapter the possible future directions of government's policies and international directives' and expression of strategic interaction between all stakeholders that depends on all agents' choices are discussed. The illustrative example is given to be clear how to use definition of the evaluation and the importance levels for what kind of sustainability issue and the criteria is considered. The main part in that research is to be able to create any kind of conditions for current situation and expected future. The industry has a current opinion and the expectations from the future and also the other two stakeholder have similar conditions. However, the time scale and the different goals of them make the policy making process and the impact of that complicated. The result of this process has many options. In that research, dominance stakeholder is considered to have right and power to pick the most applicable policy decision and the others should obey and take a step according to the dominant one. This reasearch is important because in future is never clear and they should have idea abut any possibility and dominance conditions regarding to the mutual interactions..

8.2.2 Political Decisions, the Impact on Business Sustainability- Macro Level Policy Making Strategies

According to the definition of future directions of each stakeholders in Policy making, Chapter 4 proposed a unique matrix study and the relation between the all possible results and the analytical mathematical programming for CLSC end of life product flow structure is discussed. The author believe that, Unified Relation Matrix is simply applicable to define any kind of expectations and the possibilities regarding to the predefined criteria given on the top of the matrix. Furthermore; author thinks that the matrix visualize the most common hidden but also important policy making issues b a matrix and creating the structure by that results easily is now applicable through the mathematical modeling.

Unified Relation Matrix is easy to be used but at the same time, it is open to the changes on defining new criteria and addition of new functions or changes in the CLSC. The literature has several research for the explanation how o define the relation between three legs sustainability, the criteria may have effects and the functions of the industry. This matrix is one of the answer and visual guide to set clear goals and see the future options and how much each stakeholders cares of criteria and sustainability goals in name of CLSC function. Furthermore, the evaluation result or even the intervals is clearly used to shape network flows of industry by setting three objectives ; social development; economic development and decreasing environmental impact. Also should be noted that macro level policy making issues is in progress in that chapter, and the Unified Matrix is discussing the crossing center of macro level policy making through the micro policy making issues by the functions of CLSC.

8.2.3 Restructure of Reverse Logistic Side of CLSC in Auto Industry- Effects of Macro Level Policies

In Chapter 5 the impact of the all possible political decisions related to the end of life products is discussed by defining the logistic model of used parts and the management of trade between dismantling centers. As a result of the governmental policies considering the limitations for CO emissions, recycling targets, or restricted materials are pushed the industries to recheck their supply chain. They can not keep their structure as it is because of traditional supply chain are not mainly include the reverse logistics into their structure but as a different part. However, recently, the reverse logistic are considered to be the one of the main inner part of supply chains and the restructuring should be made through the possible expectations of policies. The result of this chapter is visualization of the possible structures regarding to the feasible and the optimum solutions based on the cost objective. In literature, there are many research dealing with the reverse logistic issues in supply chain management in operational stage, but however, this research is dealing with the restructuring problem in tactical stage. The change in network is a strategic decision and the pressure from the environment is one of the drivers. National and international regulations may be named as the resource of pressure.

In that chapter, cost is the objective to define new flows or delete some of the flows in reverse logistic. Main target is minimizing the waste and the maximizing the profit by defining the results of policies which are represented by government. Recycling targets are the drivers of reconstructing the reverse logistic network. This chapter is the highlighted of the thesis because it opened new ways for the author to realize several issues related to the combination of network structure decisions and the sustainability movement. In that chapter, the macro policy making and the impacts of it on inner business issues take place but generally the network design decisions are reflecting the micro level decision making and still that is the result of the macro level policies.

8.2.4 Scenario Generation Mechanism Logically Considering Macro Level Policy Making

Chapter 6 are one of the most important part of this thesis. That chapter answers the question how to choose to appropriate structure according to the future expectations of government based on the tax system changes or the recycling level percentage changes.Feasibility and the optimality are the key factors. Creating the scenarios based on the several possible taxation and the definition of percentages for predefined reusable, recyclable or recoverable amount of main parts. The automobile industry is also key industry to lower the environmental impacts and the taxation system also important to control the society. So the hybrid and the electric cars' main engine parts such as battery, hybrid engine and the ordinary engine is discussed according to the several conditions for future definitions.

The highlighted part of this chapter is the representing all type of tax options exists now for the 3R activities. It may seem that the subsidy from the government is always the best option, however this is not realistic and that makes the industry and the society feel to have rights for extravagance. One of the main target is also decrease the usage of raw material and natural resources which are getting lower and lower by population growth and other many reasons. So, the other taxation options is checked for the feasible and the optimal solutions related to he changes in network design. As a result it can be said that, the cost of 3R activities and the transportation and the percentage level has great impact on network design.

