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SHIFTING ORDERS AMONG SUPPLIERS CONSIDERING RISK, PRICE AND TRANSPORTATION COST

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Declare that my thesis entitled:

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Is a complete independent work of mine, completed without using any illegal information, nor the work of others that I recognize as my own work.

All cited and references are listed in the bibliography.

If it turns out that this statement is not true, I am willing to accept the consequences in accordance with the regulations.

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Alhamdulillah, my greatest gratitude to Allah SWT because of his grace and blessing, author successfully complete this thesis with tittle **"SHIFTING ORDERS AMONG SUPPLIERS CONSIDERING RISK, PRICE AND TRANSPORTATION COST"**

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SHIFTING ORDERS AMONG SUPPLIERS CONSIDERING RISK, PRICE AND TRANSPORTATION COST

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ABSTRACT

Order allocation for supplier is an important decision for an enterprise to realize a sustainable production. It was related to the suppliers function as a raw material provider and other supporting materials that will be used in production process. Initially most of previous research only focus on system analysis of order allocation supplier without doing analysis of risk and overall supply chain cost. Problem encountered in this research is to determine shifting order among suppliers that considering risk and transportation cost for single commodity multi supplier. The supply chain risk management process is investigated and a procedure was proposed in the risk mitigation phase as a form of risk profile. In this research model is proposed an initial procurement plan by using linear programming and also is revised the first optimal solution by including the risk profile factor. The objective of analysis risk profile in order allocation is to maximize the product flow from a risky supplier to a relatively less risky supplier. This supply chain risk management procedure including this proposed procedure is applied to a sugar company. The model is able to demonstrate that the result are different than the initial model.The result suggested that order allocations should be maximized in suppliers that have a relatively less risk profile value and minimized on suppliers that have a relatively larger risk profile value based on the risk factor, capacity, purchasing cost, transportation cost for each supplier and also demand from each manufacturer.

Keywords : Shifting Order, Multiple Sourcing, Supply Side Risk, Linier Programming.

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TABLE OF CONTENTS

LIST OF FIGURES

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LIST OF TABLES

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CHAPTER I
INTRODUCTION

This chapter will explain about research background, research questions, objectives and benefits of the research, limitations, and assumptions.

1.1 Research Background

In today's competitive environment, improvement of the whole supply chain performance is an important thing for every company. Every company is attempting to meet demand, improving the quality and reducing costs to optimize the business processes (Chen & Wu 2013). In most industries, cost of raw materials and components formed as a major part of production cost until up to 70% (Sawik 2013). Raw material costs can increase up to 80% from total production cost. An efficient and effective supply chain also depends on the company in selecting the best supplier to manage the right materials at the right time, by managing the processes that significantly will reducing not only purchasing cost but also enhancing the competitiveness of the company (Pazhani et al., 2016). Therefore, selecting appropriate suppliers is a thing that needed a full attention because suppliers have a significant effect on reducing purchasing costs, increasing customer satisfaction, and strengthening the competitiveness of company (Sodenkamp et al. 2016). In addition, among the various components in the supply chain, sourcing and transportation are recognized as primary.

Partnering with the right supplier has proven to be an important strategic effort for supply chain management (Oguzhan & Erol 2016). Due to the mistakes in the selection of suppliers can be a thing that can disrupt the production schedule that has been made and also make the company stop operating for a while (Yu et al. 2016). This is related to the function of the supplier itself as a provider of raw materials and supporting materials that will be used in the production process. The process of selecting the right supplier give an impact to overall cost of purchase (the cost of raw materials and components) as a major contributor to the percentage of final product cost (Sawik 2013). According to Shaw et al. (2012), the purpose of the supplier selection process is identified each supplier to ultimately choose the supplier with the highest potential to be able to work together and meet the demand. There are two kinds of supplier selection systems, the first is single sourcing system where 1 supplier is able to meet all the needs of the company so that the management only needs to make a decision to choose one of the best suppliers. While the second one is the multiple sourcing system, where no supplier is able to meet the needs of the company, so that in these conditions management must divide the order on each supplier with a variety of considerations of certain conditions. The problem is what will be resolved in this research.

Beside that, company have to concern to organize overall supply chain cost to control and minimize the procurement cost, transportation cost as a part of supply chain cost is also an important aspect to be considered (Pazhani et al. 2016). However, a lot of inventory management models in the literature assume that transportation costs are included in the purchase cost of the product (Zepeda et al. 2016). Transportation costs should be considered in determining the amount of the order and also the removal order to improve the efficiency of the overall supply chain (Yu et al. 2016).

Research on supply chain optimization has mainly focused on two problems: first, the manufacturer has to determine its optimal production, distribution and inventory policies considering its capacity, setup costs, distribution costs and operating costs, and deliver the final products to customers and second the manufacturer has to determine the suppliers/vendors from which to purchase raw materials as well as the corresponding order quantities on supplier selection (Lee et al. 2015). Solving these two problems separately (in sequence) may yield to optimal solutions for the entire supply chain. Therefore, this research considers an integrated approach consisting of a multistage supply chain system that simultaneously addresses the problems of supplier selection and shifting order among supplier considering purchasing, setup, holding, and transportation costs. The advantages of optimizing the supply chain considering purchasing and transportation costs simultaneously are illustrated using a numerical example. Sensitivity analysis is carried out to determine the effect of cost parameters on supplier order allocation (Supply et al. 2015). The analysis shows that the supplier selection and the corresponding order quantities are affected with changes in the supply chain cost parameters. Moreover, the proposed integrated approach is compared with the sequential approach, where the inventory planning and supplier selection problems are solved sequentially (Oguzhan & Erol 2016). The results from the analysis show that the integrated approach yields significant savings in terms of logistics and overall supply chain costs.

Some researchs only focused on creating an optimal order allocation for each suppliers to fulfill demands of each manufacturer as conducted in Sodenkamp et al. (2016), Nazari-shirkouhi et al. (2013), Pazhani et al. (2016), Guo & Li (2014) and (Jadidi et al., 2014). All of that researches have considered the various parameters of overall supply chain cost in determined order allocations for suppliers, but it does not conducted risk analysis to reduce error of results for order allocations for each suppliers. In research conducted by Oguzhan & Erol (2016), it is described risk factors which is very important to be included in formulation model to calculate the optimal order allocation for suppliers. Risk factors are used as parameters for formulation to produce an optimal order allocation that can maximize orders suppliers to supplier that have a relatively less risk factors value. Each supplier has different risks, therefore it is necessary to analyze risk for each supplier, then calculate the order allocation by entering the risk factor in formulation model (Sawik 2013).

However, from all the researchs that were described earlier, there is no prior risk identification has been done to formulate the order allocation by considering all supply chain costs between suppliers and manufactures including the transportation costs, therefore an approach is needed to resolve the problem. The approach used is a proactive risk management planning procedure which in this research is conducted to take precaution against misallocation of order allocation for each suppliers by considering supply chain cost thoroughly including transportation cost. In this research will be known as the results of order allocations without considering risk and optimal results of order allocations for each supplier after considering risk aspects. For the initial results of order allocation, it is obtained through the formulation of linear programming model with objective function that is minimization of two aspects of costs, purchasing cost and transportation cost.

Then the results will be processed by conducting risk assessment of all suppliers qualitatively. Risk assessment is obtained in the form of risk profile, where the risk profile will be used as a parameter to change the order allocations from the order allocations that have not considered risk factors. Risk profile is incorporated into linear programming formulation model as an effort to optimize the allocation of orders for each supplier considering the supplier's capacity and demand of each manufacturer.

Risk identification used in this research is in the form of risk profile. Because by using a risk profile it would be easier to categorize and list the possible risks which is caused by suppliers that can influence pattern and number of allocation of orders for each supplier in fulffilling the demand of each manufacturer. Risk profile is also used as a parameter which the function is to reflect the risk status of each supplier which used as a parameter to modify the initial procurement plan. By using these parameters, the results of the order allocations will be maximized to suppliers that have a relatively less risk profile value and minimize the order allocations insuppliers that have a relatively larger risk profile value, but also have to stay attention of two factors, the order allocation which should not exceeds capacity of each supplier and must fulfill the demand of each manufacturer. If purchasing unit cost of supplier is cheaper but supplier has a higher risk profile value than the other, number of allocations orders that have been planned through minimization of costs should consideration risk profile value dan well purchasing power of manufacturers that have a relatively less risk profile value that also have to considering capacity of supplier. The Allocations from the suppliers that have a relatively lower risk are modeled as a network to facilitate the allocation of such order allocations.

The procedures proposed in this study can be applied by manufacturers from all sectors with a single product from multiple suppliers procurement plan This research is using LINGO as a tool to process the model of linear programming model. This research began with a framework of order allocation pattern from supplier and manufacturer as well as the risk identification in each supplier in form of risk profile which is used as parameter for modeling lininer programming and also used as parameter in order allocation plan and analysis for each supplier. The benefit of this research is to refer the strategy for manufacturing with a single product from multiple suppliers procurement to make an optimal of order allocation by considering risk factor to reduce impact from supplier problem, to maximize flow of materials from supplier to manufacture, to optimize production process and increase the company profit.

1.2 Research Questions

With regards to the research gap explained in the previous section, this research focuses on these following aspects.

1. How to incorporate cost and price into the decisions of procurement quantity allocation among available suppliers?
2. How are the changing parameter value like demand, risk profile and price affect the order allocation?

1.3 Objectives

This research aims to develop a procedure of determining shifting orders process in the supplier selection. The proposed method tested through case studies which have the following specific objectives.

1. To develop a model of procurement plan that incorporates cost and price into the decision making of procurement plan.
2. To analyze the sensitivity of demand, risk profile and price toward order allocation.

1.4 Benefit

The benefits from the implementation of this research are.

1. Theoretical Contribution.

   This study contributes in adding alternative quantitative approach in supply chain risk management, particularly at the stage of determining the risk mitigation strategies that are proactive. The formulation of network model is using Linier programming to present a procedure of supplier selection processes as a whole.

2. Practical implications.
    a. The method of determining the proposed risk mitigation strategies in supplier selection can be generalized to other supply chain risk management, not limited to this study. Linier Programming is very promising to be applied in process of shifting orders among suppliers.
    b. The proposed risk mitigation strategy can be used as a risk management policy recommendations for companies that have business processes and risk profile as a factor as shown in this study. Through mitigation strategies, companies can reduce the probability of occurrence of risk and reducing the impact if the risk actually occurs.

1.5 Limitations

Limitation used in this research are.

1. The supply chain network involves two steps, namely supplier and manufacturer.
2. We only consider the case of a single material in the numerical example, namely soda caustic.

1.6 Assumptions

The assumptions used in this research are.

1. Transportation costs from third party parties assumed are constant.
2. The number of suppliers is fixed.
3. In this research assumed that all soda caustic delivered by trucks with capacity 22 ton.

1.7 Research Outline

As an outline, the systematic writing of this study is as follow.

CHAPTER 1 INTRODUCTION

This chapter gives a brief description about the content of this research specify problem background, problem identification, research objectives, research benefit, research limitation and assumptions, as well as the systematic writing for the final report.

CHAPTER 2 LITERATURE REVIEW

This Chapter describes about the general description of the theories that being used and literature relating to previous research as a references.

CHAPTER 3 RESEARCH METHODOLOGY

This chapter describes the research method, which contains systematic stages to answer the problem identification on research.

CHAPTER 4 DATA COLLECTION AND PROCESSING

This chapter describes the model used in solving issues that will be discussed, along by plans development models and mathematic formulation according to data from company.

CHAPTER 5 ANALYSIS AND DISCUSSION

This chapter describes the data collection and running of model.

CHAPTER 6 CONCLUSIONS

This chapter explains the conclusions from the discussion along with the suggestions or recommendations.

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CHAPTER 2
LITERATURE REVIEW

This chapter contains some references and theories conducted from various journals, books and previous research. Where the theory and references is expected to be used as a reference in solving the problem that related with risk and allocation order to support this research.

2.1 Supply Chain Risk Management (SCRM)

Supply chain risk management (SCRM) is the implementation of strategies to manage both daily and exceptional risks along the supply chain based on continuous risk assessment with the objective of reducing vulnerability and ensuring continuity (Tang et al. 2012). According to Musa (2012). SCRM also define as an activity which integrated recognition of risk, risk assessment, developing strategies to manage it, and mitigation of risk using managerial resources. Some traditional risk managements are focused on risks stemming from physical or legal causes. Supply chain risk management aims to develop an approach to identify, assess, analyze, and address areas that are vulnerable in the supply chain. Hallikas & Lintukangas (2016) was present as the intersection between risk management and supply chain management

2.2 Supply Chain Risk Management Processes

Supply chain risk management process begins with identifying internal and external environments (Thun & Hoenig 2011). Supply chains are often consist of complex network system, reaching hundreds or thousands of participants around the globe (Olson & David 2014). The term has been used both at the strategic level (coordination and collaboration) and the tactical level (management of logistics across functions and between businesses). Supply chain risk management is interested in the coordination and collaboration of processes and activities across functions within a network of organizations (Ho et al. 2016). Supply chains enable manufacturing outsourcing to take advantage of global relative advantages, as well as increase product variety. There are many risks inherent in this more open, dynamic system.

Enterprises may inadvertently overlook internal risks (Qi & Lee 2015). These may include those posed by a rogue employee, as well as those posed by inadequate policies, strategies, or 5 organizational structures. The external environment in which an enterprise, and its suppliers, must work will also pose differing risks. For example, some suppliers will face meteorological risks, while others, because of their distance, may have greater transportation risks. Mapping its supply chain can help an enterprise identify the risks it faces and how best to prioritize and address them (Heckmann et al. 2015). To prioritize and address risks, firms will need to identify criteria for determining what may pose a risk to its operations. One potential starting point is the supply chains for the products most affecting firm profitability (Ghadge et al. 2017).

Once a firm understands how to identify risks, it may undertake risk identification and assessment, which includes risk identification, risk analysis, and risk evaluation (Tang et al. 2012). Risk identification may entail using a list of common risks including external risks such as natural disasters, accidents, sabotage, or labor uncertainty; supplier risks such as production problems, financial issues, or subcontractor problems; distribution risks such as cargo damage, warehouse inadequacies, or supply pipeline constrictions; and internal risks such as personnel availability or facility unavailability (Chen & Wu 2013). Such process will also involve prioritizing risks by the threat (as measured by likelihood and consequence) they can pose to a firm's operations.

Enterprises must also undertake continual communication and consultation as well as monitoring and review throughout this process. Monitoring and review entails not only evaluating the effects of risk treatment but also maintaining the plan and responding to changes in suppliers, processes, and regulation affecting elements of the supply chain. It also entails continually identifying opportunities for improvement (Chen & Wu 2013). Detail of supply chain risk management processes is shown at figure 2.1.

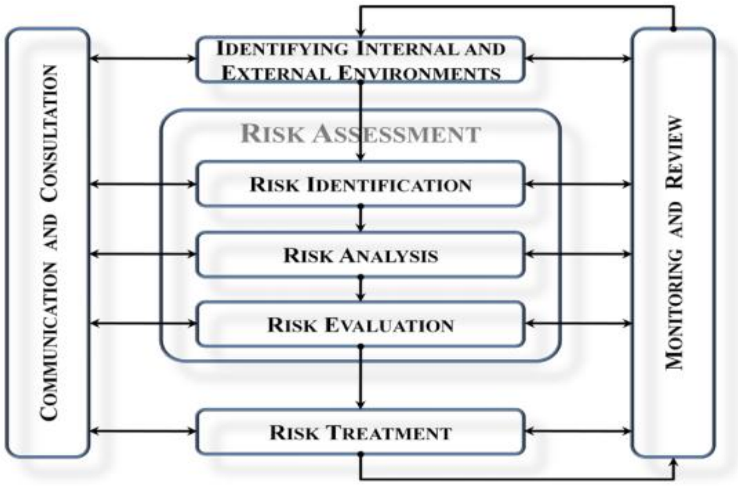

Figure 2.1 Supply Chain Risk Management Process
Source : Chopra, S (2015)

2.2.1 Risk Identification

Risk identification of a particular system, facility or activity may yield a very large number of potential accidental events and it may not always be feasible to subject each one to detailed quantitative analysis. In practice, risk identification is a screening process where events with low or trivial risk are dropped from further consideration (Musa 2012).

Risk identification is the first and the most important stage of the risk management (Peng et al. 2014). For an efficient risk management, supply chain must be divided into elements such as suppliers, manufacturers, warehouses, and distribution channels (Schmitt & Singh 2012). And the risks associated with each element should be examined and identified specifically and elaborately. This is called supply chain mapping and risk registering. Firms should form an SCRM department in their organization structure.

2.2.2 Risk Measurement

There are two criteria used for the risk measurement; the probability and the impact of a risky event (Urianty et al. 2015). Expected impact, which is the product of probability and impact, is referred to as the risk measurement. A probability distribution function or occurrence frequency of a risky event is used to find the value of probability (Zepeda et al. 2016) . In order to use probability functions, we must have historical data on that event first. The type of distribution function must be identified by fitting tests. Then, the parameters of the distribution function must be calculated and the probability of a risky event can be found (Heckmann et al. 2015). Data might be available for some risks such as currency rate and lead time but might be rare and insufficient for events as earthquake, terrorism etc. In this situation, the likelihood of an event can be used. Likelihood is related to the frequency of occurrence of an event. This method is more practical than and might be as accurate as the other method when experts evaluate the risky event meticulously (Peng et al. 2014).

The second component of the risk measurement is the impact of a risky event. It is very difficult to estimate and compute the impact in advance because a disruption in any part of the supply chain usually affects other parts as well (Li et al. 2016). Risk impact is usually expressed in terms of cost but performance loss, physical loss, psychological loss, social loss, time loss etc. are also other types of impacts (Platon & Constantinescu 2014). Moreover, the impact of environmental events varies according to the firm’s size. For instance, small companies might be affected more than large-scale companies from an economic crisis or currency rate risk. As mentioned earlier, expected impact is the product of impact and probability of a risky event.Based on (Sherwin et al. 2016) showed that the probability impact matrix is a useful tool to visualize and define the expected impacts (Table 2.1) and is widely used in literature. A risky event which is unlikely but has a high impact has an index of 8 out of 25. Both the likelihood and impact index of a risky event increases as we move towards the lower right of the matrix.

Table 2.1 Risk Mitigation strategies in supply chain

			Impact				
			Very Low	**Low**	**Medium**	**High**	**Very High**
			1	**2**	**3**	**4**	**5**
Likelihood	**Very unlikely**	**1**	1	2	3	4	5
	Unlikely	**2**	2	4	6	8	10
	Medium	**3**	3	6	9	12	15

Table 2.1 Risk Mitigation strategies in supply chain

			Impact				
			Very Low	Low	Medium	High	Very High
			1	**2**	**3**	**4**	**5**
Likelihood	**Likely**	**4**	4	8	12	16	20
	Very Likely	**5**	5	10	15	20	25

Adapted : Fahimnia et al. (2015)

2.2.3 Risk Evaluation

Risk evaluation is the process of comparing the results of risk analysis with risk criteria to determine whether the risk is acceptable or tolerable (Oguzhan & Erol 2016). Risk criteria are based on organizational objectives and can be derived from standards, laws, policies and other requirements (ISO Guide 73, 2009). It is impossible and unreasonable to refrain from all risks. At the end of the risk evaluation phase, a risk owner can select one of the four different strategies: avoid risk, reduce the probability and/or impact of risk, accept the occurrence of risk and prepare contingency plans (Chen & Wu 2013). Selection of the strategy mainly depends on the trade-off between the expected impact and the cost associated with the implementation of the selected strategy. García et al. (2013)

propose a quantitative decision support system (DDS) to select appropriate mitigation measures for supply chain risks. They do not propose a new mitigation measure but formulates a stochastic integer linear programming framework, which elaborates the supply chain managers' judgments' by way of utility functions and fuzzy-extended pairwise comparisons.

2.2.4 Risk Mitigation

Risk mitigation planning is the process of developing options and actions to enhance opportunities and reduce threats to project objective (Qi & Lee 2015). Risk mitigation implementation is the process of executing risk mitigation actions. Risk mitigation progress monitoring includes tracking identified risks, identifying new risks, and evaluating risk process effectiveness throughout the project.