8.2.5 Macro Level Policy Impacts Inner Company Strategies - Supplier Evaluation in Micro Level

Chapter 7 explains directly the inner impacts of macro level and the micro level policy changes on the CLSC structure and stakeholder decisions. The change in structure may cause the rechecking the contracted stakeholders in the supply chain. Some of the dealers, manufacturing or dismantling centers may not be appropriate anymore after the reconstruction. So in that point, supplier of the material gains importance to define the inner impact on the CLSC. In that chapter, evaluation of several key material supplier performance is discussed in a case study considering the environmental aims and the possible changes to keep up with policy changes. One of the highlighted part of this chapter is; accepting that the network design itself is a great step however is not still enough to have the robust CLSC without rechecking the performance of elements of the CLSC.

8.3 Overall Discussion

In Chapter 3, and 4, as an overall discussion, firstly, sustainability issues and the relation between the macro level policy making by the definition of the future strategies is discussed. Then, how to define the evaluation processes and the decisions for tactical issues regarding to the industry is discussed. In Chapter 5, after that in the micro level decision making which is inner company policies and the macro level issues are crossed each other. Creation f the reverse logistic side in the CLSC of auto industry and the several example parts are considered to be traded through flows which should be decided to continue or not. In chapter 6 the topic becomes a 3R activities and network structure analysis for that and development of scenario generation mechanism of macro level policy making and micro level decision making issues for the industry are discussed. Finally, the author wanted to show the macro level policy still have a great impact on strategic inner company decisions. To create a robust CLSC management, the stakeholders of it should be reconsidered and evaluated to be sure that they are still appropriate for their new CLSC aims or not.

Chapter 9

Summary and Conclusion

The final chapter **Chapter 9** summarizes the all research studies finalized through the thesis and conclude the results. For future recommendations, the author expressed several ideas and the way to develop this topic in future.

9.1 Conclusion of This Thesis

In *Chapter 1*, general explanation of the main topics are discussed. Overview of the sustainability, policy making, closed loop supply chain and the evaluations of CLSC stakeholders shown that all are related top to down to realize the aims. Sustainability and the policy making are the macro level decision making issues; and CLSC and the evaluations are the micro level decision making issues in this thesis.

Chapter 2 includes the Literature Review for all topics mentioned above and the contribution of this thesis for each subtopic is discussed. Problem statement is expressed as into five main problems;

- 1. Strategic policy making process to define possible future directions for all policy making stakeholders
- 2. Impact analysis of the political decision on the business sustainability and the affects on the objectives of companies
- 3. Construction of the reverse logistic side in CLSC by impact analysis of governmental policies.
- 4. Creation of scenario mechanism based on the possible political decisions and how to choose the appropriate one.
- 5. Micro level impacts of the policy making and the results of the rechecking of the CLSC structure and the evaluation of the suppliers

Chapter 3 defined the possible future directions of government's policies and international directives' related to the mini car strategies of auto industry considering Japan case. Objective of this research is expressing strategic interaction between government, international directives and industry that depends on all agents' choices. These interactions create many conditions and each of them makes a significant impact on auto industry's future strategies related to the mini car regulations. Current and future situations of each stakeholder is discussed and by evolutionary game theory the triangles made the all possible interactions and the explanation of that importance rates of the stakeholders are possible in this chapter.

In *Chapter 4* Strict policies related to the sustainability issues from the international directives and the governments are discussed here. Rapidly growing negative impacts on environment and new global trade conditions are defined that has a great impact on the industry. The main gap here was how to clarify the expectations and the solution which can make every stakeholder in a feasible solution. Therefore, business should be flexible to meet the revisions that affect industrial structures. This chapter explained the influence of regulations and policies on industries? strategic decisions simultaneously. As a solution, generic decision making strategy to represent scenario generation mechanism by Unified Matrix for Interactive Impacts structure which can define the relations between criteria and functions of closed-loop supply chain from planning to the 3R activities (Reuse, Recover, Recycle) level. is created. In this scenario generation mechanism, the results could be applicable in analytical solution methodology of mathematical modeling. The parameters coefficients and the weights of each objective function in model are related to the range of evaluation results. The coefficients are defined by the probable range of results considering the effects of stakeholders in each function and sustainability issues from unified matrix.