Data collected from previous stage can be use as a risk mitigation input to classify the most suitable mitigation strategy to use (Oguzhan & Erol 2016).

General guidelines for applying risk mitigation handling options are based on the assessed combination of the probability of occurrence and severity of the consequence for an identified risk. These guidelines are appropriate for many, but not all, projects and programs. Risk mitigation handling options include Sherwin et al. (2016):

a. Assume/Accept, Acknowledge the existence of a particular risk, and make a deliberate decision to accept it without engaging in special efforts to control it. Approval of project or program leaders is required.
b. Avoid: Adjust program requirements or constraints to eliminate or reduce the risk. This adjustment could be accommodated by a change in funding, schedule, or technical requirements.
c. Control: Implement actions to minimize the impact or likelihood of the risk
d. Transfer: Reassign organizational accountability, responsibility, and authority to another stakeholder willing to accept the risk.
e. Watch/Monitor: Monitor the environment for changes that affect the nature and/or the impact of the risk.

2.3 Risk Management Strategy

Supply chain risk management strategies can be classified as a strategy of proactive and reactive strategies. Risk mitigation measures referred to as reactive in dealing with the risks of the supply chain. Table 2.2 is show the example of differences between proactive and reactive strategy.

Table 2.2 Proactive and Reactive Strategy

Risk Management Strategy Proactive	Risk Management Strategy Reactive
Developing supply chain, risk sharing through contracts, multi sourcing	Contingency planning, incident management risk, increase flexibility
Supply chain contracts, developing incentive contracts, contract flexibility mix and volume, VMI / buffer stock	Disaster Management, robust recovery, rebuild the supply chain, use a management of resources for scenario analysis at future disruptions
Product management process, postponement, product design, delivery management	Demand Management, operational rerouting, moving the consumer demand, dynamic pricing

Adapted : Heckmann et al. (2015)

2.4 Linear Programming

Linear programming theory and technique have been successfully applied to various supply chain problems almost since its early beginning (Shaw et al. 2012). There are study that use Linear programming to manage demand and inventory risk in a consumer electronics supply chain (Pazhani et al. 2016). Linear programming is an effective tools for analyzing and understanding supply chain risk problem.

Nazari-shirkouhi et al. (2013) dealed with actual problems on production and work force assignment in a housing material manufacturer and a subcontract firm. The research formulated two kinds of two-level programming problems: one is a profit maximization problem of both the housing material manufacturer and the subcontract firm, and the other is a profitability maximization problem of them. Applying the interactive fuzzy programming for two-level linear and linear fractional programming problems, he obtained the satisfactory solution to the problems. Brandenburg et al (2014) show that a mixed integer programming model is used to determine optimal supplier relationship, optimal supply work design, optimal supplier order allocation and optimal supply contract.

Yu et al. (2016) used a fuzzy approach to deal with the supplier selection problem in supply chain. The method is based on hierarchical multiple criteria decision making (MCDM) using fuzzy approach to select suitable supplier. In such type of decision making problems, all the decision makers are assumed to be equally important resulting in impractical aggregation of decision. Therefore, an analytic hierarchy process (AHP) like, the procedure based on Eigen value has been proposed to derive the weightages of decision makers. Then, the weightages of decision makers are incorporated with fuzzy decision making paradigm to arrive at robust selection of suppliers in SCM. The methodology has been demonstrated with the help of a case study in a steel plant.

Oguzhan & Erol (2016) showed that linear programming can used as a optimal solution two solve the problem. Such as, construct an initial procurement plan via linear programming model, considering the cost criterion as the first priority and solve a product transfer among suppliers. Finally, the model can be proposed to apply at international automotive car. Ghorbani et al. (2012) applied fuzzy MCDM technique for the selection of suppliers and proposed three phase multi criteria method that uses AHP and goal programming to the supplier selection problem.

2.5 Supplier Selection and Order Allocation

Supplier selection is one of the major problem of organizational competitiveness. The decisions on supplier selection are inherently complicated because of the necessity to consider simultaneously a variety of conflicting issues in a broad set of criteria from strategic to operational, and from quantitative to qualitative Hamdan & Cheaitou (2017). Order allocation is one of the most critical activities of purchasing management in a supply chain those are related with multiple criteria decision making problem including cost, quality, delivery and service etc. Integrated supplier selection and order allocation is an important decision for both designing and operating supply chains. This decision is often influenced by the concerned stakeholders, suppliers, plant operators and customers in different tiers.(Nazari-shirkouhi et al. 2013). Lee et al. (2015) provided optimum decision making for selecting and allocating order by applying the proposed method for integrated fuzzy TOPSIS and MCGP (Multi Choice Goal Programming) to make a final decision for supplier selection and order allocation that obtained by integrating the closeness coefficients model. Chen & Wu (2013) modified failure mode and effects analysis (FMEA) method to select new suppliers from the supply chain risk's perspective and applies the analytic hierarchy process (AHP) method to determine the weight of each criterion and sub-criterion for supplier selection. The sub criterion can be used to determine unsatisfactory suppliers with valuable feedback that will help them improve and become its partners in the future.

Moghaddam (2015) develop a fuzzy multi-objective mathematical model to identify and rank the candidate suppliers and find the optimal number of new and refurbished parts and final products in a reverse logistics network configuration. This modeling approach captures the inherent uncertainty in customers' demand, suppliers' capacity, and percentage of returned products as well as existence of conflicting objectives in reverse logistics systems. The other model for defining supplier selection and order allocation is at research of Jadidi et al. (2014), that research solve problem of supplier selection as a multi objective optimization problem where minimization of price, rejects and lead time. The aim is to achieve some levels of consistency among different objectives for the best supplier that will be chosen and defined the optimal allocation order for supplier. Guo & Li (2014) summarized the particular characteristics of the supply chain of Chinese petroleum enterprises, analyzed the limitations of the traditional methods of supplier selection, and brought forward the method based on case reasoning system for petroleum enterprises. The method based on data mining techniques which solves three key problems of CBR, includes calculating the weights of the attributes with information entropy in case warehouse organizing process objectively, evaluating the similarities with k-prototype clustering between the original and target cases in case retrieving process exactly, and extracting the potential rules with back propagation neural networks from conclusions in maintenance and revising process efficiently and the last determine optimum order allocation considering the weight of attributes.

Talluri and Narasimhan (2014) presented a model in which customers have to set the target score. This model utilizes two different LP models for maximizing and minimizing the supplier performance in order to provide a broad understanding of a supplier performance. Two years later, these researchers developed a Data Envelopment Analysis model (DEA) for telecommunications companies Amid *et al.*, (2012) formulated a mixed integer model to consider simultaneously the imprecision of information, and determine the quantities to each supplier based on price breaks. The proposed model set different objective functions by minimizing the net cost, net rejected items, and the net late deliveries. Satisfying capacity and demand requirement are also set as two difference constraints to determine the quantity of order allocation for each suppliers. Prasannavenkatesan & Goh (2016) proposed a web based decision support system for casting supplier evaluation by using AHP method. The authors specified 18 criteria, for example, Quality, Cost, and Delivery, and categorized into four groups, namely, product development capability, manufacturing capability, quality capability, and cost and delivery. Customers need to sign up to their system first, and then choose the casting specification located in the portal. Chan (2013) designed a method called chain of interaction using AHP to create the overall weights for nominated suppliers based on the relative importance ratings. Recently, García et al. (2013) proposed a fuzzy AHP approach for group decision making. To initialize and integrate the preferences of the group of decision makers, the author mixed fuzzy AHP with the geometric average method. The other example of combining supplier selection process and determine order allocation is in the research of Scott et al. (2015), that research proposed an integrated method for dealing with such problems using a combined Analytic Hierarchy Process Quality Function Deployment (AHP–QFD) and chance constrained optimization algorithm approach that selects appropriate suppliers and allocates orders optimally between them.

2.6 Research Position and Gap

Based on a review journal or paper that has been done, it is known that research on supplier selection have often done. However, research on supplier selection that considering the risk and transportation cost has never been done yet. Supplier selection decision model considering risk is important because companies have to know that the procedure can reduce the risk of errors in evaluation and selection of suppliers that will affect the company's production activities and also give impact to on time delivery for customers. The proposed model is to combine the supplier selection model considering analysis of risk in the research Oguzhan & Erol (2016) and supplier selection model and supplier order allocation considering transportation cost on research Pazhani et al. (2016).

Table 2.3 Research Position and Gap

No.	Author (Year)	**Supplier Selection Identification**		**Sourcing Type**		**Unit Analysis**			**Method**				Focus on Analysis
		Using analysis of Risk	Without analysis of Risk	Single Sourcing	Multi Sourcing	Procurement Planning	Green Supply Chain	Supplier Selection Process	Fuzzy	AHP	Linier Program ming	Goal Program ming	
1.	Chen & Wu (2013)	√		√				√		√			Weight of each criterion for supplier selection and supplier evaluation.
2.	Nazari-shirkouhi et al. (2013)		√	√		√		√	√				Supplier selection and order allocation problem via an interactive decision making process.
3.	Hamdan & Cheaitou (2017)		√		√		√		√				Supplier selection criteria and order allocation problem with green criteria.
4.	Pazhani et al. (2016)		√			√						√	Order quantities that affected by variations in supply chain costs parameters.
5.	Shaw et al. (2012)		√		√		√					√	Supplier Evaluation considering carbon emission.
6.	Oguzhan & Erol (2016)	√		√				√			√		Supplier selection process and order allocation for each supplier.
7.	Sodenkamp et al. (2016)		√	√				√				√	Weighted criteria and order allocation of supplier.
8.	Sawik (2013)		√	√				√				√	Stochastic scheduling for supplier selection.
9.	Tracey (2013)		√	√				√	√				Sub-Criterion for supplier selection.
10.	Hosseini et al. (2014)		√	√		√			√				Supplier ordering Cost and Weighted Factor.
11.	**This Research**	√			√	√					√		**The quantity of orders allocation among suppliers considering risk, price and transportation cost in single commodity multi supplier.**

Table 2.3 above shows the comparison of model previous research. In general, the proposed model resembles with previous model. Wherein, the model is used to determine order allocation suppliers according risk and transportation cost. However, unlike the models has been proposed by previous researchers, this research will observe an additional factor to the allocation order supplier problem. In this research the formulation of allocation orders suppliers is considering risk and transportation cost.

In this proposed model is concern on allocation order problem by considering risk and transportation cost as a parameter to optimize the solution for allocation order supplier. This research is focus in single commodity multi supplier problem.

CHAPTER 3
RESEARCH METHODOLOGY

In this chapter will be explained about all of the steps to do in this research.

3.1 Identification of Supply Chain Network

Identify of an efficient risk management can be maintained by dividing supply chain into elements such as suppliers, manufacturers, warehouses, distribution channel, etc. Fig 3.1 shows an example of supply chain network that consist of five suppliers and three manufacturers. Data that required to enable model development for supply chain network below are:

a. Capacity and unit purchasing price of each supplier.
b. Demand of each manufacturer/assembler.
c. Risk profile of each supplier.
d. Transportation cost from supplier to manufacturer/assemblers.

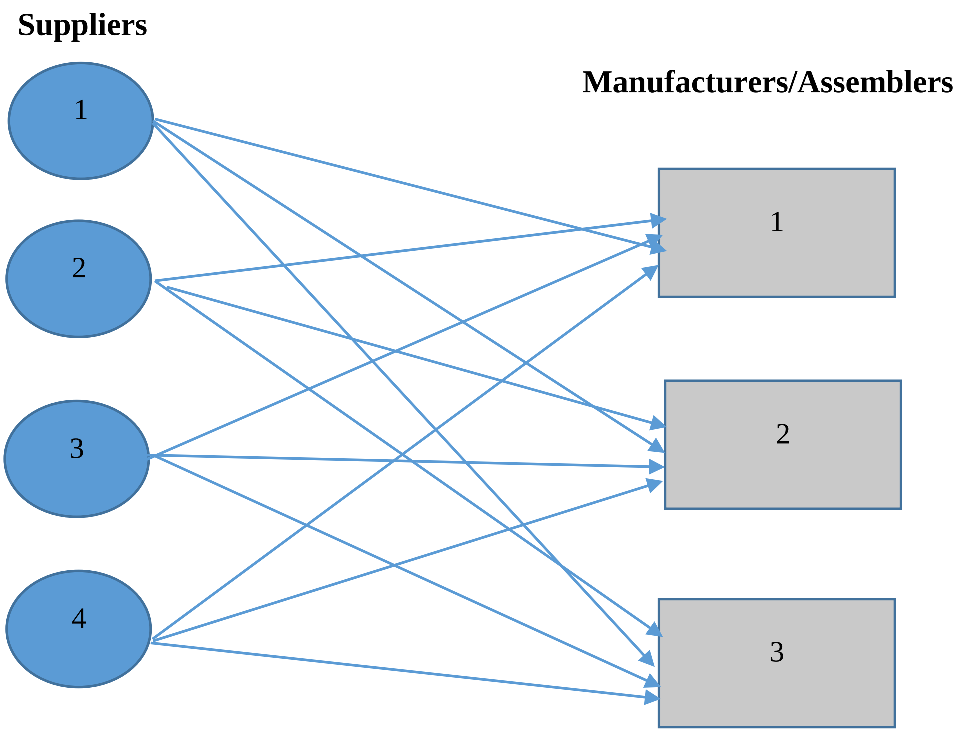

Figure 3.1 Supply Chain Network

3.2 Formulation the Minimum Cost of Procurement

In this procedure cost is considered to be the first priority goal. The problem can be solved by develop a model using a concept of a bipartite directed graph G(V_1 ∪ V_2 A), where V_2 is suppliers and the vehicles line V_2 is represent the manufacturing/assembly plants. The arcs in $A = V_1 \text{ x } V_2$ represent product flows between the suppliers and the manufacturing/assembly plan. In this step, an initial procurement plan is created using linier programming.

This formulation is initial procurement plan without considering risk factor. The objective function of formulation (3.1) is to minimize cost which consist of purchasing cost and transportation cost. The constraints include consideration of capacity and demand.

$$Mincost = \sum_{ieV_1} P_i \sum_{jeV_2} y_{ij} + \sum_{ieV_i} \sum_{jeV_2} T_{ij} * y_{ij} \quad (3.1)$$

$$\sum_{jeV_2} y_{ij} \leq C_i \; i \in V_1$$

$$\sum_{ieV_1} y_{ij} \leq D_j \; i \in V_2$$

$$y_{ij} \geq i \in V_1 , i \in V_2$$

Where :

i	: suppliers
J	: manufacturers/assemblers
P_i	: unit purchasing price of supplier i
y_{ij}	: quantity to be transported from supplier i to manufacturer j
T_{ij}	: unit transportation cost from supplier i to manufacturer j
C_i	: capacity of supplier i
Dj	: demand of manufacturer j

3.3 Risk Analysis

This stage performs risk identification and risk analysis. Risk identification is identified by Head of the General Secretariat based on assessment points as applied by the company and also the existing research. Risk identification will generate risk profile value for each supplier. Risk profile value use as a parameter in modifying the order of each supplier to each manufacturer. From risk parameter that used, risk profile will be modified that depends on the order quantity from a supplier which is found by minimum cost criterion to the risk profile of that supplier and the amount is transferred to a more reliable suppliers.

3.4 Product Quantity Transferred

There is not an actual product movement in this transfer but it is a transfer in plans. In other words, the revised procurement plan is put in action and products are ordered only after the analysis is done. Suppliers with relatively less cost and lower risk profiles are highly utilized considering capacity constraint. Since the model includes capacity constraints, the quantity to be transferred from suppliers with high risk profiles to suppliers with low profiles are limited to the capacity of the latter. After the transfer quantity is calculated, how much of it will be transferred to which supplier is determined via a linear programming model. In this directed network, there is an arc from supplier i to a relatively less risky supplier j. Decision variables (Xij) in the linear programming model are the product quantities transferred from supplier i to supplier j. The objective is to maximize the product flow from a risky supplier to a relatively less risky supplier. So the parameters of the decision variables in the objective function are the positive differences between the normalized risk values of suppliers.

The difference between suppliers in terms of risk is identified. For this, the total risk index (Rt) (risk profile) of the least risky supplier is set to zero and the risk profile value of this supplier is subtracted from the risk pro- files of other suppliers and then values are normalized. By this way, the risk differentiation between all suppliers is maintained (Table 3.1). (Let Supplier-2 be the least risky among suppliers). These normalized risk values represent the risk status of suppliers according to the least risky supplier. So, they can also be used to find the quantity to be transferred as a percentage of the initial procurement quantity (Table 3.2).

Table 3.1 Normalized Risk Value

Suppliers	Total Risk Value	Relative total risk values	Normalized values
Suppliers - 1	R_{t1}	R_{t1} - R_{t2}	$R_{N1} = (R_{t1} - R_{t2}) / R_{GT}$
Suppliers - 2	R_{t2}	0	$R_{N1} = 0$
Suppliers - 3	$R_{t.}$	$R_{t.}$ - R_{t2}	$R_{N.} = (R_{t.} - R_{t2}) / R_{GT}$
Suppliers - 4	R_{tn}	R_{tn} - R_{t2}	$R_{Nn} = (R_{tn} - R_{t2}) / R_{GT}$
Total		R_{GT}	1

Table 3.2 Parameters used in the model

Suppliers	Number of Product procured according to min cost	Normalized risk Values	Product to be transfer red	Product to be kept in the supplier	Remaining capacity of the supplier
Suppliers -1	Q_{c1}	R_{N1}	$Q_{c1} * R_{N1}$	$Q_{c1} – (Q_{c1} * R_{N1})$	RC_1
Suppliers -2	Q_{c2}	R_{N2}	$Q_{c2} * R_{N2}$	$Q_{c2} – (Q_{c2} * R_{N2})$	RC_2
Suppliers -3	$Q_{c.}$	$R_{N.}$	$Q_{c.} * R_{N.}$	$Q_{c.} – (Q_{c.} * R_{N.})$	$RC_.$
Suppliers -4	Q_{cn}	R_{Nn}	$Q_{cn} * R_{Nn}$	$Q_{cn} – (Q_{cn} * R_{Nn})$	RCn

The objective function of formulation (3.2) does not represent any quantity but since the objective function is maximization, it is explain the condition of transfer from a risky supplier to a less risky supplier. There is one constraint for the lowest and the highest risky nodes (suppliers) each and two constraints for all other nodes.

$$Maxz = \sum_{ij} N_{ij} * X_{ij} \tag{3.2}$$

$$\sum_{j}^{J} X_{ij} \leq \ Q_{Ti} \forall\, i \neq j$$

$$\sum_{k}^{K} X_{ki} - \sum_{j}^{J} X_{ij} \leq \ C_{Ri}$$

Where :

N_{ij}	: Positive difference between the normalized risk value of the node (supplier) i and node j
J	: indicates all suppliers less risky than supplier i
Q_n	: quantity to be transferred less risky than supplier i
K	: all suppliers more risky than supplier i
C_{rj}	: remained capacity of supplier i

3.5 Risk Evaluation

The risk management process is a cycle and the risk monitoring and control phase enables this process to be dynamic. Since risk is related to the future, events should be observed and the data about events should be updated and assessed all the time. This phase includes both observations about previous assessments and observations about changing situations and environment. New risks may be identified and or new judgments about previously identified risks may be revised by means of this phase. Information systems should be utilized and a high coordination and information sharing system should be established for efficient monitoring and control. Real time observation and tracking is also very critical for efficient risk monitoring.

3.6 Verification

Verification is the process to determine if the model can reflect the conceptual model appropriately. The purpose of verification is to solving the equation right. In this research, verification process can be analyzed from the output of the lingo.

Formulation of this research will be declared verified if the output of formulation meet two criteria below:

1. The number of orders to be delivered by each supplier does not exceed the capacity of each supplier.
2. The number of orders for each supplier have to fulfill the demand of each manufacturer.

CHAPTER 4
DATA COLLECTION AND PROCESSING

At the stage of data collection and processing will be explained regarding data required in conduct of processing data, such as data of suppliers, determination of risk profile criteria for each supplier, and data required to perform processing order allocation on each supplier.