Chapter 5 provides a method for the construction of vehicle recycling logistics to improve reuse rate. Recycling concerns such as construction problems of recycling logistics of reuse part traders have attracted attention over the years. Therefore, this chapter express an optimal reverse logistics structure of the auto-industry to maximize the total profit of side traders.As a solution proporsal for the revere logistic side of a CLSC, a reverse logistics construction model of the auto-industry as a case study is presented, and a mathematic formulation is proposed from a win-win point of view. Finally, by using the analytical solution method of the LP problem, the optimal and feasible reverse logistics structure can be clarified based on the reused parts demand. Our results indicate that when the demand rate of companies is well-balanced, the cooperative distribution structure is the optimal logistics constructions; meanwhile, when the internal sourcing costs of related traders are zero (e.g. receiving subsidies from the government), the no cooperation distribution structure becomes optimal. This method is supporting to define the robust design of a company to represent the feasible and then the optimal structure and how to change the structure and creating new business partnership is also possible to understand.

Chapter 6 expresses that to create a sustainable growing business in a tricky and with full of harder global trade rules, effects and pressure on companies is important. Policies which are decided in order to reduce many negative effects are getting stricter to be sensitive about reverse logistics and recycle management of their own products. This study aims to represent selections and changes on constructions expressed in Chapter 5, regarding to several policy scenarios accordance with possible real case regulations of government. The main policies are expressed as cost of 3R activities where is necessary, cost of transportation and percentage rate relation between the hybrid car engine parts, ordinary car engine parts and electric car engine parts. Last part is unique in this thesis because this problem expresses a future problem which will take a great place in close time. So, different combinations fo these policies make the industry to choose a new and flexible reverse logistic network for their robust CLSC management.

In *Chapter 7*, the author discussed that environmental legislation in a macro level decision making has also have a significant impact for closed-loop supply chain management which is the micro level of the policy decisions inner side of the companies. Now it has become an important issue for global companies so we all know that not to be global is almost impossible recently. Hence, for a performance evaluation in CLSC, as it is easy to understand that the key point is always the start point of CLSC; supplier evaluation and then if necessary cancellation of contract and selecting the new suppliers. That phase in CLCS is one of the crucial decision point not only for QCD but also environmental impacts. As well as choosing the suppliers to work with is one of the key points of sustainable development for company and reflecting expectations of government and international directives as well. So, annually evaluation is very important to keep track of vendors? performance level to be successful on sustainable development. In this chapter author define several criteria due to their firm culture, aim and mission. There are various approaches to determine performance level of suppliers. This chapter presented a supplier evaluation method for sustainable closed-loop supply chain management and aims to create a model to help evaluating suppliers by using hybrid grey relational analysis for a firm in cable industry (case study). To be developed model is compared with hybrid fuzzy logic and AHP model. Results identify the current status of suppliers to keep track on sustainability of outsourcing success in CLCS network. As result, the company has three main raw materials and there are many suppliers for them. According to this chapter, the company may now have a great power to evaluate their suppliers regarding to any kind of criteria they want to use or any method by choosing their aims.

9.2 Future Recommendations

This thesis aimed to defined a unique problem statement which has a gap between the impact analysis of political decision on industry and the methods to express this issues in academia and society as well. The author started the research considering the resurrecting of CLSC of industry but also in further steps, she realized that the sustainability and the political decisions are the pioneer drivers of this problem. So, this thesis is one of the few research try to present the relation between these three aspects.

For future, there are still remaining issues of course. The fast changing global conditions is not stopping and it seems that will be more and more fast so, that will have more great pressure on industries from the thesis topics point of view. Business programs and the environmental programs are always considered separately and the collaboration between the other industries related to the environmental programs is totally necessary because these issues is not the responsibility of a single company or a single industry . They may find many great opportunities while collaborating to solve environmental problems also. This topic is related to the Shared Values philosophy, and I may recommend the researchers to find the unique contacts inter companies related to change this messy problem into a great opportunity.

9.3 Published Papers related to This Thesis

This thesis is based on the author's papers shown below in published order.