4.1 Collecting Data

In this sub section describe data that used in this research will be described, the data included primary and secondary data. In this research, a case study conducted in PTPN X, especially in the general secretariat department for data of several sugar factory as member of PTPN X, such as PG.Lestari, PG. Djombang Baru and PG.Meritjan. The data used in this study includes data supplier **soda caustic** products are used as supporting data for order allocation decisions to supplier.

PTPN X has 4 suppliers for providing soda caustic as material that supports sugar production process. The first supplier is PT.Verona Multikimia Abadi that located at Wonokitri Indah Blok S-31, Surabaya. The second supplier is PT.Cipta Teknik Abadi that located at Jalan Dr.Ciptomangunkusumo No.16, Semarang. The third supplier is PT. Kharisma Putra Jaya that located at Jalan Pahlawan No.70, Surabaya at Jalan Pahlawan No.70, Surabaya. Fourth supplier is PT. Widya Cipta Teknik at Jalan Ketintang Baru Selatan I/30, Surabaya.

The information below is decision supporting data of order allocation for all suppliers that provide soda caustic for sugar production process, purchasing capacity and unit price of each supplier is in table 4.1, demand of each sugar factory is in table 4.2

Table 4.1 Capacity and Unit Purchasing Price of Each Supplier

Suppliers	**1**	**2**	**3**	**4**	**Total**
Capacity (C_i) per kg	31800	30200	29450	28800	120250
Unit Price (P_i) per kg	8300	8100	8400	8650	33450

Source : PTPN X

Table 4.2 Demand of each Manufacturer/Assembler

Manufacturers/assemblers	**1**	**2**	**3**	**Total (kg)**
Demand (D_j) - kg	38400	34600	29650	102650

Source : PTPN X

Transportation Costs from suppliers to manufacturers/assemblers (T_{ij})

Table 4.3 Transportation Costs from Suppliers to Manufacturers from Expedition Company

		Manufacturers/assemblers (j)		
		1	**2**	**3**
Suppliers (i)	**1**	Rp 1.400.000	Rp 1.220.000	Rp 1.550.000
	2	Rp 2.150.000	Rp 2.250.000	Rp 2.100.000
	3	Rp 1.450.000	Rp 1.250.000	Rp 1.600.000
	4	Rp 1.300.000	Rp 1.250.000	Rp 1.500.000

Source : PTPN X

From transportation costs in Table 4.3, it can be seen that unit transportation cost for each supplier to the manufacturers according to the pattern of distribution. Formulations for calculating unit transportation cost is as follows:

Unit transportation cost (T_{ij}) = $\frac{\text{Transportation Cost}}{Truck\ Capacity\ (kg)}$

In this research, it is assumed that all soda caustic delivered by trucks with capacity 22 ton = 22000 kg.

Example calculation for Unit Transporation Cost (T_{ij}) from supplier 1 to manufacturer 1

Unit transportation cost (T_{11}) = $\frac{\text{Rp 1.400.000}}{22000\ kg}$ = Rp 63,64/kg

Example calculation for Unit Transporation Cost (T_{ij}) from supplier 2 to manufacturer 2

Unit transportation cost (T_{22}) = $\frac{\text{Rp 2.250.000}}{22000\ kg}$ = Rp 102,27/kg

Table 4.4 Unit Transportation Costs from Suppliers to Manufacturers

		Manufacturers/assemblers (j)		
		1	**2**	**3**
Suppliers (i)	**1**	63.64	55.45	70.45
	2	97.73	102.27	95.45
	3	65.91	56.82	72.73
	4	59.09	56.82	68.18

4.2 Risk Profile.

There are some criteria in determining risk profile of each supplier that's done through brainstorming with the company based on the approach of Dickson's Vendor Selection Criteria. Based on the results of literature review and brainstorming that we obtained a set of criteria by PTPN X to determine risk profile for each supplier, in this study:

1. Price

   Price of material is the main criteria for assessing the risks that could be caused by inconsistencies in pricing and the price is too high that can cause financial loses for the company. Supplier with cheaper prices of material will be a priority in the selection process.

2. Quality

   Quality of products delivered by the suppliers are the criteria that should be considered in assessing suppliers. Because the quality of delivered material will have an influence in sugar production process. Suppliers that has a good quality of materials, then it will be a priority in the supplier selection and order allocation because it can reduce the risk of delays in the production process.

3. Delivery

   Delivery is an important factor that should be assessed for the suppliers because if materials ordered has been delayed, it will make sugar production process interrupted. In this delivery process there are some risk posed by suppliers to be controlled, such as delay in delivery process, low distribution capability and transportation failure.

4. Service

   Service provided by suppliers have a variety of risks that can be caused, such as low flexibility, level of difficulty to be contacted, low responsibility of after sales service, difficulty of compliance procedure. All that risk is very detrimental for sugar factory therefore all of risk factors must be controlled and received special attention.

5. Supplier ability

   The ability of suppliers to know and understand give positive effect to the company. But if it can't be fulfilled then it will be detrimental to the sugar factory as a result of the risks posed, such as the low professionalism of suppliers and suppliers can't fulfill the demand.

6. Safety

   Safety is an important factor for all business units including suppliers because errors and losses can occur because safety is less controlled, There are some risks that can be appear due to low protection of safety management and low protection of extreme weather condition.

The following information is a table of risk profiles for suppliers, which will be filled by a part of the general secretariat as the people that directly have a process with suppliers.

Table 4.5 Risk Profile

Risk	Sub Risk	1	2	3	4	5	Total
Price	Unstable of Product price						
	High Delivery cost						
Quality	Product quality is below the standard						
	Specification of product in not appropriate						
Delivery	Delay in delivery process						
	Low Distribution capability						
	Transportation failure						
Service	Low Flexibility						
	Level of difficulty to be contacted						
	Low responsibility of after sale service						
	Difficulty of Compliance Procedure						

Table 4.5 Risk Profile (Cont.)

Risk	Sub Risk	1	2	3	4	5	Total
Supplier ability	Low professionalism of supplier						
	Supplier can’t fulfill the demand						
Safety	Low protection of Safety management						
	Low protection of extreme weather condition						
TOTAL							

Adapted from Prasannavenkatesan & Goh (2016) and Nazari-shirkouhi et al. (2013)

Risk Assessment Profile for each suppliers was conducted by head of the Department of the General Secretariat and the data obtained as follows.

Table 4.6 Risk Profile of each Supplier.

	Supplier 1	Supplier 2	Supplier 3	Supplier 4
Risk profiles (R_{Ti})	58	24	44	32

According to the risk profile data at Table 4.6, Supplier 2 has the lowest risk profile value and Supplier 1 has the highest risk profile value. Lower risk profile value equals to lower risk, hence the order allocation should be assigned firstly to the supplier that has the lowest risk profile value.

4.3 Procurement Plan

This procurement plan is obtained without consideration of risk profile. The procurement quantity of each supplier found by the cost criterion should be modified in proportion to its risk profile. The formulation is developed to consider the supply chain network in figure 4.1 below.

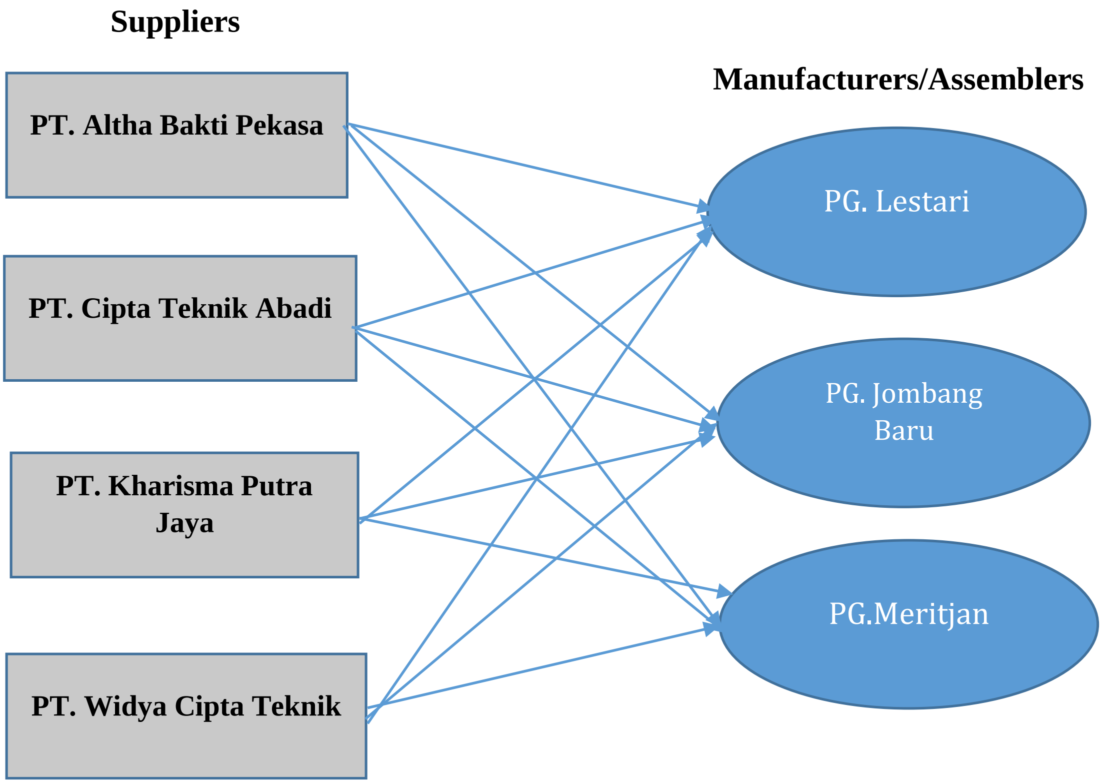

Figure 4.1 Supply Chain Network

From scheme of supply chain network in Figure 4.1, it can be seen that all of the four suppliers has to supply all manufacturers. To make an optimal order allocation, we use the following model to minimize procurement cost:

$$Mincost = \sum_{ieV_1} P_i \sum_{jeV_2} y_{ij} + \sum_{ieV_i} \sum_{jeV_2} T_{ij} * y_{ij} \qquad (4.1)$$

$$\sum_{jeV_2} y_{ij} \leq C_i \; i \in V_1$$

$$\sum_{ieV_1} y_{ij} \leq D_j \; i \in V_2$$

$$y_{ij} \geq \; i \in V_1 \, , i \in V_2$$

Where :

i	: suppliers
J	: manufacturers/assemblers
P_i	: unit purchasing price of supplier i
y_{ij}	: quantity to be transported from supplier i to manufacturer j
T_{ij}	: unit transportation cost from supplier i to manufacturer j
C_i	: capacity of supplier i
Dj	: demand of manufacturer j

The objective function of formulation (4.1) is to minimize cost which consist of purchasing cost and transportation cost. The constraints include consideration of capacity and demand.

<u>Objective function : minimize procurement cost :</u>

Mincost = $(8300 + 63.64)\, y_{11} + (8300 + 55.45)\, y_{12} + (8300 + 70.45)\, y_{13} + (8100 + 97.73)\, y_{21} + (8100 + 102.27)\, y_{22} + (8100 + 95.45)\, y_{23} + (8400 + 65.91 y_{31} + (8400 + 56.82)\, y_{32} + (8400 + 72.73)\, y_{33} + (8650 + 59.09)\, y_{41} +(8650 + 56.82)\, y_{42} + (8650 + 68.18)\, y_{43}$

Mincost = $8364y_{11} + 8355y_{12} + 8370y_{13} + 8198y_{21} + 8202y_{22} + 8195y_{23} + 8466y_{31} + 8457y_{32} + 8473y_{33} + 8709y_{41} + 8707y_{42} + 8718y_{43}$

Subject To

$y_{11} + y_{12} + y_{13} \leq 31800$

$y_{21} + y_{22} + y_{23} \leq 30200$

$y_{31} + y_{32} + y_{33} \leq 29450$

$y_{41} + y_{42} + y_{43} \leq 28800$

$y_{11} + y_{21} + y_{31} + y_{41} \leq 38400$

$y_{12} + y_{22} + y_{32} + y_{42} \leq 34600$

$y_{13} + y_{23} + y_{33} + y_{43} \leq 29650$

Optimal Solution of processing the formulation using LINGO software, as follows.

Table 4.7 Optimal Solution Lingo

Manufacturers/Assemblers (j)					
		1	**2**	**3**	**Total (kg)**
Suppliers (i)	**1**	0	31800	0	31800
	2	550	0	29650	30200
	3	26650	2800	0	29450
	4	11200	0	0	11200
Total (kg)		38400	34600	29650	102650

Table 4.7 shows the optimal order allocation for each supplier to each manufacturer, In accordance with the objective function, constrains and data of PTPN X (PG.Lestari, PG. Djombang Baru and PG.Meritjan). So to fulfill the demand of each Sugar Factory Supplier 1 have to supply 31800 kg for manufacturer 2, Supplier 2 have to supply 550kg for Manufacturer 1 and 29650 kg for manufacturer 3, Supplier 3 have to supply 26650 kg for manufacturer 1 and 2800 kg for manufacturer 2 and Supplier 4 have to supply 11200 kg for manufacturer 1.

However, the order allocation in Table 4.7 is not optimal because it had not considered the risk factor. In this study, risk factor was included in the procurement plan to reduce risk in determining the order allocation between supplier and manufacturer. By using risk as factor to determine order allocation, it will produce an optimal order allocation. Optimal order allocation in this study was presented that order allocation started from a supplier that has a low risk factor to minimize the order on suppliers that have the higher risk factor. The risk factors in this study presented in the form of risk profile.

4.4 Procurement Plan based on Risk Value

According to Table 4.9, Supplier 2 is the most reliable and Supplier 1 is the most risky supplier. Product Transfer will perform from a risky suppliers to a relatively risky supplier by using value in Table 4.9. In order to achieve this, the value of 24 is the most reliable, is subtracted from other supplier's risk profile values. Since there will be no product transfer from suppliers 1 to others, zero is the base value and the differences between the risk profiles of suppliers remain the same. Finally, these values are normalized.

The product transfer network based on risk profiles of suppliers is presented in fig. 4.2 and parameters used in the model are presented in Table 4.10 and Table 4.11.

Table 4.8 Normalized Risk Value

Suppliers	Total Risk Value	Relative total risk values	Normalized values
Suppliers – 1	58	58-24=34	$R_{N1} =$ (34-0)/63=0.54
Suppliers – 2	24	0	$R_{N2} =$ 0
Suppliers – 3	44	44-24=20	$R_{N3} =$ (20-0)/63=0.32
Suppliers – 4	32	32-24 = 9	$R_{N4} =$ (9-0)/63= 0.14
	Total	63	1

Table 4.9 Parameters used in the Model

Suppliers	Number of Product procured according to min cost	Normalized risk Values	Product to be transferred	Product to be kept in the supplier	Remaining capacity of the supplier
Suppliers -1	31800	0.54	17172	14628	0
Suppliers -2	30200	0	0	30200	0
Suppliers - 3	29450	0.32	9424	20026	0
Suppliers - 4	11200	0.14	1568	9632	17600

Illustration in Figure 4.1 below was made based on value and calculation in Table 4.9 which is the existing parameters on the model that including the risk. Shifting order illustration began from maximizing order for supplier that has the lowest risk profile value (Supplier 2), therefore first pattern was made for directing the order from all other supplier to supplier 2. The amount of order reallocated to supplier 2 should not exceed its constraint, therefore the excess supply order for supplier 2 will be directed to the supplier that has the second lowest risk profile value (Supplier 4). The same steps repeated for reallocating the excess supply order from Supplier 4 to the next supplier that has larger value of risk profile than Supplier 4 (in this case supplier 3).

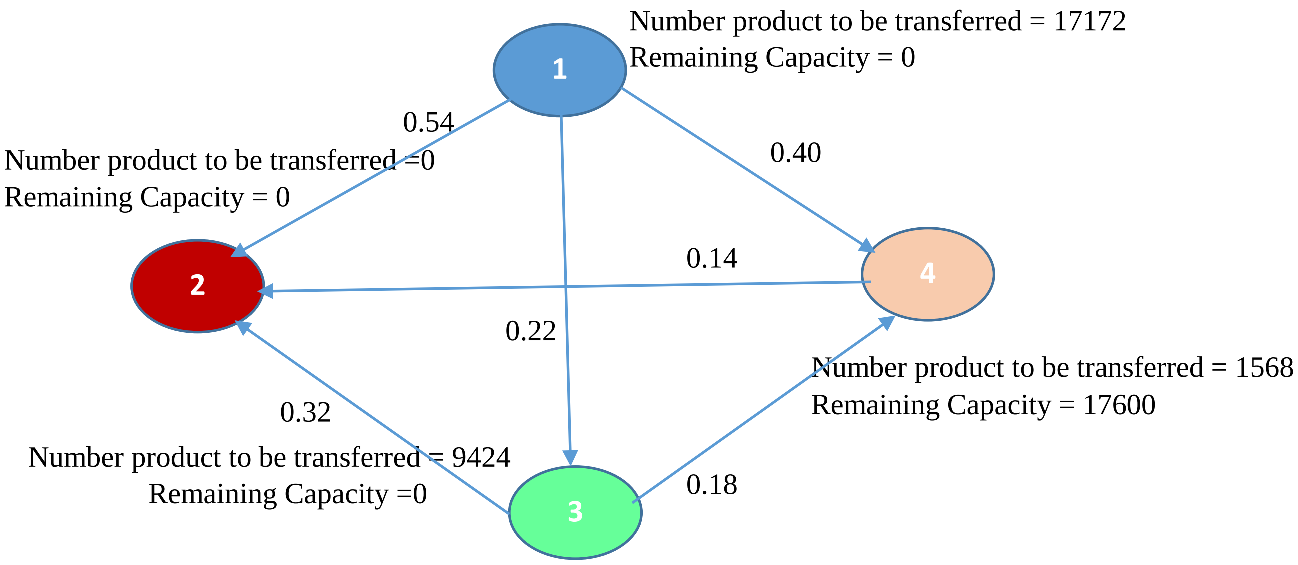

Figure 4.2 Illustration of shifting order between suppliers

Table 4.10 Recapitulation The Difference between the Normalized Risk Values of Suppliers (R_{ij})

R_{12}	R_{32}	R_{42}	R_{14}	R_{34}	R_{13}
0.54	0.32	0.14	0.40	0.18	0.22

Table 4.10 shows the recapitulation of normalized value of risk between suppliers. Normalized risk value will be used as a value in objective function for formulation (4.2) The objective function of formulation (4.2) does not represent any quantity but since the objective function is maximization, it determines condition of transfer from a risky supplier (supplier with relatively higher risk profile value) to a less risky supplier (supplier with relatively less risk profile value). The model to transfer the product from a risky supplier to a relatively less risky supplier is:

$$Maxz = \sum_{ij} N_{ij} * Y_{ij} \tag{4.2}$$

$$\sum_{j}^{J} X_{ij} \leq Q_{Ti} \forall i \neq j$$

$$\sum_{k}^{K} X_{ki} - \sum_{j}^{J} X_{ij} \leq C_{Ri}$$

Where :

N_{ij}	: Positive difference between the normalized risk value of the node (supplier) i and node j
J	: indicates all suppliers less risky than supplier i
Q_n	: quantity to be transferred less risky than supplier i
K	: all suppliers more risky than supplier i
C_{Ri}	: remained capacity of supplier I
X_{ij}	: number of products to be transferred from supplier i to supplier j

<u>Objective Function : maximize transfer product according to normalized risk value:</u>

Max Z = $0.54*X_{12} + 0.32X_{32} + 0.14*X_{42} + 0.40*X_{14} + 0.18*X_{34} + 0.22*X_{13}$

Subject To

$X_{12} + X_{13} + X_{14} \leq 17172$

$X_{12} + X_{32} + X_{42} \leq 0$

$X_{13} - X_{32} - X_{34} \leq 0$

$X_{32} + X_{34} \leq 9424$

$X_{14} + X_{34} - X_{42} \leq 17600$

$X_{42} \leq 1568$

$X_{ij} \geq 0$

The formulation is solved via LINGO and the optimal solution is presented in Table 4.13 below.

Table 4.11 Optimal Solution Lingo Considering Risk

R_{12}	R_{32}	R_{42}	R_{14}	R_{34}	R_{13}
0	0	0	17172 kg	9424 kg	0

In conclusion, the optimal solution was the solution before conducting risk analysis subtracted with solution after conducting risk analysis.

R_{14} = 17172 kg, means that Supplier 1 have to minus 17172 kg of their supply and supplier 4 have to add 14431kg of their supply.

Supplier 1 = 31800– 17172 = 14628 kg

Supplier 4 = 11200 + 17172 = 28372 kg

R_{34}= 9424 means that Supplier 3 have to minus 9424 kg of their supply and supplier 4 have to add 9424 kg of their supply.

Supplier 3 = 29450 – 9424 = 20026 kg

Supplier 4 = 28372 + 9424 = 37796 kg

Table 4.12 Optimal Solution of Order Allocation According Risk

Manufacturers/Assemblers (j)					
		1	**2**	**3**	**Total (kg)**
Suppliers (i)	**1**	0	14628	0	14628
	2	550	0	29650	30200
	3	17226	2800	0	20026
	4	20564	17172	0	37796
Total (kg)		38400	34600	29650	102650

Optimal Solution in Table 4.12 is the optimal solution that has considered the risk aspects that have been processed by Lingo according to the formulations (4-2). This solution is focused on prioritizing the order allocations based on the risk profile. Table 4.12 shown the order allocation of each supplier for each manufacturers,. in accordance with the objective functions, constrains, data of PTPN X (PG.Lestari, PG. Djombang Baru and PG.Meritjan) and also risk profile. So to fulfill demand of each Sugar Factory Supplier 1 have to supply 14628 kg for Manufacturer 2, Supplier 2 have to supply 550 kg for Manufacturer 1 and 29650 kg for manufacturer 3, Supplier 3 have to supply 17226 kg for supplier 1 and 2800 kg for manufacturer 2 and Supplier 4 have to supply 20564 kg to manufacturer 1 and 17172 to manufacturer 2.

Table 4.13 Modified Procurement Plan

Current Procurement Plan		**Modified Procurement Plan**		**Decrease**	**Increase**	**Percentage (%)**
Supplier 1	31800 kg	**Supplier 1**	14628 kg	17172 kg	0	(–) 54%
Supplier 2	30200 kg	**Supplier 2**	30200 kg	0	0	0
Supplier 3	29450 kg	**Supplier 3**	20026 kg	9424 kg	0	(–) 32%
Supplier 4	11200 kg	**Supplier 4**	37796 kg	0	26596 kg	(+) 42%
Total (kg)	102650 kg	**Total(kg)**	102650 kg			

Modified procurement plan in Table 4.13 was a comparison between optimal solution of data processing that not considering risk and optimal solution of data processing that including risk. Table 4.13 also shown order allocation changing in supplier 1,3, and 4. Supplier 1 should decrease 54% of total supply order, supplier 3 should decrease 32% of their supply order; while supplier 4 should increase 42% of supply order. This condition occurred because supplier 1 and supplier 3 has relatively higher risk profile value so both of supplier 1 and 3 have to decrease their order allocation and reallocate their order to the supplier that has relatively less risk profile value (supplier 4), therefore supplier 4 should increase their supply order. There was no changing order allocation for supplier 2 because the number of supply is already reach the maximum capacity.

4.5 Model Verification

In this research, verification process can be analyzed from the output of the computation. Referring to formula (4.1) and (4.2), the formulation of these problems will be verified against the two criteria below :

1. The number of orders to be delivered by each supplier does not exceed the capacity of suppliers.
2. The number of orders for each supplier have to fulfill the demand of each manufacturer.
3. For Order Allocation according risk profile, the order have to maximized at supplier that have relatively lower risk profile

From the optimal solutions in Table 4.7 and 4.12 can be determined that both of those solutions meet the above criteria.

4.6 Sensitivity Analysis

After performing the calculation and data processing using the proposed model, sensitivity analysis is conducted to determine the impact in system if some of the parameters changed.

4.6.1 Sensitivity Analysis for demand

Sensitivity analysis is done by changing the value of demand. Changes in the value of demand will have a different variation in in each scenario. In this scenario, the parameter that will be changed is only for demand, so the risk factors that is in this research risk profile using the same parameters as shown in Table 4.8.

a. Scenario 1 : Increase 5% of each manufactures demand

Table 4.14 Demand for Scenario 1a

Manufacturers/assemblers	**1**	**2**	**3**	**Total (kg)**
Demand (D_i) - kg	40320	36330	31133	107783

By using the formula (4-1) and (4-2), the optimal solution is obtained as follows:

Table 4.15 Optimal Solution Lingo Considering Risk Scenario 1a

		Manufacturers/Assemblers (j)			
		1	**2**	**3**	**Total (kg)**
Suppliers (i)	**1**	0	17600	933	18533
	2	0	0	30200	30200
	3	23987	5463	0	29450
	4	16333	12467	0	28800
Total (kg)		40320	36330	31333	107783

From Table 4.15 can be determined that increasing number of demand affect the order of allocation patterns for each suppliers. If compared to optimal solution in Table 4.12 with the optimal solution by increasing demand 5% in Table 4.15, it is found that Supplier 1 that previously served to supply demand for manufacturer 2, now supplier 1 have to supply manufacturer 2 and 3 with the number of supply orders greater than previous supply for manufacturer 2. Supplier 2 that previously served to supply demand for manufacturer 1 and 3, now supplier 2 have to supply manufacturer 3 with the number of supply orders lower than previous supply for manufacturer 3. Supplier 3 in previous optimal solution and new optimal solution have the same pattern to supply order, those are supply order for manufacturer 1 and 2 with the number of supply order is greater for both manufacturers. And the last, for supplier 4 also have the same pattern for order allocation, those are supply order for manufacturer 1 and 2 with the number of supply fewer than previous order.

b. Scenario 2 : Give variation with increase and decrease 10% of each manufacturer demand

Table 4.16 Demand for Scenario 2a

Manufacturers/assemblers	**1**	**2**	**3**	**Total (kg)**
Demand (D_i) - kg	42240	38060	32615	112915

By using the formula (4.1) and (4.2), the optimal solution is obtained as follows:

Table 4.17 Optimal Solution Lingo Considering Risk Scenario 2a

Manufacturers/Assemblers (j)					
		1	**2**	**3**	**Total (kg)**
Suppliers (i)	**1**	0	29385	2415	31800
	2	0	0	22865	22865
	3	20775	1340	0	22115
	4	21465	14670	0	36135
Total (kg)		42240	38060	32615	112915

From Table 4.17 can be determined that increasing number of demand affect the order of allocation patterns for each suppliers. If compared to optimal solution in Table 4.12 with the optimal solution by increasing demand 5% in Table 4.17, it is found that Supplier 1 that previously served to supply demand for manufacturer 2, now supplier 1 have to supply manufacturer 2 and 3 with the number of supply orders greater than previous supply for manufacturer 2. Supplier 2 that previously served to supply demand for manufacturer 1 and 3, now supplier 2 have to supply manufacturer 3 with the number of supply orders lower than previous supply for manufacturer 3. Supplier 3 in previous optimal solution and new optimal solution have the same pattern to supply order, those are supply order for manufacturer 1 and 2 with the number of supply order is greater for both manufacturers. And the last, for supplier 4 also have the same pattern for order allocation, those are supply order for manufacturer 1 and 2 with the number of supply fewer than previous order. So, it can be concluded that by increasing 5% and 10% of demand have the same effect to the number of order allocation and pattern of shifting order among suppliers.

4.6.2 Sensitivity Analysis for Risk Profile

In this study, the emphasis is the determination of the order allocation to the supplier by considering risks factor Therefore sensitivity analysis is also associated with risk aspects, the form of risk aspect is risk profile. Sensitivity analysis according to risk profile is needed to know the changing pattern of order allocation. In this sensitivity for a number of Product procured According to the minimum cost is fixed use the calculation done using the lingo in Table 4.9.

a. Scenario 1 : Changing the risk of each supplier, suppliers who previously has the smallest risk change into greatest value of risk profile, also have same rule with opposite

Table 4.18 Risk Profile for Scenario 1b

	Supplier 1	**Supplier 2**	**Supplier 3**	**Supplier 4**
Risk profiles (R_{Ti})	54	46	20	30

By using the formula (4-2), the optimal solution is obtained as follows:

Table 4.19 Optimal Solution Lingo Considering Risk Scenario 1b

Manufacturers/Assemblers (j)					
		1	**2**	**3**	**Total (kg)**
Suppliers (i)	**1**	0	17118	0	17118
	2	550	0	29650	30200
	3	26650	2800	0	29450
	4	11200	17482	0	25882
Total (kg)		38400	34600	29650	102650

From Table 4.19 can be determined that changes in the value of risk profile give affect to the changing of order allocation for each supplier. That condition occurs because the order allocation is maximized for supplier that had relatively less risk profile value and minimized the order allocations for suppliers with relatively high risk value. Results from Table 4.19 can be determined that the lowest number of order allocation was for supplier 1 because supplier 1 have highest number of risk profile value. All of the supply order in Table 4.19 have the same pattern of order allocation compare with optimal order allocation in Table 4.12, but have different number of order allocation depend on the value of risk profile.

b. Scenario 2 : Changing the risk of each supplier, Supplier 4 that previously have the second greater number of risk profile now supplier 4 have the second fewer number of risk profile.

Table 4.20 Risk Profile for scenario 2b

	Supplier 1	**Supplier 2**	**Supplier 3**	**Supplier 4**
Risk profiles (R_{Ti})	39	48	35	26

By using the formula (4-2), the optimal solution is obtained as follows:

Table 4.21 Optimal Solution Lingo Considering Risk Scenario 2b

Manufacturers/Assemblers (j)					
		1	**2**	**3**	**Total (kg)**
Suppliers (i)	**1**	0	31800	0	31800
	2	790	0	14320	15110

Table 4.21 Optimal Solution Lingo considering risk scenario 2b (Cont.)

Manufacturers/Assemblers (j)					
		1	**2**	**3**	**Total (kg)**
Suppliers (i)	**3**	26410	2800	0	29210
	4	11200	0	15330	26630
Total (kg)		38400	34600	29650	102650

From Table 4.21 can be determined that changes in the value of risk profile give affect to the changing of order allocation for each supplier. The condition occurs because the order allocation is maximized for supplier that had relatively less risk profile and minimized the allocation of orders for suppliers with the relatively high risk value. From Table 4.21 can be seen that supplier 1 have to supply 31800 kg for manufacturer 2, supplier 2 have to supply order 790 kg to manufacturer 1 and 14320 kg to manufacturer 3. In addition the supplier 3 have to supply 26410 kg to manufacturer 1 and 2800 kg for manufacturer 2 and also for supplier 4 have to supply 11200 kg to manufacturer 1 and 15330 kg for manufacturer 3. It is known that supplier order allocation is maximized at supplier 1,3 and 4 because those supplier had a relatively less number of risk profile. And the smallest number of order allocation is for supplier 2 because supplier 2 had the greatest number of risk profile.

c. Scenario 3 : Changing the risk of each supplier, Supplier 2 has the largest risk profile value and supplier 1 has the lowest risk profile value

Table 4.22 Risk Profile for scenario 3b

	Supplier 1	**Supplier 2**	**Supplier 3**	**Supplier 4**
Risk profiles (R_{Ti})	22	56	42	34

By using the formula (4-2), the optimal solution is obtained as follows:

Table 4.23 Optimal Solution Lingo Considering Risk Scenario 3b

		Manufacturers/Assemblers (j)			
		1	2	3	Total (kg)
Suppliers (i)	1	0	31800	0	31800
	2	550	0	9724	10274
	3	30576	2800	0	33376
	4	7274	1600	19926	28800
Total (kg)		38400	36200	29650	102650

From Table 4.23 can be determined that changes in the value of risk profile give affect to the changing of order allocation for each supplier. From Table 2.23 can be seen that supplier 1 have to supply 31800 kg for manufacturer 2, supplier 2 have to supply 550 kg to manufacturer 1 and 9724 kg to manufacturer 3. In addition the supplier 3 have to supply 30576 kg to manufacturer 1 and 2800 kg to manufacturer 2. Supplier 4 have to supply 7274 kg to manufacturer 1600 kg to manufacturer 2 and 19926 kg to manufacturer 3. It is known that supply of order is minimized in supplier 2 has the largest risk profile value.

d. Scenario 4 : Changing the risk of each supplier, Supplier 3 has the largest risk profile value and supplier 2 has the lowest risk profile value

Table 4.24 Risk Profile for scenario 4b

	Supplier 1	Supplier 2	Supplier 3	Supplier 4
Risk profiles (R_{Ti})	30	21	58	41

By using the formula (4-2), the optimal solution is obtained as follows:

Table 4.25 Optimal Solution Lingo Considering Risk Scenario 4b

		Manufacturers/Assemblers (j)			
		1	2	3	Total (kg)
Supplier (i)	1	0	31800	0	31800
	2	550	0	29650	30200
	3	12219	2800	0	15019
	4	25631	0	0	25631
Total (kg)		38400	34600	29650	102650

From Table 4.25 can be determined that changes in the value of risk profile give affect to the changing of order allocation for supplier 1, 3 and 4. From Table 4.25 can be seen that supplier 1 have to supply 31800 kg for manufacturer 1 Supplier 3 have to supply 12219 kg to manufacturer 1 and 2800 kg to manufacturer 2. Supplier 4 have to supply 25631kg to manufacturer 1. It is known that fewer order allocation is at supplier 3 because supplier 3 has the highest number of risk profile. And order allocation is maximized in supplier 1 and 2 because both supplier had lower risk profile value.

e. Scenario 5 : Changing the risk of each supplier, Supplier 1 has the largest risk profile value and supplier 2 has the lowest risk profile value

Table 4.26 Risk Profile for scenario 5b

	Supplier 1	Supplier 2	Supplier 3	Supplier 4
Risk profiles (R_{Ti})	24	43	50	33

By using the formula (4-2), the optimal solution is obtained as follows:

Table 4.27 Optimal Solution Lingo Considering Risk Scenario 5b

		Manufacturers/Assemblers (j)			
		1	**2**	**3**	**Total (kg)**
Suppliers (i)	**1**	0	31800	0	31800
	2	0	0	26736	26736
	3	12514	2800	0	15314
	4	25886	0	2914	28800
Total (kg)		38400	34600	29650	102650

From Table 4.27 can be determined that changes in the value of risk profile give affect to the changing of order allocation for each supplier. The condition occurs because the order allocation is maximized for supplier that had relatively less risk profile and minimized the allocation of orders for suppliers with the relatively higher risk value. From Table 4.23 can be seen that order allocation is minimized at supplier 3 because supplier 3 has the highest risk profile value, beside that order allocation is maximized at supplier 1 supplier 1 has the lowest value of risk profile.

4.6.3 Sensitivity Analysis for Price

Sensitivity analysis is done by changing the value of price. Changing value of price will have a different variation for each scenario. Because this sensitivity analysis process only give changed value of price, then for the risk factors in this part is use same parameters as the values in Table 4.8.

a. Scenario 1 : Increase 10% price of soda caustic for supplier 1 and 2 and decrease 10% price for supplier 3 and 4

Table 4.28 Purchasing Price of each Supplier Scenario 1c

Suppliers	**1**	**2**	**3**	**4**	**Total**
Unit Price (P_i)	9130	8910	7560	9515	35115

By using the formula (4-1) and (4-2), the optimal solution is obtained as follows:

Table 4.29 Optimal Solution Lingo Considering Risk Scenario 1c

Manufacturers/Assemblers (j)					
		1	**2**	**3**	**Total (kg)**
Suppliers (i)	**1**	31800	0	0	31800
	2	6600	19286	2316	28202
	3	0	15314	0	15314
	4	0	0	27334	27334
Total (kg)		38400	34600	29650	102650

From Table 4.29 can be determined that the changing value of price give significant influence, but sequence order allocation for suppliers to manufacturer have the same pattern with the previous optimal solution, but there was change in number of order allocation for all suppliers. Decreasing order allocation that contained in supplier 3 and 4, and also increasing order allocation on suppliers 1, that condition occurs because the scenario give plan for increasing 10% price for supplier 1 and decreasing 10% price for supplier 3 and 4.

b. Scenario 2 : Increasing 15% price of soda caustic for supplier 2 and 4, decrease 15% price for supplier 1 and 3.

Table 4.30 Purchasing Price of each Supplier 2c

Suppliers	**1**	**2**	**3**	**4**	**Total**
Unit Price (P_i)	7055	9315	7140	9948	33458

By using the formula (4-1) and (4-2), the optimal solution is obtained as follows:

Table 4.31 Optimal Solution Lingo Considering Risk Scenario 2c

		Manufacturers/Assemblers (j)			
		1	**2**	**3**	**Total (kg)**
Suppliers (i)	**1**	0	31800	0	31800
	2	10216	2800	12050	25066
	3	16984	0	0	16984
	4	0	0	28800	28800
Total (kg)		27200	34600	40850	102650

From Table 4.31 can be determined that the changing value of price give significant influence, Decreasing of order allocation that contained in supplier 2 and increasing of order allocation in supplier 3, that condition occurs because the scenario give plan for increasing 10% price for supplier 3 and decreasing 10% price for supplier 2.

CHAPTER 5

ANALYSIS AND DISCUSSION

This chapter described analysis of calculation about order allocation that considering risks factor and transportation cost that was done before in Chapter 4.

5.1 Order Allocation to Suppliers Considering Risk and Transportation Cost

This research is the development of research that have been much earlier for supplier selection and allocation of orders to suppliers. But in this study the development concept of is about order allocation between suppliers consider the risks and transportation cost. This is done to optimize the results of order allocation between suppliers. It can be seen from the results in Chapter 4, the comparison between Table 4.9 and 4.14 that can be known that the results of the allocation of orders that have not been considered the risk and that has been considered the risk have different pattern of order allocation according to risk factors where in this research is risk profile. By considering the risk profile, the highest order allocation will be maximized in a supplier that has a relatively less number of risk profile and minimize order allocation on suppliers who have relatively high values of risk profile. Beside that, this research also considered transportation cost, because to create the procurement cost also have to include transportation cost and complete with purchasing cost to the objective functions. Both of those cost is included in objective function to determine minimize procurement cost and optimal order allocation that also considering demand of each manufacturer and capacity of each supplier.

5.2 Solution Based on Different Objective Functions

At this stage is the initial stage of determining the parameters used to determine the objective functions of the formulation. In this research, there are two formulations so that there are two objective function, namely

1. The first objective function is to minimize procurement cost is using two parameters, those are considered price and transportation cost as an input to the

formulation

2. The second objective function is to maximize the allocation of orders based on risk parameters that obtained from the previous calculation and risk profile value.

5.3 Risk Parameter used in the model

Parameters used in determining the order allocation is based on risk profile is the optimal solution produced before considering the risk in the form of number of products procured according to a minimum cost, the result will be associated with a normalized risk value, risk value is derived from the risk profile. The procedure is done to determine the number of product to be transferred and remaining capacity of the supplier. So that the value can be used as a parameter in determining constrained.

5.4 Shifting Order Supplier According to Risk

From processing data in Chapter 4, then performed an analysis of the order allocation. Based on Table 4.9 showed that the order allocation is created based on the objective function with the aim of minimizing procurement costs by considering constrains of supplier capacity and demand of each sugar company. From Table 4.9 it can be seen the initial pattern order allocation, but the result of the order allocation is not optimal because it has not considered a risk factor.

Therefore, to optimize the order allocation for each supplier, the step that have to be done is calculation phase 2 by making the initial results of the order allocation and risk profile as parameter. In addition the parameters used in constrains is the number of product to be transferred and remaining capacity of the supplier. Taking into account the risk aspects, the obtained results can be seen in Table 4.12, from Table 4.12 can be seen that the allocation of order following the pattern conformed to the value of risk profile. For suppliers that have a value relatively less number of risk profile will be allocated more orders compared with those suppliers who have greater risk profile value. From Table 4.14 also be known that the order allocation for each supplier has met the demand of each sugar mill and also not exceed the capacity of supplier.