No.	Chapter, Section	Paper	Refereed Paper	Year
1	1, 2, 4, 8	*Şule ERYÜRÜK*, Ichiro KOSHIJIMA, Tomoyuki KATO, "Impact Analysis of Political Decisions on Business Sustainability", Asian Journal of Management Science and Applications (Accepted, In press)	Yes	2014
2	1, 2, 6, 8	*Şule ERYÜRÜK*, Jing SUN, Norio TOKUMARU, Ichiro KOSHIJIMA, "Development of Political Decisions and Effects on Recycle Management in Auto Industry" presented in International Symposium on Marketing, Logistics, and Business, Nagoya, Japan	Yes	2013
3	1, 2, 5, 8	Jing SUN, Ichiro KOSHIJIMA, Yoshihiro HASHIMOTO, Jun KATO, *Şule ERYÜRÜK*, "Analysis of Reuse Trader Construction in the Global Auto- Industry Supply Chain", Information - An International Interdisciplinary Journal, Vol.16, No.7 (A), pp.4539-4554	Yes	2013
4	1, 2 , 3, 8	*Şule ERYÜRÜK,* Ichiro KOSHIJIMA, "Defining Future Directions of Strategic Policy Decisions by Evolutionary Game Theory" presented in 2nd International Conference on Innovations in Engineering and Technology, Penang, Malaysia	Yes	2014
5	1, 2, 7, 8	*Şule ERYÜRÜK*, Ali TÜRKYıLMAZ, Ichiro KOSHIJIMA, Jing SUN, "A Supplier Evaluation Method for Sustainable Project Management", Journal of International Association of Project &Program Management, Vol.7, No.1., pp.163-185	Yes	2012

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Appendix A

Chapter 4 Mathematical Modelling and Notations

F_1 Number of used parts AX and ABX from market of used cars to dismantling trader M per unit time.

F_2 Number of used part X from dismantling trader M to crushing trader per unit time.

F_3 Number of used part A from dismantling trader M to A reused part user per unit time.

F_4 Number of BD used parts from dismantling trader M to trader N per unit time.

F_5 Number of used parts BX and ABX from market of used cars to dismantling trader N per unit time.

F_6 Number of used part X from dismantling trader N to crushing trader per unit time.

F_7 Number of used part B from dismantling trader N to B reused part user per unit time.

F_8 Number of AX used parts from dismantling trader N to trader M per unit time

ε_{A1} = m_3 Probability of A obtained from $F1$

ε_{A2} = m_4 Probability of A obtained from $F8$

ε_{B1} = n_3 Probability of B obtained from $F5$

ε_{B2} = n_4 Probability of B obtained from $F4$

r_A Existence rate of AX in $F8$

r_B Existence rate of BX in $F4$

η_A Probability of ABX in $F1$

η_B Probability of ABX in $F5$

m$_1$ $(1-\varepsilon_{A1})(1-\eta_A)+(1-\varepsilon_{A1})\eta_A$

m$_2$ $(1-\varepsilon_{A2})$

m$_5$ $\gamma_A\eta_A$

n$_1$ $(1-\varepsilon_{B1})(1-\eta_B)+(1-\varepsilon_{B1})\eta_B$

n$_2$ $(1-\varepsilon_{B1})$

n$_5$ $\gamma_B\eta_B$

C_{AX} Cost of single AX

C_{BX} Cost of single BX

C_{ABX} Cost of single ABX

C_X Cost of single waste X

I$_i$ Income of single reusable part in Fi, where i =3, 4, 7, 8.

E_{AX} Environmental impact of single AX

E_{BX} Environmental impact of single BX

E_{ABX} Environmental impact of single ABX

Ex Environmental impact of single waste X.

E$_i$ Environmental impact of single reusable part in Fi, where i =3, 4, 7, 8.

S_{AX} Social development impact of single AX

S_{BX} Social development impact of single BX

S_{ABX} Social development impact f single ABX

S_X Social development impact of single waste X

S$_i$ Social development impact of single reusable part in Fi, where i =3, 4, 7, 8.

Appendix B

Calculation Sheets for Hybrid GRA

Evaluation of Copper suppliers

	CS1	CS2	CS3	CS4	CS5	CS6
C1	1.00	1.00	5.00	5.00	5.00	1.00
C2	10.00	10.00	5.00	10.00	5.00	5.00
C3	10.00	10.00	5.00	5.00	5.00	5.00
C4	5.00	5.00	5.00	5.00	5.00	1.00
C5	5.00	5.00	5.00	15.00	10.00	5.00
C6	7.00	9.00	7.00	7.00	9.00	9.00
C7	10.00	5.00	5.00	5.00	10.00	10.00
C8	15.00	15.00	15.00	15.00	10.00	15.00
C9	5.00	6.00	6.00	5.00	5.00	6.00
C10	10.00	10.00	5.00	5.00	10.00	10.00
C11	10.00	10.00	5.00	5.00	10.00	10.00
C12	9.00	7.00	7.00	7.00	7.00	9.00
C13	10.00	5.00	10.00	5.00	10.00	10.00
C14	7.00	7.00	7.00	7.00	9.00	9.00
C15	7.00	7.00	7.00	7.00	9.00	9.00
C16	10.00	5.00	10.00	5.00	10.00	10.00
C17	1.50	1.50	2.50	1.50	1.50	0.50
C18	10.00	5.00	10.00	10.00	5.00	10.00
C19	7.00	9.00	7.00	7.00	7.00	9.00
C20	9.00	7.00	7.00	7.00	7.00	7.00
C21	9.00	9.00	7.00	7.00	7.00	7.00