In research of Oguzhan & Erol (2016) explained that by incorporating risk analysis in procurement formulation in single sourcing supplier to obtain optimal order allocation, it will be obtained that order allocation will be maximized in suppliers with relatively less risk profile value. In this study, it can be seen from Table 4.7 and Table 4.13 That the two results of order allocation have significant differences. Comparison of optimal results after incorporating risk profile in linear programming formulation, then get the same order pattern with which has been done by Oguzhan & Erol (2016), order allocation maximized at supplier which have relatively less risk profile value and minimized at supplier have relatively higher risk profile value. So it can be determined that results of this research had significant to the results of previous studied when applied in multi sourcing supplier. In addition, this study also included transportation costs as a parameter in minimizing procurement costs that also had been described in Pazhani et al. (2016) that in selected suppliers and determined order allocations for suppliers should be considered the overall supply chain cost to obtain optimal order allocation results. This research is also considering transportation cost and purchasing cost as an parameter in objective function to obtain a minimum procurement cost. In this research also conducted risk analysis and can be determined that change of value of purchasing cost influence to number of order allocation for each supplier to each manufacturer. It proved that a whole supply chain gave effect to pattern of orders allocation that appropriate with research that has been done by Nazari-shirkouhi et al. (2013).

Table 5.1 Modified Procurement Plan

Current Procurement Plan		**Modified Procurement Plan**		**Decrease**	**Increase**	**Percentage (%)**
Supplier 1	31800 kg	**Supplier 1**	14628 kg	17172 kg	0	(–) 54%
Supplier 2	30200 kg	**Supplier 2**	30200 kg	0	0	0%
Supplier 3	29450 kg	**Supplier 3**	20026 kg	9424 kg	0	(–) 32%
Supplier 4	11200 kg	**Supplier 4**	37796 kg	0	26596 kg	(+) 42%
Total	102650 kg	**Total**	102650 kg			

Modified procurement plan in Table 5.1 was a comparison between optimal solution of data processing that excluding risk and optimal solution of data processing that including risk. Table 5.1 also shown order allocation changing in supplier 1, 3, and 4. Supplier 1 should decrease 54% of total supply order, supplier 3 should decrease 32% of their supply order; while supplier 4 should increase 42% of supply order. The result show that suppliers with lower risks are given priority in allocating orders That condition occurred because supplier 1 and 3 had relatively higher risk profile value so they had to decrease their order and reallocate their order to the supplier that had relatively lower risk profile value (supplier 4), therefore supplier 4 should increase their supply order. There was no changing order allocation for supplier 2 because the number of supply is already reach their maximum capacity.

5.5 Sensitivity Analysis Parameter

Sensitivity Analysis done based on parameter that used in formulation of procurement plan, so sensitivity analysis only done for demand factor, risk profile factor and price factor. From calculation process in chapter 4, it can be concluded that these three factors have influence in the determination the order allocation. Changes in demand affect to order allocation sequence and number of order allocation for each supplier. While the changes in the value of risk profile and price give effects to changing number of the order allocation for each supplier. The following Table 5.2 is a recapitulation for each scenario with aspects of demand, risk profile and price.

Table 5.2 Recapitulation of Optimal to Solution Sensitivity Analysis for demand factor

Current Optimal Solution		**Scenario 1a**	**Percentage**	**Scenario 2a**	**Percentage**
Supplier 1	31800 kg	18533 kg	(−) 41,7%	31800 kg	0
Supplier 2	30200 kg	30200 kg	0	22865 kg	(−) 24,3%
Supplier 3	29450 kg	29450 kg	0	22115 kg	(−) 24,9%
Supplier 4	11200 kg	28800 kg	(+) 61,1%	36135kg	(+) 69,1%
Total	102650 kg	106983 kg		112915 kg	

From Table 5.2 can be determined that increasing and decreasing number of demand affect to the changing order of allocation patterns for each suppliers and number of order allocation for each supplier. For scenario 1a can be seen that supplier 1 have to decrease 41,7 % of their order allocation and supplier 4 have to increase 61,1 % of their order allocation. Besides that, For scenario 2a can be seen that supplier 2 have to decrease 24,3% of their order allocation, supplier 3 have to decrease 24,9% of their order allocation supplier 4 have to increase 69,1% of their order allocation. So it was proved that order allocation t is also depend on demand for manufacturer, because by changing demand for each manufacturer give effect to change the pattern for order allocation and changing number of order allocation for each suppliers.

Table 5.3 Recapitulation of Optimal Solution to Sensitivity Analysis for Risk Profile

	Supplier 1	**Supplier 2**	**Supplier 3**	**Supplier 4**
Current optimal solution	31800	30200	29450	11200
Scenario 1b	17118	30200	29450	25882
Percentage	(−) 46%	0%	0%	(+) 57%
Scenario 2b	31800	15110	29210	26630
Percentage	0%	(−) 50%	(−) 1%	(+) 58%
Scenario 3b	31800	10274	33376	28800
Percentage	0	(−) 66%	(+) 12%	(+) 61%
Scenario 4b	31800	30200	15019	25631
Percentage	0	0	(−) 49%	(+) 56 %
Scenario 5b	31800	26736	15314	28800
Percentage	0	(−) 11%	48%	(+) 61%

From Table 5.3 can be determined that changing risk profile value give effect of changing order allocation patterns for each suppliers and number of order allocation for each supplier. From all the scenario of sensitivity analysis considering risk profile aspect. It can be known that order allocation is maximized to the supplier that have relatively lower risk profile value and minimized to the supplier that have relatively higher risk profile value. There was no changing order allocation for some suppliers in each scenario because the number of supply is already reach their maximum capacity.

Table 5.4 Recapitulation of Optimal Solution to Sensitivity Analysis for Price factor

Current Optimal Solution		Scenario 1c	Percentage	Scenario 2c	Percentage
Supplier 1	31800 kg	31800 kg	0	31800	0
Supplier 2	30200 kg	28202 kg	(−) 7 %	25066	(−) 17%
Supplier 3	29450 kg	15314 kg	0	16984	(−) 42 %
Supplier 4	11200 kg	27334 kg	(+) 59 %	28800	(+) 61 %
Total	102650 kg	102650kg		102650 kg	

From Table 5.4 can be determined that increasing and decreasing number of demand affect to the changing order of allocation patterns for each suppliers and number of order allocation for each supplier. For scenario 1c can be seen that supplier 2 have to decrease 7% of their order allocation and supplier 4 have to increase 59% of their order allocation. Besides that, For scenario 2c can be seen that supplier 2 have to decrease 17% of their order allocation, supplier 3 have to decrease 42% of their order allocation supplier 4 have to increase 61% of their order allocation. So it was proved that order allocation also depend on price for manufacturer, because by changing demand for each manufacturer give effect to change the pattern for order allocation and changing number of order allocation for each suppliers. All company want to minimize their production cost, so the will prefer to choose supplier with lower price but the most critical for each company is not only price but also quality of material that produced by suppliers.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATION

In this study a model of order allocation considering risk has been developed and tested in a sugar manufacturing company. The following conclusions are obtained.

6.1 Conclusions

From the results of this research obtained some conclusions.

1. Results of data processing and analysis showed that risk parameters included in linear programming formulation can be used to determine the optimal order allocation for suppliers. This method can be used effectively and efficiently in finding solution of optimal procurement plan for order allocation for suppliers without considering risk and also including risk for optimal solution of order allocation.
2. The model is able to incorporate risk in order allocation decision. The result show that suppliers with lower risks are given priority in allocating orders.
3. Results of order allocation for supplier based on the risk parameter had two conditions that must be fulfilled. Order allocation should not exceed the capacity of each supplier and must be able to fulfilled demand of each manufacturer. From data processing using risk analysis it is found that, supplier 1 and supplier 3 should decrease their supply order, while supplier 4 should increase the supply order. This condition occurred because supplier 1 and supplier 3 has relatively higher risk profile value so both of supplier 1 and 3 have to decrease their order allocation and reallocate their order to the supplier that has relatively less risk profile value (supplier 4), therefore supplier 4 should increase their supply order. There was no changing order allocation for supplier 2 because the number of supply is already reach the maximum capacity.
4. Sensitivity analysis have been done by changing the value of demand, risk profile and price. It can be concluded that those three factors have influence on

determine the order allocation. Changing in demand, risk profile and price affect to the sequence of order allocation and number of order allocation for each supplier. The detail analysis for each factor of sensitivity analysis is explained below.

a. Based on demand factor, scenario 1a determined that supplier 1 have to decrease 41,7 % of their order allocation and supplier 4 have to increase 61,1 % of their order allocation. Besides that, For scenario 2a can be seen that supplier 2 have to decrease 24,3% of their order allocation, supplier 3 have to decrease 24,9% of their order allocation supplier 4 have to increase 69,1% of their order allocation.
b. Based on risk profile factor, all scenario determined that order allocation is maximized to the supplier that have relatively lower risk profile value and minimized to the supplier that have relatively higher risk profile value according to demand from manufacturers and capacity of each suppliers.
c. Based on price factor, scenario 1c determined that supplier 2 have to decrease 7% of their order allocation and supplier 4 have to increase 59% of their order allocation. Besides that, For scenario 2c can be seen that supplier 2 have to decrease 17% of their order allocation, supplier 3 have to decrease 42% of their order allocation supplier 4 have to increase 61% of their order allocation.

6.2 Recommendation

After doing all the steps in this research, this research have recommendation for further research and managerial implications.

6.2.1 Recommendation for future research

Recommendation given for further research are.

1. The procedure can be extended to multi-period, multi commodity and multi echelon Supply Chain in further research.
2. Risk analysis as parameter in determining allocation order for suppliers can use more parameter as supporting data to determine risk profile value.

3. Processing data and analysis of supply chain allocation order for supplier by considering the risks and transportation costs can be developed by using the integration of fuzzy method, AHP, revised analytic hierarchy process or TOPSIS fuzzy.

6.2.2 Managerial Implications

From data processing and analysis result, there are some consideration for company’s management if they want to make allocation order decision for suppliers.

1. Decisions for order allocation are more effective and efficient because formulation used in this research considered risk factors and transportation costs as part of overall supply chain costs. Taking into account many factors, then decision will be more profitable for the company because company has previously considered risk that may occur.
2. Order allocation strategy by consideration risk can be used as a preventive effort to overcome the error caused by supplier, so that suppliers can perform their function properly and can support the company's production process optimally.

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REFERENCES

Brandenburg, M., Govindan, K., Sarkis, J., & Seuring, S.2014. "Quantitative Models for Sustainable Supply Chain Management : Developments and Directions." *European Journal of Operational Research* 233(2):299–312. Retrieved (http://dx.doi.org/10.1016/j.ejor.2013.09.032).

Chen, P. & Wu, M. 2013. A modified failure mode and effects analysis method for supplier selection problems in the supply chain risk environment : A case study q. *Computers & Industrial Engineering*, 66(4), pp.634–642. Available at: http://dx.doi.org/10.1016/j.cie.2013.09.018.

Chopra, S.2015.Supply Chain Management : Strategy, Planning and Operation SIXTH EDITION.

Fahimnia, B., Tang, C. S., Davarzani, H., & Sarkis, J. 2015. Quantitative models for managing supply chain risks : A review. *European Journal of Operational Research*, 247(1), pp.1–15. Available at: http://dx.doi.org/10.1016/j.ejor.2015.04.034.

García, N., Puente, J., Fernández, I., & Priore, P. 2013. Supplier selection model for commodities procurement . Optimised assessment using a fuzzy decision support system. *Applied Soft Computing Journal*, *13*(4), 1939–1951. http://doi.org/10.1016/j.asoc.2012.12.008

Ghadge, A., Dani, S., Ojha, R., & Caldwell, N. 2017. Computers & Industrial Engineering Using risk sharing contracts for supply chain risk mitigation : A buyer-supplier power and dependence perspective. *Computers & Industrial Engineering*, *103*, 262–270. http://doi.org/10.1016/j.cie.2016.11.034

Ghorbani, M., Bahrami, M. & Arabzad, S.M., 2012. An Integrated Model For Supplier Selection and Order Allocation ; Using Shannon Entropy , SWOT and Linear Programming. Journal of Purchasing & Supply Management , 41, pp.521–527. Available at: http://dx.doi.org/10.1016/j.sbspro.2012.04.064.

Guo, C. & Li, X., 2014. A multi-echelon inventory system with supplier selection and order allocation under stochastic demand. *Intern. Journal of Production Economics*, 151, pp.37–47. Available at:

http://dx.doi.org/10.1016/j.ijpe.2014.01.017.

Hallikas, J. & Lintukangas, K.2016. An investigation of risk management performance. *Intern. Journal of Production Economics*, 171, pp.487–494. Available at: http://dx.doi.org/10.1016/j.ijpe.2015.09.013.

Hamdan, S. & Cheaitou, A. 2017. Supplier selection and order allocation with green criteria : An MCDM and multi-objective optimization approach. *Computers and Operations Research, Omega*, 81. pp.282–304. Available at: http://dx.doi.org/10.1016/j.cor.2016.11.005.

Heckmann, I., Comes, T. & Nickel, S. 2015. A critical review on supply chain risk – De fi nition , measure. *Omega*, 52, pp.119–132. Available at: http://dx.doi.org/10.1016/j.omega.2014.10.004.

Ho, W., Zheng, T., Yildiz, H., & Talluri, S. 2016. Supply chain risk management : a literature review. Omega, 7543. pp.5432–5439. http://doi.org/10.1080/00207543.2015.1030467

Hosseini, R., Razmi, J., Sadegh, M., & Fallah, Z.2014. Int . J . Production Economics Optimizing an integrated vendor-managed inventory system for a single-vendor two-buyer supply chain with determining weighting factor for vendor ' s ordering cost. *Intern. Journal of Production Economics*, *153*, 295–308. http://doi.org/10.1016/j.ijpe.2014.03.013

Jadidi, O., Zolfaghari, S. & Cavalieri, S.2014. A new normalized goal programming model for multi-objective problems : A case of supplier selection and order allocation. *Intern. Journal of Production Economics*, 148, pp.158–165. Available at: http://dx.doi.org/10.1016/j.ijpe.2013.10.005.

Lee, J., Cho, H. & Seog, Y.2015. Expert Systems with Applications Assessing business impacts of agility criterion and order allocation strategy in multi-criteria supplier selection. *EXPERT SYSTEMS WITH APPLICATIONS*, 42(3). pp.1136–1148. Journal of Purchasing & Supply Management. Available at: http://dx.doi.org/10.1016/j.eswa.2014.08.041.

Li, C., Ren, J. & Wang, H.2016. A system dynamics simulation model of chemical supply chain transportation risk management systems. *Computers and Chemical Engineering*, 89, pp.71–83. Available at: http://dx.doi.org/10.1016/j.compchemeng.2016.02.019.

Moghaddam, K.S.2015. Expert Systems with Applications Fuzzy multi-objective model for supplier selection and order allocation in reverse logistics systems under supply and demand uncertainty. *Expert Systems With Applications*, Omega.pp.6237–6254.

Musa, S.N.2012. *Supply Chain Risk Management : Identification , Evaluation and Mitigation Techniques*.Omega. pp.5412–5420

Nazari-shirkouhi, S., Shakouri, H., Javadi, B., & Keramati, A.2013. Supplier selection and order allocation problem using a two-phase fuzzy multi-objective linear programming. *Applied Mathematical Modelling*, Journal of Purchasing & Supply Management.pp.9308–9323.

Oguzhan, K. & Erol, S.2016. A proactive approach to supply chain risk management : Shifting orders among suppliers to mitigate the supply side risks. Journal of Purchasing & Supply Management. pp.8428–8439

Olson, D.L.2014. Supply Chain Risk Management Tools for Analysis Second Edition. Business Expert Press.

Pazhani, S., Ventura, J.A. & Mendoza, A.2016. A serial inventory system with supplier selection and order quantity allocation considering transportation costs. Journal of Purchasing & Supply Management , 40, pp.612–634.

Peng, M., Peng, Y. & Chen, H.2014. Computers & Operations Research Post-seismic supply chain risk management : A system dynamics disruption analysis approach for inventory and logistics planning. *Journal Computers and Operation Research*, 42, pp.14–24. Available at: http://dx.doi.org/10.1016/j.cor.2013.03.003.

Platon, V. & Constantinescu, A.2014. Monte Carlo Method in risk analysis for investment. *Journal Economics and Finance*, 15(14), pp.393–400. Available at: http://dx.doi.org/10.1016/S2212-5671(14)00463-8.

Prasannavenkatesan, S. & Goh, M.2016. Multi-objective supplier selection and order allocation under disruption risk. *Transportation Research Part E*, 95, pp.124–142. Available at: http://dx.doi.org/10.1016/j.tre.2016.09.005.

Qi, L. & Lee, K.2015. Supply chain risk mitigations with expedited shipping $. *Omega*, 57, pp.98–113. Available at: http://dx.doi.org/10.1016/j.omega.2014.07.010.

Sawik, T.2013. Joint supplier selection and scheduling of customer orders under disruption risks : Single vs . dual sourcing. *Omega*, pp.1–13. Available at: http://dx.doi.org/10.1016/j.omega.2013.06.007.

Schmitt, A.J. & Singh, M.2012. A quantitative analysis of disruption risk in a multi-echelon supply chain. Int . J . Production Economics , 139, pp.22–24.

Scott, James, William Ho, Prasanta K. Dey & Srinivas Talluri. 2015. "Int . J . Production Economics A Decision Support System for Supplier Selection and Order Allocation in Stochastic , Multi-Stakeholder and Multi-Criteria Environments." *Intern. Journal of Production Economics* 166:226–37. Retrieved (http://dx.doi.org/10.1016/j.ijpe.2014.11.008).

Shaw, K., Shankar, R., Yadav, S. S., & Thakur, L. S. 2012. Expert Systems with Applications Supplier selection using fuzzy AHP and fuzzy multi-objective linear programming for developing low carbon supply chain. *Expert Systems With Applications*.*Omega*.39(9), pp.8182–8192. Available at: http://dx.doi.org/10.1016/j.eswa.2012.01.149.

Sherwin, M.D., Medal, H. & Lapp, S.A.2016. Proactive cost-effective identi fi cation and mitigation of supply delay risks in a low volume high value supply chain using fault-tree analysis. *Intern. Journal of Production Economics*, 175, pp.153–163. Available at: http://dx.doi.org/10.1016/j.ijpe.2016.02.001.

Sodenkamp, M.A., Tavana, M. & Di, D.2016. Modeling synergies in multi-criteria supplier selection and order allocation : An application to commodity trading. *European Journal of Operational Research*, 0, pp.1–16. Available at: http://dx.doi.org/10.1016/j.ejor.2016.04.015.

Supply & De, B. 2015. Strategic Supplier Selection Using Multi-Stakeholder and Multi-Perspective Approaches. *International Journa and Production Economics*..166:152–54.

Tang, O., Matsukawa, H. & Nakashima, K.2012. Supply chain risk management. *Intern. Journal of Production Economics*, 139(1), pp.1–2. Available at: http://dx.doi.org/10.1016/j.ijpe.2012.06.015.

Thun, Ã. & Hoenig, D.2011. An empirical analysis of supply chain risk management in the German automotive industry. Int . *J . Production Economics*, 131, pp.242–249.

Urianty, D., Rohmah, M., Agustin, W., Dania, P., & Atsari, I.2015. Risk Measurement of Supply Chain Organic Rice Product using Fuzzy Failure Mode Effect Analysis in MUTOS Seloliman Trawas Mojokerto. *Italian Oral Surgery*, *Int . J . Production Economics* 3, pp.108–113. Available at: http://dx.doi.org/10.1016/j.aaspro.2015.01.022.

Yu, F., Xue, L., Sun, C., & Zhang, C.2016. Product transportation distance based supplier selection in sustainable supply chain network. *Journal of Cleaner Production*, *137*, 29–39. http://doi.org/10.1016/j.jclepro.2016.07.046

Zepeda, E.D., Nyaga, G.N. & Young, G.J.2016. Supply chain risk management and hospital inventory : Effects of system af fi liation. *Journal of Operations Management*, 44, pp.30–47. Available at: http://dx.doi.org/10.1016/j.jom.2016.04.002.

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APPENDIX 1

EXAMPLE
QUESTIONNAIRE FOR RISK PROFILE

NAME :
SUPPLIER :

Objective: To assess performance of each supplier.
Instructions :
Select the importance level of variable in the interest column with sign (√):
1 : Excellent
2 : Very Good
3 : Good
4 : Bad
5 : Very Bad

Risk	Sub Risk	1	2	3	4	5	Total
Price	Unstable of Product price						
	High Delivery cost						
Quality	Product quality is below the standard						
	Specification of product in not appropriate						
Delivery	Delay in delivery process						
	Low Distribution capability						
	Transportation failure						
Service	Low Flexibility						
	Level of difficulty to be contacted						
	Low responsibility of after sale service						
	Difficulty of Compliance Procedure						
Supplier ability	Low professionalism of supplier						
	Supplier can't fulfill the demand						
Safety	Low protection of Safety management						
	Low protection of extreme weather condition						
TOTAL							

Thanks for the time and information provided to us.

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APPENDIX 2

Input LINGO 11.0

Procurement Plan without considering risk according to formulation (4.1)

```
MIN = 8364*Y11 + 8355*Y12 + 8370*Y13 + 8198*Y21 + 8202*Y22 + 8195*Y23
      + 8466*Y31 + 8457*Y32 + 8473*Y33 + 8709*Y41 + 8707*Y42 +
      8718*Y43 ;

Y11 + Y12 + Y13 <= 31800 ;
Y21 + Y22 + Y23 <= 30200 ;
Y31 + Y32 + Y33 <= 29450 ;
Y41 + Y42 + Y43 <= 28800 ;
Y11 + Y21 + Y31 + Y41 >= 38400 ;
Y12 + Y22 + Y32 + Y42 >= 34600 ;
Y13 + Y23 + Y33 + Y43 >= 29650 ;

@GIN (Y11);
@GIN (Y12);
@GIN (Y13);
@GIN (Y21);
@GIN (Y22);
@GIN (Y23);
@GIN (Y31);
@GIN (Y32);
@GIN (Y33);
@GIN (Y41);
@GIN (Y42);
@GIN (Y43);

END
```

Order allocation supplier considering risk (4.2)

```
MAX =  0.54*X12 + 0.32*X32+ 0.14*X42 + 0.40*X14 + 0.18*X34 +
       0.22*13 ;

X12 + X13 + X14 <= 17172 ;
X12 + X32 + X42 <= 0 ;
X13 - X32 - X34 <= 0;
X32 +  X34 <= 9424;
X32 + X34 - X42<= 17600 ;
X42<= 1568;

@GIN (Y12);
@GIN (Y13);
@GIN (Y14);
@GIN (Y32);
@GIN (Y34);
@GIN (Y42);

END
```

Sensitivity analysis for demand

Scenario 1a
Procurement Plan without considering risk according to formulation (4.1)

```
MIN = 8364*Y11 + 8355*Y12 + 8370*Y13 + 8198*Y21 + 8202*Y22 +
      8195*Y23 + 8466*Y31 + 8457*Y32 + 8473*Y33 + 8709*Y41 +
      8707*Y42 + 8718*Y43 ;

Y11 + Y12 + Y13 <= 31800 ;
Y21 + Y22 + Y23 <= 30200 ;
Y31 + Y32 + Y33 <= 29450 ;
Y41 + Y42 + Y43 <= 28800 ;
Y11 + Y21 + Y31 + Y41 >= 40320 ;
Y12 + Y22 + Y32 + Y42 >= 36330 ;
Y13 + Y23 + Y33 + Y43 >= 31133 ;

@GIN (Y11);
@GIN (Y12);
@GIN (Y13);
@GIN (Y21);
@GIN (Y22);
@GIN (Y23);
@GIN (Y31);
@GIN (Y32);
@GIN (Y33);
@GIN (Y41);
@GIN (Y42);
@GIN (43);

END
```

Scenario 1a
Order allocation supplier considering risk (4.2)

```
MAX  =  0.54*X12  +  0.32*X32+  0.14*X42  +  0.40*X14  +  0.18*X34  +

       0.22*X13;


X21 + X13 + X14 <= 16740 ;
X12 + X32 + X42 <= 0;
X13 - X32 a- X34 <= 0;
X32 + X34 <= 9424;
X14 + X34 - X42 <= 12467 ;
X42 <= 2287 ;


@GIN (Y12);
@GIN (Y13);
@GIN (Y14);
@GIN (Y32);
@GIN (Y34);
@GIN (Y42);


END
```

Scenario 2a
Procurement Plan without considering risk according to formulation (4.1)

```
MIN = 8364*Y11 + 8355*Y12 + 8370*Y13 + 8198*Y21 + 8202*Y22 +
      8195*Y23 + 8466*Y31 + 8457*Y32 + 8473*Y33 + 8709*Y41 +
      8707*Y42 + 8718*Y43 ;

Y11 + Y12 + Y13 <= 31800 ;
Y21 + Y22 + Y23 <= 30200 ;
Y31 + Y32 + Y33 <= 29450 ;
Y41 + Y42 + Y43 <= 28800 ;
Y11 + Y21 + Y31 + Y41 >= 42240;
Y12 + Y22 + Y32 + Y42 >= 38060 ;
Y13 + Y23 + Y33 + Y43 >= 32615;

@GIN (Y11);
@GIN (Y12);
@GIN (Y13);
@GIN (Y21);
@GIN (Y22);
@GIN (Y23);
@GIN (Y31);
@GIN (Y32);
@GIN (Y33);
@GIN (Y41);
@GIN (Y42);
@GIN (y43);

END
```

Scenario 2a
Order allocation supplier considering risk (4.2)

```
MAX =   0.54*X12 + 0.32*X32+ 0.14*X42 + 0.40*X14 + 0.18*X34 +
        0.22*X13;


X21 + X13 + X14 <= 16740 ;
X12 + X32 + X42 <= 0;
X13 - X32 - X34 <= 0;
X32 + X34 <= 9424;
X14 + X34 - X42 <= 7335;
X42 <= 3005 ;

@GIN (Y12);
@GIN (Y13);
@GIN (Y14);
@GIN (Y32);
@GIN (Y34);
@GIN (Y42);

END
```

Sensitivity analysis for Risk Profile

Scenario 1b
Order allocation considering risk (4.2)

```
MAX =  0.07*X13 + 0.39*X23+ 0.08*X43 + 0.15*X14 + 0.07*X24 +
       0.46*X12 ;

X12 + X13 + X14 <= 14682 ;
X12 - X23 - X24 <= 0 ;
X23 + X24 <= 11778 ;
X13 + X23 + X43 <= 0;
X14 + X24 - X43 <= 17600;
X43 + X43 <= 1680 ;


@GIN (Y12);
@GIN (Y13);
@GIN (Y14);
@GIN (Y23);
@GIN (Y24);
@GIN (Y43);

END
```

Scenario 2b
Order allocation considering risk (4.2)

```
MAX =  0.3*X14 + 0.2*X24+ 0.2*X34 + 0.1*X13 + 0.4*X23 + 0.5*X21 ;

X21 - X13 - X14 <= 0 ;
X13 + X14 <= 9540 ;
X21 + X23 + X24 <= 15100 ;
X13 + X23 - X34 <= 0 ;
X34  <= 5890 ;
X14 + X24 + X34 <= 17600 ;

@GIN (Y13);
@GIN (Y14);
@GIN (Y21);
@GIN (Y23);
@GIN (Y24);
@GIN (Y34);

END
```

Scenario 3b
Order allocation considering risk (4.2)

```
MAX =  0.51*X21 + 0.22*X31+ 0.18*X41 + 0.26*X24 + 0.04*X34 +
       0.3*X23;

X21 + X31 + X41 <= 0 ;
X21 + X23 + X34 <= 15704 ;
```

```
X23 - X31 - X34 <= 0 ;
X31 + X34 <= 8835 ;
X24 + X34 - X41 <= 17600 ;
X41 <= 2016;

@GIN (Y21);
@GIN (Y23);
@GIN (Y24);
@GIN (Y31);
@GIN (Y34);
@GIN (Y41);


END
```

Scenario 4b
Order allocation considering risk (4.2)

```
MAX =  0.12*X12 + 0.39*X32+ 0.47*X42 + 0.37*X31 + 0.39*X41 +
       0.02*X34 ;

X31 + X41 -  X12 <= 0 ;
X12 <= 3816;
X12 + X32 + X42 <= 0 ;
X31 + X32 + X34 <= 14431 ;
X34 - X41 - X42 <= 17600;
X41 +  X42 <= 4368 ;

@GIN (Y12);
@GIN (Y32);
@GIN (Y32);
@GIN (Y31);
@GIN (Y41);
@GIN (Y34);


END
```

Scenario 5b
Order allocation considering risk (4.2)

```
MAX =   0.35*X21  +  0.48*X31+  0.17*X41  +  0.18*X24  +  0.31*X34  +
        0.13*X32;

X21 + X31 + X41 <= 0 ;
X32 - X21 - X24 <= 0 ;
X21 - X24 <= 10570 ;
X31 + X32 + X34 <= 14136;
X24 + X34 - X41 <= 17600;
X41  <= 1904;

@GIN (Y21);
@GIN (Y24);
@GIN (Y31);
@GIN (Y32);
@GIN (Y34);
@GIN (Y41);
```

```
END
```

Sensitivity analysis for price

Scenario 1c
Procurement Plan without considering risk according to formulation (4.1)

```
MIN = 9194*Y11 + 9228*Y12 + 9200*Y13 + 9008*Y21 + 9012*Y22 +
      9005*Y23 + 7626*Y31 + 7617*Y32 + 7633*Y33 + 9574*Y41 +
      9572*Y42 + 9483*Y43 ;

Y11 + Y12 + Y13 <= 31800 ;
Y21 + Y22 + Y23 <= 30200 ;
Y31 + Y32 + Y33 <= 29450 ;
Y41 + Y42 + Y43 <= 28800 ;
Y11 + Y21 + Y31 + Y41 >= 38400 ;
Y12 + Y22 + Y32 + Y42 >= 34600 ;
Y13 + Y23 + Y33 + Y43 >= 29650 ;

@GIN (Y11);
@GIN (Y12);
@GIN (Y13);
@GIN (Y21);
@GIN (Y22);
@GIN (Y23);
@GIN (Y31);
@GIN (Y32);
@GIN (Y33);
@GIN (Y41);
@GIN (Y42);
@GIN (Y43);

END
```

Scenario 1c
Order allocation considering risk (4.2)

```
MAX =  0.35*X41 + 0.17*X21+ 0.48*X31 + 0.18*X24 + 0.15*X34 +
       0.31*32 ;

X21 + X31 + X41 <= 0 ;
X32 - X21 - X24 <= 18450 ;
X21 +  X24 <= 1998;
X13 + X32 + X34 <= 14136;
X24 + X34 - X41 <= 17600 ;
X41 <= 3920 ;

@GIN (Y21);
@GIN (Y24);
@GIN (Y31);
@GIN (Y32);
@GIN (Y34);
@GIN (Y41);
```

```
END
```

Scenario 2c
Procurement Plan without considering risk according to formulation (4.1)

```
MIN = 7119*Y11 + 7110*Y12 + 7125*Y13 + 9413*Y21 + 9417*Y22 +
      9410*Y23 + 7206*Y31 + 7197*Y32 + 7213*Y33 + 10007*Y41 +
      10004*Y42 + 10016*Y43 ;

Y11 + Y12 + Y13 <= 31800 ;
Y21 + Y22 + Y23 <= 30200 ;
Y31 + Y32 + Y33 <= 29450 ;
Y41 + Y42 + Y43 <= 28800 ;
Y11 + Y21 + Y31 + Y41 >= 38400 ;
Y12 + Y22 + Y32 + Y42 >= 34600 ;
Y13 + Y23 + Y33 + Y43 >= 29650 ;

@GIN (Y11);
@GIN (Y12);
@GIN (Y13);
@GIN (Y21);
@GIN (Y22);
@GIN (Y23);
@GIN (Y31);
@GIN (Y32);
@GIN (Y33);
@GIN (Y41);
@GIN (Y42);
@GIN (Y43);

END
```

Scenario 2c
Order allocation considering risk (4.2)

```
MAX =  0.35*X41 + 0.17*X21+ 0.48*X31 + 0.18*X24 + 0.15*X34 +
       0.31*32 ;

X21 + X31 + X41 <= 0 ;
X32 - X21 - X24 <= 0 ;
X21 +  X24 <= 5134 ;
X13 + X32 + X34 <= 14136;
X24 + X34 - X41 <= 17600 ;
X41 <= 3920 ;

@GIN (Y21);
@GIN (Y24);
@GIN (Y31);
@GIN (Y32);
@GIN (Y34);
@GIN (Y41);

END
```

Output LINGO 11.0

Procurement Plan without considering risk according to formulation (4.1)

```
Global optimal solution found.
  Objective value:                              0.8600190E+09
  Objective bound:                              0.8600190E+09
  Infeasibilities:                               0.000000
  Extended solver steps:                                0
  Total solver iterations:                              9

      Variable           Value        Reduced Cost
           Y11        0.000000            8364.000
           Y12        31800.00            8355.000
           Y13        0.000000            8370.000
           Y21        550.0000            8198.000
           Y22        0.000000            8202.000
           Y23        29650.00            8195.000
           Y31        26650.00            8466.000
           Y32        2800.000            8457.000
           Y33        0.000000            8473.000
           Y41        11200.00            8709.000
           Y42        0.000000            8707.000
           Y43        0.000000            8718.000

           Row    Slack or Surplus      Dual Price
             1      0.8600190E+09       -1.000000
             2        0.000000           0.000000
             3        0.000000           0.000000
             4        0.000000           0.000000
             5        17600.00           0.000000
             6        0.000000           0.000000
             7        0.000000           0.000000
             8        0.000000           0.000000
```

Order allocation considering risk (4.2)

```
Global optimal solution found.
  Objective value:                                 3160.860
  Objective bound:                                 3160.860
  Infeasibilities:                                 0.000000
  Extended solver steps:                                  0
  Total solver iterations:                                0


                      Variable           Value        Reduced Cost
                           X12        0.000000            0.000000
                           X32        0.000000           0.1600000
                           X42        0.000000           0.1600000
                           X14        17172.00            0.000000
                           X34        9424.000            0.000000
                           X13        0.000000           0.1400000
                           Y12        0.000000            0.000000
                           Y13        0.000000            0.000000
                           Y14        0.000000            0.000000
                           Y32        0.000000            0.000000
                           Y34        0.000000            0.000000
```

Variable	Value	Reduced Cost
Y42	0.000000	0.000000

Row	Slack or Surplus	Dual Price
1	3160.860	1.000000
2	0.000000	0.1400000
3	0.000000	0.4000000
4	9424.000	0.000000
5	0.000000	0.8000000E-01
6	8176.000	0.000000
7	1568.000	0.000000

Output Sensitivity analysis for demand

Output Scenario 1a
Procurement Plan without considering risk according to formulation (4.1)

```
Objective value:                              0.9321629E+09
Objective bound:                              0.9321629E+09
Infeasibilities:                               0.000000
Extended solver steps:                                0
Total solver iterations:                             11
```

Variable	Value	Reduced Cost
Y11	0.000000	8364.000
Y12	27717.00	8355.000
Y13	4083.000	8370.000
Y21	0.000000	8198.000
Y22	0.000000	8202.000
Y23	30200.00	8195.000
Y31	20837.00	8466.000
Y32	8613.000	8457.000
Y33	0.000000	8473.000
Y41	19483.00	8709.000
Y42	0.000000	8707.000
Y43	0.000000	8718.000

Row	Slack or Surplus	Dual Price
1	0.9321629E+09	-1.000000
2	0.000000	0.000000
3	0.000000	0.000000
4	0.000000	0.000000
5	9317.000	0.000000
6	0.000000	0.000000
7	0.000000	0.000000
8	0.000000	0.000000

Order allocation considering risk (4.2)

```
Global optimal solution found.
Objective value:                                 3253.220
Objective bound:                                 3253.220
Infeasibilities:                                 0.000000
Extended solver steps:                                  0
Total solver iterations:                                3
```

Variable	Value	Reduced Cost

X12	0.000000	0.000000
X32	0.000000	0.1600000
X42	0.000000	0.1600000
X14	3043.000	0.000000
X34	9424.000	0.000000
X13	9424.000	0.000000
X21	0.000000	0.000000
X41	0.000000	0.000000
Y12	0.000000	0.000000
Y13	0.000000	0.000000
Y14	0.000000	0.000000
Y32	0.000000	0.000000
Y34	0.000000	0.000000
Y42	0.000000	0.000000

Row	Slack or Surplus	Dual Price
1	3253.220	1.000000
2	4273.000	0.000000
3	0.000000	0.5400000
4	0.000000	0.2200000
5	0.000000	0.1600000
6	0.000000	0.1400000
7	0.000000	0.000000

Output Scenario 2a
Procurement Plan without considering risk according to formulation (4.1)

```
Global optimal solution found.
Objective value:                              0.9493985E+09
Objective bound:                              0.9493985E+09
Infeasibilities:                               0.000000
Extended solver steps:                                0
Total solver iterations:                             11
```

Variable	Value	Reduced Cost
Y11	0.000000	8364.000
Y12	29385.00	8355.000
Y13	2415.000	8370.000
Y21	0.000000	8198.000
Y22	0.000000	8202.000
Y23	30200.00	8195.000
Y31	20775.00	8466.000
Y32	8675.000	8457.000
Y33	0.000000	8473.000
Y41	21465.00	8709.000
Y42	0.000000	8707.000
Y43	0.000000	8718.000

Row	Slack or Surplus	Dual Price
1	0.9493985E+09	-1.000000
2	0.000000	0.000000
3	0.000000	0.000000
4	0.000000	0.000000
5	7335.000	0.000000
6	0.000000	0.000000
7	0.000000	0.0

8	0.000000	0.000000

Order allocation considering risk (4.2)

Global optimal solution found.