Evaluation of DOP suppliers

	DS5	DS2	DS3	DS4	DS5
C1	5.00	10.00	10.00	10.00	10.00
C2	5.00	5.00	5.00	5.00	10.00
C3	5.00	5.00	5.00	5.00	10.00
C4	5.00	5.00	5.00	5.00	10.00
C5	5.00	5.00	5.00	10.00	10.00
C6	10.00	15.00	15.00	10.00	10.00
C7	7.00	9.00	7.00	9.00	9.00
C8	5.00	10.00	10.00	5.00	5.00
C9	6.00	5.00	6.00	5.00	6.00
C10	5.00	10.00	5.00	5.00	1.00
C11	10.00	10.00	1.00	5.00	10.00
C12	7.00	5.00	5.00	7.00	5.00
C13	5.00	10.00	10.00	1.00	10.00
C14	5.00	7.00	5.00	7.00	7.00
C15	7.00	7.00	7.00	7.00	9.00
C16	10.00	5.00	5.00	10.00	10.00
C17	0.50	1.50	1.50	6.00	1.50
C18	5.00	10.00	10.00	5.00	10.00
C19	7.00	5.00	5.00	7.00	7.00
C20	7.00	9.00	7.00	7.00	7.00
C21	9.00	7.00	7.00	7.00	7.00

Evaluation of PVC Suppliers

	PS1	PS2	PS3	PS4	PS5	PS6	PS7
C1	1.00	5.00	5.00	5.00	1.00	1.00	5.00
C2	10.00	5.00	5.00	5.00	10.00	10.00	10.00
C3	5.00	10.00	5.00	5.00	10.00	5.00	10.00
C4	5.00	5.00	5.00	5.00	1.00	10.00	10.00
C5	5.00	5.00	5.00	5.00	5.00	15.00	5.00
C6	9.00	9.00	7.00	9.00	9.00	9.00	9.00
C7	7.00	5.00	7.00	9.00	5.00	9.00	5.00
C8	5.00	5.00	5.00	10.00	10.00	5.00	10.00
C9	6.00	5.00	5.00	6.00	5.00	5.00	5.00
C10	10.00	10.00	5.00	5.00	10.00	10.00	10.00
C11	10.00	10.00	5.00	5.00	15.00	5.00	10.00
C12	5.00	7.00	7.00	5.00	7.00	9.00	5.00
C13	10.00	10.00	5.00	10.00	5.00	10.00	10.00
C14	7.00	7.00	9.00	5.00	7.00	9.00	5.00
C15	9.00	3.00	5.00	7.00	7.00	5.00	7.00
C16	5.00	10.00	5.00	5.00	10.00	10.00	5.00

C17	0.50	0.50	0.50	1.50	1.50	1.50	1.50
C18	10.00	5.00	5.00	10.00	10.00	10.00	10.00
C19	7.00	5.00	9.00	7.00	7.00	7.00	5.00
C20	7.00	7.00	7.00	7.00	9.00	7.00	7.00
C21	7.00	9.00	7.00	9.00	9.00	7.00	7.00

Table of Normalization of data calculation for Cooper Suppliers

	L/S	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**
C1	0	0.56	0.56	0.00	0.00	0.00	1.00
C2	1	1.00	0.00	1.00	0.00	0.00	0.00
C3	0	0.00	0.56	1.00	1.00	0.00	0.00
C4	1	0.00	0.44	1.00	1.00	0.44	1.00
C5	0	1.00	0.00	1.00	1.00	1.00	1.00
C6	1	0.00	0.00	0.50	1.00	1.00	0.50
C7	1	1.00	0.00	0.33	1.00	0.33	1.00
C8	0	0.56	1.00	0.56	0.56	0.00	0.00
C9	1	1.00	0.00	0.25	0.75	0.75	1.00
C10	1	1.00	0.44	1.00	0.00	1.00	0.44
C11	1	0.00	0.00	0.00	0.00	1.00	0.00
C12	1	0.00	0.00	0.50	1.00	1.00	1.00
C13	1	0.44	0.44	1.00	0.00	1.00	0.00
C14	1	1.00	0.00	0.33	0.67	1.00	0.33
C15	1	0.00	1.00	0.00	0.50	1.00	0.50
C16	1	1.00	0.44	0.00	1.00	1.00	1.00
C17	0	0.00	0.27	0.45	0.64	0.82	1.00
C18	1	0.00	0.00	1.00	0.00	0.00	0.00
C19	1	0.67	0.67	0.33	0.67	1.00	0.00
C20	1	1.00	1.00	1.00	0.00	0.00	0.00
C21	1	0.67	0.00	0.00	0.00	0.00	1.00

Table of Normalization of data calculation for DOP Suppliers

	L/S	**DS1**	**DS2**	**DS3**	**DS4**	**DS5**
C1	0	0.00	0.00	1.00	0.00	0.00
C2	1	1.00	0.00	0.00	0.00	0.00
C3	0	0.56	1.00	0.00	1.00	0.00
C4	1	0.00	0.00	0.00	1.00	0.00
C5	0	0.00	0.00	0.00	1.00	1.00

C6	1	1.00	1.00	0.50	0.00	0.50
C7	1	0.67	0.67	0.33	0.00	1.00
C8	0	0.00	0.00	0.56	1.00	0.56
C9	1	0.00	1.00	1.00	1.00	0.80
C10	1	1.00	0.44	0.44	0.44	0.00
C11	1	1.00	0.00	1.00	0.44	1.00
C12	1	0.00	0.50	1.00	1.00	0.00
C13	1	1.00	1.00	0.44	0.00	1.00
C14	1	0.00	0.00	0.00	0.50	1.00
C15	1	0.33	0.33	0.00	0.33	1.00
C16	1	0.00	0.00	1.00	1.00	1.00
C17	0	1.00	0.00	0.82	0.00	0.82
C18	1	1.00	1.00	0.00	0.44	1.00
C19	1	0.00	0.50	1.00	1.00	1.00
C20	1	0.00	1.00	0.00	0.00	0.00
C21	1	0.00	0.00	1.00	0.00	0.00

Table of Normalization of data calculation for DOP Suppliers

	L/S	**PS1**	**PS2**	**PS3**	**PS4**	**PS5**	**PS6**	**PS7**
C1	0	1.00	0.00	0.00	0.00	1.00	1.00	0.00
C2	1	1.00	0.00	0.00	0.00	1.00	1.00	1.00
C3	0	1.00	0.00	1.00	1.00	0.00	1.00	0.00
C4	1	0.44	0.44	0.44	0.44	0.00	1.00	1.00
C5	0	1.00	1.00	1.00	1.00	1.00	0.00	1.00
C6	1	1.00	1.00	0.00	1.00	1.00	1.00	1.00
C7	1	0.50	0.00	0.50	1.00	0.00	1.00	0.00
C8	1	0.00	0.00	0.00	1.00	1.00	0.00	1.00
C9	1	1.00	0.00	0.00	1.00	0.00	0.00	0.00
C10	1	1.00	1.00	0.00	0.00	1.00	1.00	1.00
C11	1	0.50	0.50	0.00	0.00	1.00	0.00	0.50
C12	1	0.00	0.50	0.50	0.00	0.50	1.00	0.00
C13	1	1.00	1.00	0.00	1.00	0.00	1.00	1.00
C14	1	0.50	0.50	1.00	0.00	0.50	1.00	0.00
C15	1	1.00	0.00	0.33	0.67	0.67	0.33	0.67
C16	1	0.00	1.00	0.00	0.00	1.00	1.00	0.00
C17	0	1.00	1.00	1.00	0.00	0.00	0.00	0.00
C18	1	1.00	0.00	0.00	1.00	1.00	1.00	1.00
C19	1	0.50	0.00	1.00	0.50	0.50	0.50	0.00
C20	1	0.00	0.00	0.00	0.00	1.00	0.00	0.00
C21	1	0.00	1.00	0.00	1.00	1.00	0.00	0.00