Objective value:	2200.500
Objective bound:	2200.500
Infeasibilities:	0.000000
Extended solver steps:	0
Total solver iterations:	0

Variable	Value	Reduced Cost
X12	0.000000	0.000000
X32	0.000000	0.000000
X42	0.000000	0.000000
X14	0.000000	0.1600000
X34	7335.000	0.000000
X13	7335.000	0.000000
X21	0.000000	0.000000
X41	0.000000	0.000000
Y12	0.000000	0.000000
Y13	0.000000	0.000000
Y14	0.000000	0.000000
Y32	0.000000	0.000000
Y34	0.000000	0.000000
Y42	0.000000	0.000000

Row	Slack or Surplus	Dual Price
1	2200.500	1.000000
2	9405.000	0.000000
3	0.000000	0.5400000
4	0.000000	0.2200000
5	2089.000	0.000000
6	0.000000	0.3000000
7	0.000000	0.000000

Output Sensitivity analysis for risk profile

Output Scenario 1b

Order allocation considering risk (4.2)

Objective value:	6674.940
Objective bound:	6674.940
Infeasibilities:	0.000000
Extended solver steps:	0
Total solver iterations:	0

Variable	Value	Reduced Cost
X13	0.000000	0.4000000
X23	0.000000	0.000000
X43	0.000000	0.2400000
X14	2904.000	0.000000
X24	11778.00	0.000000
X12	11778.00	0.000000
Y12	0.000000	0.000000
Y13	0.000000	0.000000

Y14	0.000000	0.000000
Y23	0.000000	0.000000
Y24	0.000000	0.000000
Y43	0.000000	0.000000

Row	Slack or Surplus	Dual Price
1	7115.640	1.000000
2	197028.0	0.000000
3	0.000000	0.4600000
4	0.000000	0.3800000
5	0.000000	0.4700000
6	0.000000	0.1500000
7	1680.000	0.000000

Output Scenario 2b
Order allocation considering risk (4.2)

```
Global optimal solution found.
  Objective value:                              12830.00
  Objective bound:                              12830.00
  Infeasibilities:                              0.000000
  Extended solver steps:                               0
  Total solver iterations:                             4
```

Variable	Value	Reduced Cost
X14	4030.000	0.000000
X24	0.000000	0.6000000
X34	13570.00	0.000000
X13	13570.00	0.000000
X23	0.000000	0.2000000
X21	15100.00	0.000000
Y13	0.000000	0.000000
Y14	0.000000	0.000000
Y21	0.000000	0.000000
Y23	0.000000	0.000000
Y24	0.000000	0.000000
Y34	0.000000	0.000000

Row	Slack or Surplus	Dual Price
1	12830.00	1.000000
2	2500.000	0.000000
3	0.000000	0.000000
4	0.000000	0.5000000
5	0.000000	0.1000000
6	4030.000	0.000000
7	0.000000	0.3000000

Output Scenario 3b
Order allocation considering risk (4.2)

```
Global optimal solution found.
Objective value:                              5204.160
Objective bound:                              5204.160
Infeasibilities:                              0.000000
Extended solver steps:                               0
Total solver iterations:                             2
```

```
Variable           Value        Reduced Cost
     X21        0.000000          0.1000000E-01
     X31        0.000000          0.000000
     X41        0.000000          0.4000000E-01
     X24        9748.000           0.000000
     X34        7852.000           0.000000
     X23        7852.000           0.000000
     Y21        0.000000           0.000000
     Y23        0.000000           0.000000
     Y24        0.000000           0.000000
     Y31        0.000000           0.000000
     Y34        0.000000           0.000000
     Y41        0.000000           0.000000

    Row    Slack or Surplus      Dual Price
      1        5204.160            1.000000
      2        0.000000           0.4800000
      3        0.000000           0.4000000E-01
      4        0.000000           0.2600000
      5        983.0000            0.000000
      6        0.000000           0.2600000
      7        2016.000            0.000000
```

Output Scenario 4b

Order allocation considering risk (4.2)

```
Global optimal solution found.
Objective value:                              288.6200
Objective bound:                              288.6200
Infeasibilities:                              0.000000
Extended solver steps:                               0
Total solver iterations:                             0
```

```
Variable           Value        Reduced Cost
     X12        0.000000           0.000000
     X32        0.000000          0.1400000
     X42        0.000000          0.4000000E-01
     X31        0.000000          0.4000000E-01
     X41        0.000000           0.000000
     X34        14431.00           0.000000
     Y12        0.000000           0.000000
     Y32        0.000000           0.000000
     Y31        0.000000           0.000000
     Y41        0.000000           0.000000
     Y34        0.000000           0.000000

    Row    Slack or Surplus      Dual Price
      1        288.6200            1.000000
      2        0.000000           0.3900000
      3        3816.000            0.000000
      4        0.000000           0.5100000
      5        0.000000           0.2000000E-01
      6        3169.000            0.000000
      7        4368.000            0.000000
```

Output Scenario 5b
Order allocation considering risk (4.2)

```
Global optimal solution found.
Objective value:                                 4382.160
Objective bound:                                 4382.160
Infeasibilities:                                 0.000000
Extended solver steps:                                  0
Total solver iterations:                                0


        Variable           Value        Reduced Cost
              X21        0.000000           0.000000
              X31        0.000000           0.1800000
              X41        0.000000           0.9000000E-01
              X24        3464.000           0.000000
              X34        14136.00           0.000000
              X32        0.000000           0.1800000
              Y21        0.000000            0.000000
              Y24        0.000000            0.000000
              Y31        0.000000            0.000000
              Y32        0.000000            0.000000
              Y34        0.000000            0.000000
              Y41        0.000000            0.000000

             Row    Slack or Surplus      Dual Price
             1        4382.160            1.000000
             2        0.000000            0.3500000
             3        0.000000            0.000000
             4        10570.00            0.000000
             5        0.000000            0.3100000
             6        0.000000            0.9000000E-01
             7        1904.000            0.000000
```

Output Sensitivity analysis for price

Output Scenario 1c
Procurement Plan without considering risk according to formulation (4.1)

```
Global optimal solution found.
Objective value:                                0.8949063E+09
Objective bound:                                0.8949063E+09
Infeasibilities:                                 0.000000
Extended solver steps:                                  0
Total solver iterations:                               10


            Variable           Value        Reduced Cost
                 Y11        31800.00            9194.000
                 Y12        0.000000            9228.000
                 Y13        0.000000            9200.000
                 Y21        6600.000            9008.000
                 Y22        5150.000            9012.000
                 Y23        18450.00            9005.000
                 Y31        0.000000            7626.000
                 Y32        29450.00            7617.000
```

Y33	0.000000	7633.000
Y41	0.000000	9574.000
Y42	0.000000	9572.000
Y43	11200.00	9483.000

Row	Slack or Surplus	Dual Price
1	0.8949063E+09	-1.000000
2	0.000000	0.000000
3	0.000000	0.000000
4	0.000000	0.000000
5	17600.00	0.000000
6	0.000000	0.000000
7	0.000000	0.000000
8	0.000000	0.000000

Order allocation considering risk (4.2)

```
Global optimal solution found.
Objective value:                              2489.960
Objective bound:                              2489.960
Infeasibilities:                              0.000000
Extended solver steps:                               0
Total solver iterations:                             0
```

Variable	Value	Reduced Cost
X41	0.000000	0.1300000
X21	0.000000	0.4900000
X31	0.000000	0.000000
X24	1998.000	0.000000
X34	14136.00	0.000000
X32	0.000000	0.1500000
X13	0.000000	0.1500000
Y21	0.000000	0.000000
Y24	0.000000	0.000000
Y31	0.000000	0.000000
Y32	0.000000	0.000000
Y34	0.000000	0.000000
Y41	0.000000	0.000000

Row	Slack or Surplus	Dual Price
1	2489.960	1.000000
2	0.000000	0.4800000
3	20448.00	0.000000
4	0.000000	0.1800000
5	0.000000	0.1500000
6	1466.000	0.000000
7	3920.000	0.000000

Output Scenario 2c

Procurement Plan without considering risk according to formulation (4.1)

```
Global optimal solution found.
Objective value:                              0.8345516E+09
Objective bound:                              0.8345516E+09
Infeasibilities:                              0.000000
Extended solver steps:                               0
Total solver iterations:                             8
```

Variable	Value	Reduced Cost
Y11	0.000000	7119.000
Y12	31800.00	7110.000
Y13	0.000000	7125.000
Y21	550.0000	9413.000
Y22	0.000000	9417.000
Y23	29650.00	9410.000
Y31	26650.00	7206.000
Y32	2800.000	7197.000
Y33	0.000000	7213.000
Y41	11200.00	10007.00
Y42	0.000000	10004.00
Y43	0.000000	10016.00

Row	Slack or Surplus	Dual Price
1	0.8345516E+09	-1.000000
2	0.000000	0.000000
3	0.000000	0.000000
4	0.000000	0.000000
5	17600.00	0.000000
6	0.000000	0.000000
7	0.000000	0.000000
8	0.000000	0.000000

Order allocation considering risk (4.2)

```
Global optimal solution found.
Objective value:                              2803.940
Objective bound:                              2803.940
Infeasibilities:                              0.000000
Extended solver steps:                               0
Total solver iterations:                             0
```

Variable	Value	Reduced Cost
X41	0.000000	0.000000
X21	0.000000	0.3600000
X31	0.000000	0.2000000E-01
X24	5134.000	0.000000
X34	12466.00	0.000000
X32	0.000000	0.000000
X13	0.000000	0.000000
Y21	0.000000	0.000000
Y24	0.000000	0.000000
Y31	0.000000	0.000000
Y32	0.000000	0.000000
Y34	0.000000	0.000000
Y41	0.000000	0.000000

Row	Slack or Surplus	Dual Price
1	2803.940	1.000000
2	0.000000	0.5000000
3	5134.000	0.000000
4	0.000000	0.3000000E-01
5	1670.000	0.000000
6	0.000000	0.1500000
7	3920.000	0.000000

APPENDIX 3

SENSITIVITY ANALYSIS

Sensitivity Analysis for Demand

Sensitivity analysis is done by changing each demand for suppliers to raise total demand.

Scenario 1 : Increase 5% of each manufacturers demand

Table Demand for Scenario 1a

Manufacturers/assemblers	1	2	3	Total
Demand (D_i) – kg	40320	36330	31133	107783

Objective function minimize procurement cost :

Mincost = $8364y_{11} + 8355y_{12} + 8370y_{13} + 8198y_{21} + 8202y_{22} + 8195y_{23} + 8466y_{31} + 8457y_{32} + 8473y_{33} + 8709y_{41} + 8707y_{42} + 8718y_{43}$

Subject To

$y_{11} + y_{12} + y_{13} \leq 31800$

$y_{21} + y_{22} + y_{23} \leq 30200$

$y_{31} + y_{32} + y_{33} \leq 29450$

$y_{41} + y_{42} + y_{43} \leq 28800$

$y_{11} + y_{21} + y_{31} + y_{41} \leq 40320$

$y_{12} + y_{22} + y_{32} + y_{42} \leq 36330$

$y_{13} + y_{23} + y_{33} + y_{43} \leq 31133$

Optimal Solution of processing the formulation using LINGO software, as follows.

Table Optimal Solution Lingo without considering risk scenario 1a

		Manufacturers/Assemblers (j)			
		1	**2**	**3**	**Total**
Suppliers (i)	**1**	0	30867	933	31800
	2	0	0	30200	30200
	3	23987	5463	0	29450
	4	16333	0	0	16333
	Total	40320	36330	31133	106983

Procurement Plan based on Risk Value

In this scenario only change the demand, so for aspect of procurement risk using risk profile parameters according to Table 4.8 and according to the results of lingo contained in Table 4.13**.**

Table Parameters used in the model scenario 1a

Suppliers	Number of Product procured according to min cost	Normalized risk Values	Number of Product to be transferred	Product to be kept in the supplier	Remaining capacity of the supplier
Suppliers -1	31800	0.54	16740	14260	800
Suppliers -2	30200	0	0	30200	0
Suppliers -3	29450	0.32	9424	20026	0
Suppliers -4	16333	0.14	2287	14046	12467

<u>Objective Function : maximize transfer product according to normalized risk value:</u>

Max Z = $0.54*X_{12}+ 0.32X_{32}+ 0.14*X_{42}+ 0.40*X_{14}+ 0.18*X_{34} + 0.22*X_{13}$

Subject To

$X_{12} + X_{13} + X_{14} \leq 16740$

$X_{12} + X_{32} + X_{42} \leq 0$

$X_{13} - X_{32} - X_{34} \leq 0$

$X_{32} + X_{34} \leq 9424$

$X_{14} + X_{34} - X_{42} \leq 12467$

$X_{42} \leq 2287$

$X_{ij} \geq 0$

Table Optimal Solution Procurement Based on Risk Profile 1a

R_{12}	R_{32}	R_{42}	R_{14}	R_{34}	R_{13}
0	0	0	3043	9424	9424

In conclusion, the optimal solution was the solution before conducting risk analysis subtracted with solution after conducting risk analysis.

R_{14} = 3043 means that Supplier 1 have to minus 3043 their supply and supplier 4 have to add 3043 of their supply.

Supplier 1 = 31000 – 3043 = 27957

Supplier 4 = 16333 + 3043 = 19376

R_{34} = 9424 means that Supplier 3 have to minus 9424 their supply and supplier 4 have to add 9424 of their supply.

Supplier 3 = 29450 – 9424 = 20026

Supplier 4 = 19376 + 9424 = 28800

R_{13} = 9424 means that Supplier 1 have to minus 9424 their supply and supplier 3 have to add 9424 of their supply.

Supplier 1 = 27957 – 9424 = 18533

Supplier 3 = 20026 + 9424 = 29450

Table Optimal Solution Lingo for scenario 1a

Manufacturers/Assemblers (j)					
		1	2	3	Total
Suppliers (i)	**1**	0	17600	933	18533
	2	0	0	30200	30200
	3	23987	5463	0	29450
	4	16333	12467	0	28800
	Total	40320	36330	31133	106983

Scenario 2 : Increase 10% of each manufactures demand

Give variation of decrease and increase for each number of demand

Table Demand for Scenario 2a

Manufacturers/assemblers	**1**	**2**	**3**	**Total**
Demand ($D_{i)}$ – kg	42240	38060	32615	112915

Objective function minimize procurement cost :

Mincost = $8364y_{11} + 8355y_{12} + 8370y_{13} + 8198y_{21} + 8202y_{22} + 8195y_{23} + 8466y_{31} + 8457y_{32} + 8473y_{33} + 8709y_{41} + 8707y_{42} + 8718y_{43}$

Subject To

$y_{11} + y_{12} + y_{13} \leq 31800$

$y_{21} + y_{22} + y_{23} \leq 30200$

$y_{31} + y_{32} + y_{33} \leq 29450$

$y_{41} + y_{42} + y_{43} \leq 28800$

$y_{11} + y_{21} + y_{31} + y_{41} \leq 42240$

$y_{12} + y_{22} + y_{32} + y_{42} \leq 38060$

$y_{13} + y_{23} + y_{33} + y_{43} \leq 32615$

Optimal Solution of processing the formulation using LINGO software, as follows.

Table Optimal Solution Lingo 2a

		Manufacturers/Assemblers (j)			
		1	**2**	**3**	**Total**
Suppliers (i)	**1**	0	29385	2415	31800
	2	0	0	30200	30200
	3	20775	8675	0	29450
	4	21465	0	0	21465
	Total	42240	38060	32615	112915

Procurement Plan based on Risk Value

Table Parameters used in the model scenario 2a

Suppliers	Number of Product procured according to min cost	Normalized risk Values	Number of Product to be transferred	Product to be kept in the supplier	Remaining capacity of the supplier
Suppliers -1	31800	0.54	17172	14628	0
Suppliers -2	30200	0	0	30200	0
Suppliers -3	29450	0.32	9424	20026	0
Suppliers -4	16333	0.14	3005	18460	7335

<u>Objective Function : maximize transfer product according to normalized risk value:</u>

Max Z = $0.54*X_{12} + 0.32X_{32} + 0.14*X_{42} + 0.40*X_{14} + 0.18*X_{34} + 0.22*X_{13}$

Subject To

$X_{12} + X_{13} + X_{14} \leq 17172$

$X_{12} + X_{32} + X_{42} \leq 0$

$X_{13} - X_{32} - X_{34} \leq 0$

$X_{32} + X_{34} \leq 9424$

$X_{14} + X_{34} - X_{42} \leq 7335$

$X_{42} \leq 3005$

$X_{ij} \geq 0$

Table Optimal Solution Procurement Based on Risk Profile 2a

R_{12}	R_{32}	R_{42}	R_{14}	R_{34}	R_{13}
0	0	0	0	7335	7335

In conclusion, the optimal solution was the solution before conducting risk analysis subtracted with solution after conducting risk analysis.

R_{34} = 7335 means that Supplier 3 have to minus 7335 their supply and supplier 4 have to add 7335 of their supply.

Supplier 2 = 30200 – 7335= 22865

Supplier 4 = 21465 + 7335 = 28800

R_{13} = 7335 means that Supplier 2 have to minus 7335their supply and supplier 4 have to add 7335 of their supply.

Supplier 3 = 29450 – 7335= 22115

Supplier 4 = 28800 + 7335 = 36135

Table Optimal Solution Lingo for scenario 2a

		Manufacturers/Assemblers (j)			
		1	**2**	**3**	**Total**
Suppliers (i)	**1**	0	29385	2415	31800
	2	0	0	22865	22865
	3	20775	1340	0	22115
	4	21465	14670	0	36135
	Total	42240	38060	32615	112915

Sensitivity Analysis for Risk Profile

Sensitivity analysis according to risk profile is needed to know the change of pattern of allocation order. In this sensitivity for a number of Product procured According to the minimum cost is fixed use the calculation done using the lingo in Table 4.9.

Scenario 1 : Changing the risk of each supplier, suppliers who previously had the smallest risk change into greatest value of risk profile, also have same rule with opposite

Table Risk Profile for scenario 1b

	Supplier 1	Supplier 2	Supplier 3	Supplier 4
Risk profiles (R_{Ti})	54	46	20	30

Table Normalized Risk Value scenario 1b

Suppliers	Total Risk Value	Relative total risk values	Normalized values
Suppliers - 1	54	51-20 = 31	$R_{N1} =$ (31-0)/67= 0.46
Suppliers - 2	46	46-20 =26	$R_{N2} =$ (26-0)/67=0.39
Suppliers - 3	20	0	$R_{N3} =$ 0
Suppliers - 4	30	30-20 = 10	$R_{N4} =$ (10- 0)/ 67 = 0.15
	Total	67	1

Table Parameters used in the model scenario 1b

Suppliers	Number of Product procured according to min cost	Normalized risk Values	Number of Product to be transferred	Product to be kept in the supplier	Remaining capacity of the supplier
Suppliers -1	31800	0.46	14628	17172	0
Suppliers -2	30200	0.39	11778	18422	0
Suppliers -3	29450	0	0	29450	0
Suppliers -4	11200	0.15	1680	9520	17600

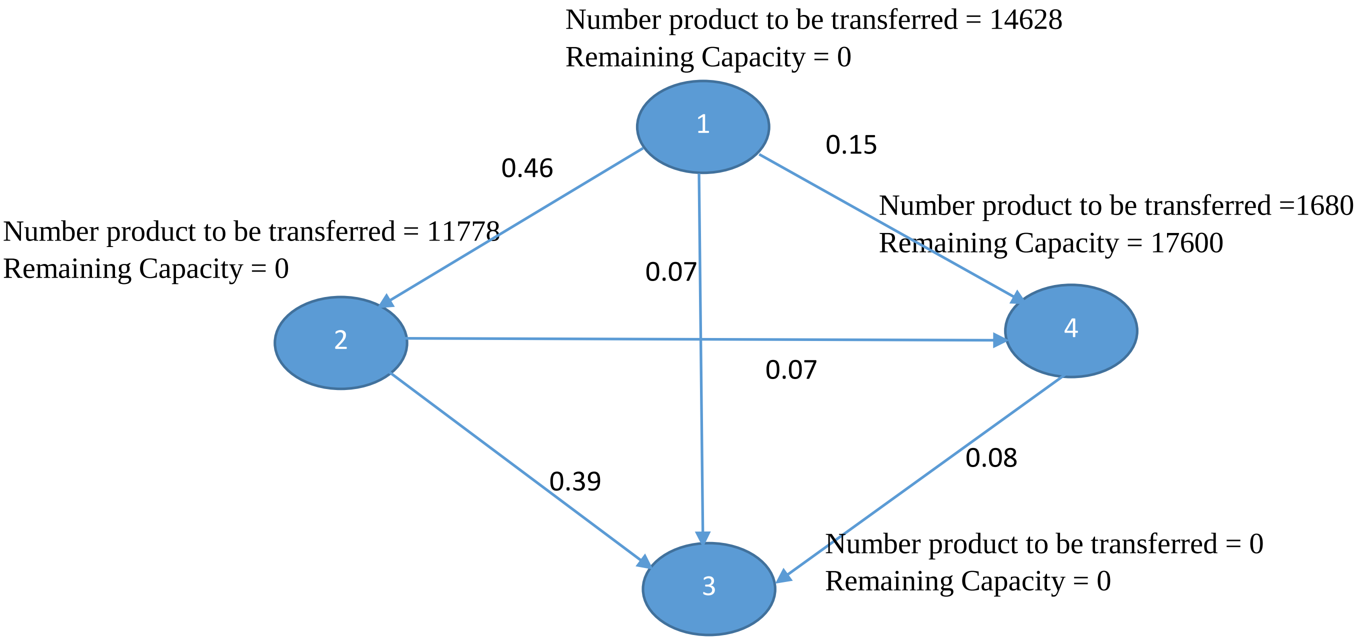

Table Recapitulation The Difference the normalized risk values of suppliers (R_{ij})

R_{13}	R_{23}	R_{43}	R_{14}	R_{24}	R_{12}
0.07	0.39	0.08	0.15	0.07	0.46

<u>Objective Function : maximize transfer product according to normalized risk value:</u>

Max Z = $0.07*X_{13}+ 0.39*X_{23}+ 0.08*X_{43}+ 0.15*X_{14}+ 0.07*X_{24} + 0.46*X_{12}$

Subject To

$X_{12} + X_{13} + X_{43} \leq 14628$

$X_{12} - X_{23} - X_{24} \leq 0$

$X_{23} + X_{24} \leq 11778$

$X_{13} + X_{23} + X_{43} \leq 0$

$X_{14} + X_{24} - X_{43} \leq 17600$

$X_{24} + X_{43} \leq 1680$

$X_{ij} \geq 0$

The formulation is solved via LINGO and the optimal solution is presented in Table below.