Table of Grey relational coefficient calculation for Copper Suppliers

	CS1	CS2	CS3	CS4	CS5	CS6
C1	0.62	0.62	1.00	1.00	1.00	0.47
C2	1.00	0.47	1.00	0.47	0.47	0.47
C3	1.00	0.62	0.47	0.47	1.00	1.00
C4	0.47	0.62	1.00	1.00	0.62	1.00
C5	0.47	1.00	0.47	0.47	0.47	0.47
C6	0.47	0.47	0.64	1.00	1.00	0.64
C7	1.00	0.47	0.57	1.00	0.57	1.00
C8	0.62	0.47	0.62	0.62	1.00	1.00
C9	1.00	0.47	0.55	0.78	0.78	1.00
C10	1.00	0.62	1.00	0.47	1.00	0.62
C11	0.47	0.47	0.47	0.47	1.00	0.47
C12	0.47	0.47	0.64	1.00	1.00	1.00
C13	0.62	0.62	1.00	0.47	1.00	0.47
C14	1.00	0.47	0.57	0.73	1.00	0.57
C15	0.47	1.00	0.47	0.64	1.00	0.64
C16	1.00	0.62	0.47	1.00	1.00	1.00
C17	1.00	0.77	0.66	0.59	0.52	0.47
C18	0.47	0.47	1.00	0.47	0.47	0.47
C19	0.73	0.73	0.57	0.73	1.00	0.47
C20	1.00	1.00	1.00	0.47	0.47	0.47
C21	0.73	0.47	0.47	0.47	0.47	1.00

Table of Grey relational coefficient calculation for DOP Suppliers

	S1	S2	S3	S4	S5
C1	1.00	1.00	0.47	1.00	1.00
C2	1.00	0.47	0.47	0.47	0.47
C3	0.62	0.47	1.00	0.47	1.00
C4	0.47	0.47	0.47	1.00	0.47
C5	1.00	1.00	1.00	0.47	0.47
C6	1.00	1.00	0.64	0.47	0.64
C7	0.73	0.73	0.57	0.47	1.00
C8	1.00	1.00	0.62	0.47	0.62
C9	0.47	1.00	1.00	1.00	0.82
C10	1.00	0.62	0.62	0.62	0.47
C11	1.00	0.47	1.00	0.62	1.00
C12	0.47	0.64	1.00	1.00	0.47
C13	1.00	1.00	0.62	0.47	1.00
C14	0.47	0.47	0.47	0.64	1.00
C15	0.57	0.57	0.47	0.57	1.00

C16	0.47	0.47	1.00	1.00	1.00
C17	0.47	1.00	0.52	1.00	0.52
C18	1.00	1.00	0.47	0.62	1.00
C19	0.47	0.64	1.00	1.00	1.00
C20	0.47	1.00	0.47	0.47	0.47
C21	0.47	0.47	1.00	0.47	0.47

Table of Grey relational coefficient calculation for PVC Suppliers

	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**
C1	0.47	0.47	1.00	0.47	1.00	0.47	1.00
C2	1.00	0.47	0.47	0.47	0.47	0.47	0.47
C3	1.00	0.62	0.47	1.00	0.47	0.47	1.00
C4	0.47	0.62	0.62	0.62	1.00	1.00	0.62
C5	1.00	1.00	1.00	1.00	0.47	0.47	1.00
C6	1.00	0.64	1.00	0.64	0.47	0.47	0.64
C7	0.57	1.00	0.73	0.57	0.47	0.47	0.57
C8	1.00	1.00	1.00	0.62	0.47	0.62	1.00
C9	0.64	1.00	0.64	0.47	0.47	0.64	0.64
C10	1.00	0.62	0.47	1.00	1.00	0.47	1.00
C11	0.72	0.47	0.72	0.72	0.72	0.56	1.00
C12	0.47	0.64	1.00	0.64	0.64	1.00	1.00
C13	1.00	1.00	0.47	1.00	0.47	1.00	0.33
C14	0.47	0.47	0.47	1.00	1.00	0.64	1.00
C15	0.73	0.73	0.64	0.47	1.00	0.57	0.73
C16	0.62	0.62	1.00	1.00	0.62	0.47	1.00
C17	0.55	1.00	0.55	0.47	0.47	1.00	0.78
C18	1.00	1.00	0.47	0.47	1.00	1.00	1.00
C19	0.73	0.73	1.00	0.47	0.47	0.73	0.57
C20	1.00	1.00	0.47	0.47	1.00	0.64	0.64
C21	0.73	1.00	0.47	1.00	0.73	0.47	0.47

Tables of Grey Relational Grade Scores for Copper Suppliers

RANK	**Name of Supplier**	**Total Performance Score**	**Price Performance Score**	**Quality Performance Score**	**Delivery Performance Score**	**Firm Profile**
3	CS1	0.65	0.11	0.08	0.37	0.08
4	CS2	0.60	0.11	0.12	0.21	0.16
5	CS3	0.56	0.12	0.11	0.28	0.06

6	CS4	0.47	0.14	0.08	0.19	0.06
2	CS5	0.68	0.12	0.09	0.41	0.06
1	CS6	0.83	0.05	0.14	0.49	0.15

Table of Grey Relational Grade Scores for DOP Suppliers

RANK	**Name of Supplier**	**Total Performance Score**	**Price Performance Score**	**Quality Performance Score**	**Delivery Performance Score**	**Firm Profil Score**
3	DS1	0.62	0.05	0.10	0.31	0.16
4	DS2	0.59	0.11	0.10	0.32	0.07
5	DS3	0.51	0.11	0.12	0.23	0.06
2	DS4	0.71	0.11	0.09	0.37	0.15
1	DS5.	0.85	0.16	0.14	0.40	0.15

Table of Grey Relational Grade Scores for PVC Suppliers

RANK	**Name of Supplier**	**Total Performance Score**	**Price Performance Score**	**Quality Performance Score**	**Delivery Performance Score**	**Firm Profil Score**
3	PS1	0.60	0.08	0.12	0.32	0.08
6	PS2	0.57	0.13	0.07	0.31	0.07
7	PS3	0.56	0.11	0.06	0.25	0.15
4	PS4	0.60	0.11	0.14	0.26	0.09
2	PS5	0.62	0.10	0.08	0.34	0.10
1	PS6	0.72	0.09	0.11	0.44	0.08
5	PS7	0.58	0.16	0.08	0.29	0.06

Table B.13: Proposed Evaluation Scale for Price Performance

Price affordability		**Easy terms of payment**		**Frequency of price increase requirement**		**Room for negotiation**	
	S		L		S		L
Lower than market price	1	Sufficient number	10	Fewer than expected	1	High	10
Market price	5	Lower than sufficient number	5	Expected	5	Fair	5
Higher than market price	10	No payment term option	1	Higher than expected	10	Low	1

Table B.14: Proposed Evaluation Scale for Company Profile Performance

After sales support		**Behave accordingly to company aims**		**Reliability**		**Financial indicators**	
	L		**L**		**L**		**L**
Good in support	**10**	Very poor	**1**	Very poor	**1**	Very poor	**1**
Fair support but not enough	**5**	Poor	**3**	Poor	**3**	Poor	**3**
No support	**1**	Fair	**5**	Fair	**5**	Fair	**5**
		Good	**7**	Good	**7**	Good	**7**
		Very good	**9**	Very good	**9**	Very good	**9**

Table B.15: Proposed Evaluation Scale for Delivery Performance

Meeting requirements of order quantity		Sending order confirmation		On time delivery		Appropriate packing		Meeting requirements of delivery contract	
	S		L		L		L		L
Lower than ordered quantity	15	No missing order confirmation in 6 months	15	On time	9	In 6 months all delivery packages certificated	10	No missing rule in delivery certifications in 6 months	6
More than exact ordered quantity	10	In 6 months 1-5 missing order confirmation 1-5	10	1-2 days late	7	In 6 months most of the delivery packages certificated	5	In 6 months 1-2 missing rule in delivery certifications	5
Exact ordered quantity	5	In 6 months more than 5 missing order confirmation	5	3-4 days late	5	In 6 months most of the delivery packages are not certificated	1	In 6 months 2-4 missing rule in delivery certifications	4
		In 6 months no order confirmation	1	5-6 days late	3			In 6 months 4-6 missing rule in delivery certifications	3
				More than 7 days late	1			In 6 months 6-8 missing rule in delivery certifications	2
								In 6 months more than 8 missing rule in delivery certifications	1

Table B.16: Proposed Evaluation Scale for Quality Performance

Product development	L	Succesful	10	Progress success	5	Not enough	1						
Process development	L	Succesful	10	Progress success	5	Not enough	1						
Quality planning	L	very poor	1	poor	3	fair	5	good	7	very good	9		
Inspection and experimantal studies	L	Succesful	10	Progress success	5	Not enough	1						
Quality audit results	L	very poor	1	poor	3	fair	5	good	7	very good	9		
Environmental audit results	L	very poor	1	poor	3	fair	5	good	7	very good	9		
Success in R&D tests and approval for new material	L	Succesful	10	Progress success	5	Not enough	1						
Raw material quality rate of return	S	%0 -%1	0,5	%1-%2	1,5	%2-%3	2,5	%3-%4	3,5	%4-%5	4,5	More than %5	6
After sales support	L	Good in support	10	Fair support but not enough	5	No support	1						

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