Table Optimal Solution Scenario 1b

R_{13}	R_{23}	R_{43}	R_{14}	R_{24}	R_{12}
0	0	0	2904	11778	11778

In conclusion, the optimal solution was the solution before conducting risk analysis subtracted with solution after conducting risk analysis.

R_{14} = 2904, means that Supplier 1 have to minus 2904 their supply and supplier 4 have to add 2904 of their supply.

Supplier 1 = 31800 – 2904 = 28896

Supplier 4 = 11200 + 2904 = 14104

R_{24} = 11778, means that Supplier 2 have to minus 11778 their supply and supplier 4 have to add 11778 of their supply.

Supplier 2 = 30200 – 11778 = 18422

Supplier 4 = 14104 + 11778 = 25882

R_{12} = 11778, means that Supplier 1 have to minus 11778 their supply and supplier 2 have to add 11778of their supply.

Supplier 1 = 28896 – 11778 = 17118

Supplier 2 = 18422 + 11778 = 30200

Table Optimal Solution Scenario 1b

Manufacturers/Assemblers (j)					
		1	**2**	**3**	**Total**
Suppliers (i)	**1**	0	17118	0	17118
	2	550	0	29650	30200
	3	26650	2800	0	29450
	4	11200	17482	0	25882
	Total	38400	34600	29650	102650

Scenario 2 : Changing the risk of each supplier , supplier 4 that previously have the second greater number of risk profile now supplier 4 have the second fewer number of risk profile.

Table Risk Profile for scenario 2b

	Supplier 1	Supplier 2	Supplier 3	Supplier 4
Risk profiles ($R_{Ti)}$	39	48	35	26

Table Normalized Risk Value 2b

Suppliers	Total Risk Value	Relative total risk values	Normalized values
Suppliers - 1	39	39 -26 = 13	R_{N1} = (13-0)/44= 0.3
Suppliers - 2	48	48 - 26 = 22	R_{N2} = (22-0)/44= 0.5
Suppliers - 3	35	35– 26 =9	R_{N3} =(9-0)/44 = 0.2
Suppliers - 4	26	0	R_{N4} = 0
	Total	44	1

Table Parameters used in the model 2b

Suppliers	Number of Product procured according to min cost	Normalized risk Values	Number of Product to be transferred	Product to be kept in the supplier	Remaining capacity of the supplier
Suppliers -1	31800	0.3	9540	22260	0
Suppliers -2	30200	0.5	15100	15100	0
Suppliers -3	29450	0.2	5890	23560	0
Suppliers -4	11200	0	0	11200	17600

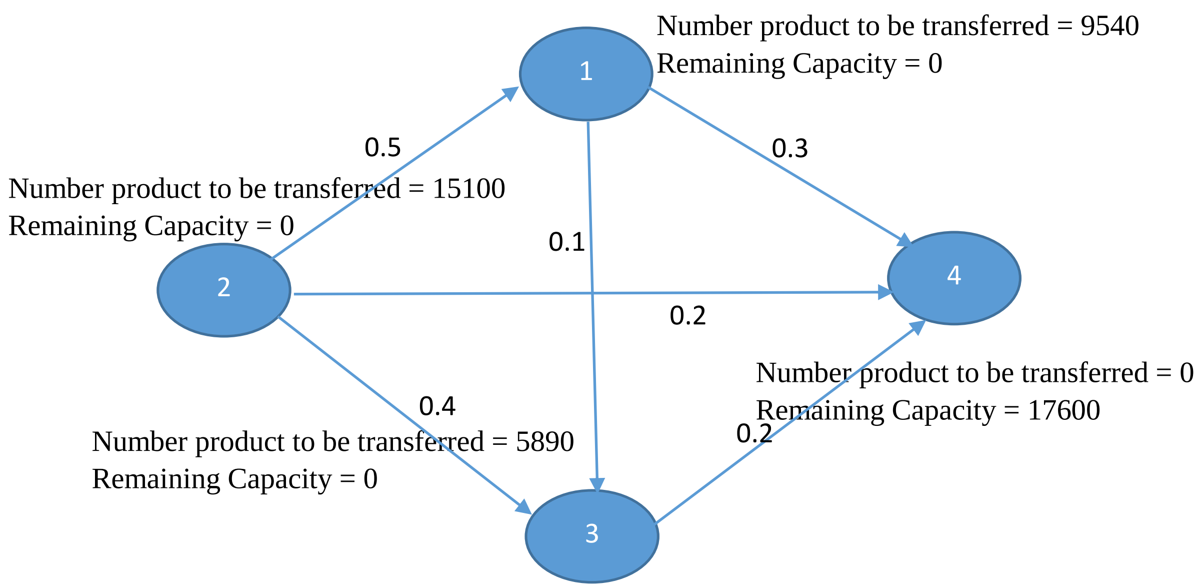

Table Recapitulation The Difference risk values of suppliers (Rij) Scenario

R_{14}	**R_{24}**	**R_{34}**	**R_{13}**	**R_{23}**	**R_{21}**
0.3	0.2	0.2	0.1	0.4	0.5

<u>Objective Function : maximize transfer product according to normalized risk value:</u>

Max Z = $0.3*X_{14} + 0.2*X_{24} + 0.2*X_{34} + 0.1*X_{13} + 0.4*X_{23} + 0.5*X_{21}$

Subject To

$X_{21} - X_{13} - X_{14} \leq 0$

$X_{13} + X_{14} \leq 9540$

$X_{21} + X_{23} + X_{24} \leq 15100$

$X_{13} + X_{23} - X_{34} \leq 0$

$X_{34} \leq 5890$

$X_{14} + X_{24} + X_{34} \leq 17600$

$X_{ij} \geq 0$

The formulation is solved via LINGO and the optimal solution is presented in Table below.

Table Optimal Solution Scenario 2b

R_{14}	**R_{24}**	**R_{34}**	**R_{13}**	**R_{23}**	**R_{21}**
9540	0	5890	0	5560	9540

In conclusion, the optimal solution was the solution before conducting risk analysis subtracted with solution after conducting risk analysis.

R_{14} = 9540, means that Supplier 1 have to minus 9540 of their supply and supplier 4 have to add 13750 of their supply.

Supplier 1 = 31800 – 9540 = 22260

Supplier 4 = 11200 + 9540= 20740

R_{34} =5890 means that Supplier 3 have to minus 5890 their supply and supplier 4 have to add 5890 of their supply.

Supplier 3 = 29450 – 5890 = 23560

Supplier 4 = 20740+ 5890 = 26630

R_{23} = 5560 means that Supplier 2 have to minus 5560 their supply and supplier 3 have to add 5560 of their supply.

Supplier 2 = 30200 – 5560 = 24640

Supplier 3 = 23650 + 5560 = 29210

R_{21} = 9540 means that Supplier 2 have to minus 9540 their supply and supplier 3 have to add 9540 of their supply.

Supplier 2 = 24640 – 9540 = 15110

Supplier 1 = 22260 + 9540 = 31800

Table Optimal Solution Lingo scenario 2b

		Manufacturers/Assemblers (j)			
		1	**2**	**3**	**Total**
Suppliers (i)	**1**	0	31800	0	31800
	2	790	0	14320	15110
	3	26410	2800	0	29210
	4	11200	0	15330	26630
	Total	38400	34600	29650	102650

Scenario 3 : Changing the risk of each supplier, Supplier 2 has the largest risk profile value and supplier 1 has the lowest risk profile value.

Table Risk Profile for scenario 3b

	Supplier 1	**Supplier 2**	**Supplier 3**	**Supplier 4**
Risk profiles (R_{Ti})	22	56	42	34

Table Normalized Risk Value scenario 3b

Suppliers	Total Risk Value	Relative total risk values	Normalized values
Suppliers – 1	22	0	$R_{N1} = 0$
Suppliers – 2	56	56-22= 34	$R_{N2} = (34-0)/66=0.52$
Suppliers – 3	42	42-22=20	$R_{N3} = (20-0)/66= 0.30$
Suppliers – 4	34	34-22 = 12	$R_{N4} = (12-0)/66 = 0.18$
	Total	66	1

Table Parameters used in the model scenario 3b

Suppliers	Number of Product procured according to min cost	Normalized risk Values	Number of Product to be transferred	Product to be kept in the supplier	Remaining capacity of the supplier
Suppliers -1	31800	0	0	31800	0
Suppliers -2	30200	0.52	15704	14496	0
Suppliers -3	29450	0.30	8835	20615	0
Suppliers -4	11200	0.18	2016	9184	17600

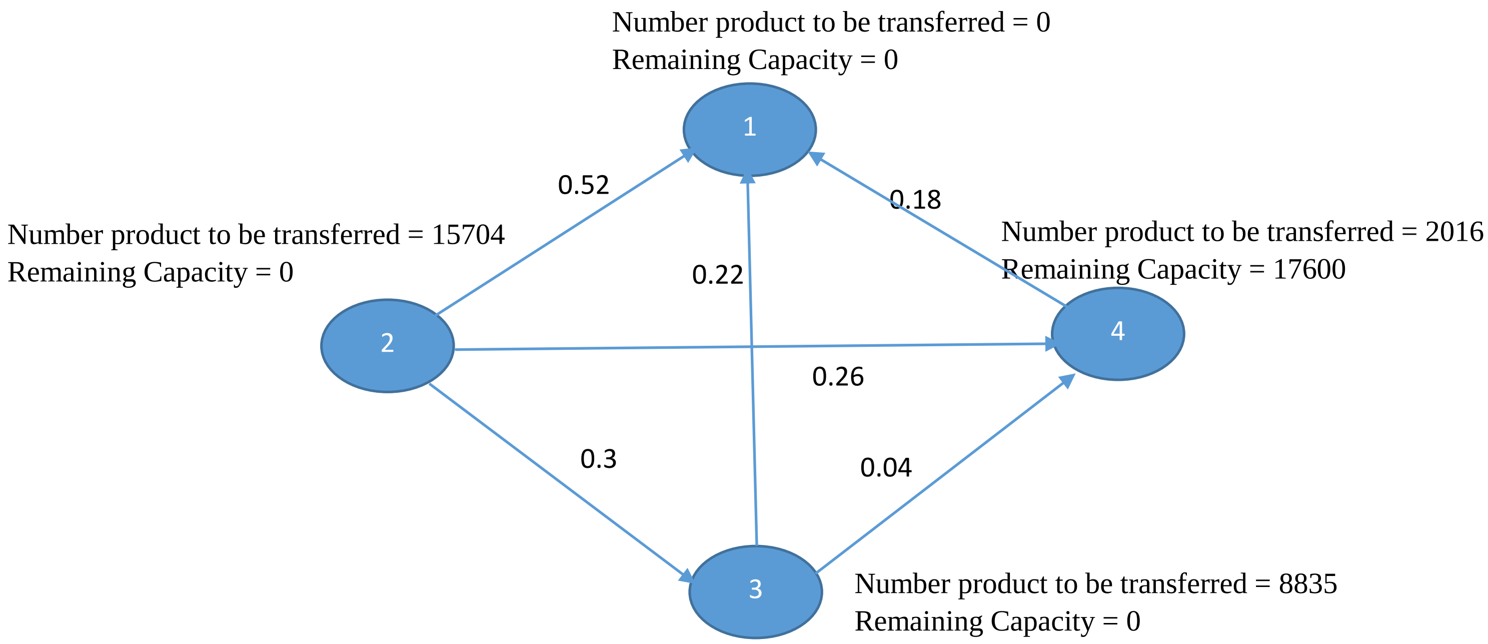

Table Recapitulation The Difference normalized risk values of suppliers (R_{ij})

R_{21}	R_{31}	R_{41}	R_{24}	R_{34}	R_{23}
0.52	0.22	0.18	0.26	0.04	0.3

Objective Function : maximize transfer product according to normalized risk value:

Max Z = $0.52*X_{21}+ 0.22*X_{31}+ 0.18*X_{41}+ 0.26*X_{24}+ 0.04*X_{34} + 0.3*X_{23}$

Subject To

$X_{21} + X_{31} + X_{41} \leq 0$

$X_{21} + X_{23} + X_{34} \leq 15704$

$X_{23} - X_{31} - X_{34} \leq 0$

$X_{31} + X_{34} \leq 8835$

$X_{24} + X_{34} - X_{41} \leq 17600$

$X_{41} \leq 2016$

$X_{ij} \geq 0$

The formulation is solved via LINGO and the optimal solution si presented in Table below.

Table Optimal Solution Scenario 3b

R_{21}	R_{31}	R_{41}	R_{24}	R_{34}	R_{23}
0	0	0	9748	7852	7852

In conclusion, the optimal solution was the solution before conducting risk analysis subtracted with solution after conducting risk analysis.

R_{24} = 9748, means that Supplier 2 have to minus 9748 their supply and supplier 4 have to add 9748 of their supply.

Supplier 2 = 31800 – 9748 = 22052

Supplier 4 = 11200 + 9748 = 20948

R_{34} = 7852, means that Supplier 3 have to minus 7852 their supply and supplier 4 have to add 7852 of their supply.

Supplier 3 = 29450 – 7852 = 21598

Supplier 4 = 20948 + 7852 = 28800

R_{23} = 7852, means that Supplier 2 have to minus 7852 their supply and supplier 3 have to add 11778of their supply.

Supplier 2 = 22052– 11778 = 10274

Supplier 3 = 21598+ 11778 = 33376

Table Optimal Solution Scenario 3b

Manufacturers/Assemblers (j)					
		1	2	3	Total
Suppliers (i)	1	0	31800	0	31800
	2	550	0	9724	10274
	3	30576	2800	0	33376
	4	7274	1600	19926	28800
	Total	38400	36200	29650	102650

Scenario 4 : Changing the risk of each supplier, Supplier 3 has the largest risk profile value and supplier 2 has the lowest risk profile value.

Table Risk Profile for scenario 4b

	Supplier 1	Supplier 2	Supplier 3	Supplier 4
Risk profiles (R_{Ti})	30	21	58	41

Table Normalized Risk Value scenario 4b

Suppliers	Total Risk Value	Relative total risk values	Normalized values
Suppliers - 1	30	30-21= 9	R_{N1} = (9-0)/76= 0.12
Suppliers - 2	21	0	R_{N2} = 0
Suppliers - 3	58	58-21= 37	R_{N3} = (37-0)/76=0.49
Suppliers - 4	41	41-21 = 30	R_{N4} = (30-0)/76 = 0.39
	Total	76	1

Table Parameters used in the model scenario 4b

Suppliers	Number of Product procured according to min cost	Normalized risk Values	Number of Product to be transferred	Product to be kept in the supplier	Remaining capacity of the supplier
Suppliers -1	31800	0.12	3816	27984	0
Suppliers -2	30200	0	0	30200	0
Suppliers -3	29450	0.49	14431	15019.5	0
Suppliers -4	11200	0.39	4368	6832	17600

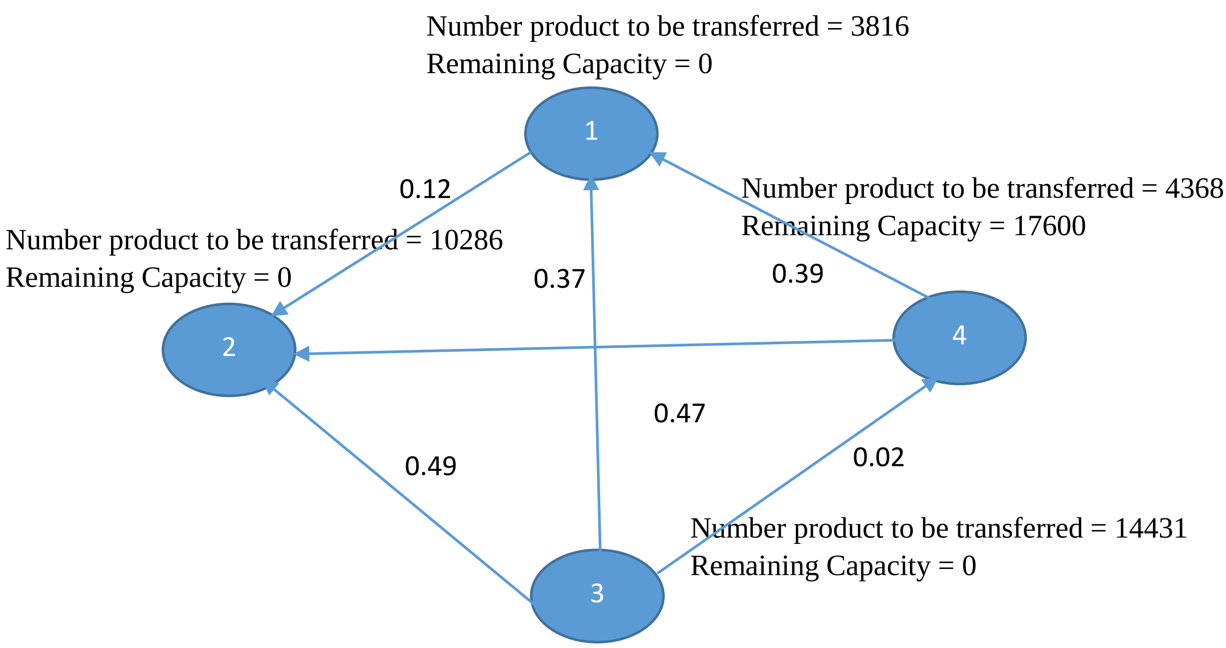

Table Recapitulation The Difference normalized risk values of suppliers (R_{ij}

R_{12}	R_{32}	R_{42}	R_{31}	R_{41}	R_{34}
0.12	0.39	0.47	0.37	0.39	0.02

<u>Objective Function : maximize transfer product according to normalized risk value:</u>

Max Z = $0.12*X_{12}+ 0.39*X_{32}+ 0.42*X_{42}+ 0.37*X_{31}+ 0.39*X_{41} + 0.02*X_{34}$

Subject To

$X_{31} + X_{41} - X_{12} \leq 0$

$X_{12} \leq 3816$

$X_{12} + X_{32} + X_{42} \leq 0$

$X_{31} + X_{32} + X_{34} \leq 14431$

$X_{34} - X_{41} - X_{42} \leq 17600$

$X_{41} + X_{42} \leq 4368$

$X_{ij} \geq 0$

The formulation is solved via LINGO and the optimal solution is presented in Table below.

Table Optimal Solution Scenario 4b

R_{12}	R_{32}	R_{42}	R_{31}	R_{41}	R_{34}
0	0	0	0	0	14431

In conclusion, the optimal solution was the solution before conducting risk analysis subtracted with solution after conducting risk analysis.

R_{34} = 14431, means that Supplier 3 have to minus 14431 their supply and supplier 4 have to add 14431of their supply.

Supplier 3 = 29450 – 14431 = 15019

Supplier 4 = 11200 + 14431 = 25631

Table Optimal Solution Scenario 4b

Manufacturers/Assemblers (j)					
		1	**2**	**3**	**Total**
Suppliers (i)	**1**	0	31800	0	31800
	2	550	0	29650	30200
	3	12219	2800	0	15019
	4	25631	0	0	25631
	Total	38400	34600	29650	102650

Scenario 5 : Changing the risk of each supplier, Supplier 1 has the largest risk profile value and supplier 2 has the lowest risk profile value.

Table Risk Profile for scenario 5b

	Supplier 1	Supplier 2	Supplier 3	Supplier 4
Risk profiles (R_{Ti})	24	43	50	33

Table Normalized Risk Value scenario 5b

Suppliers	Total Risk Value	Relative total risk values	Normalized values
Suppliers - 1	24	0	$R_{N1} = 0$
Suppliers - 2	43	43 – 24 = 19	$R_{N2} = (19 - 0)/54 = 0.35$
Suppliers - 3	50	50- 24 = 26	$R_{N3} = (26 - 0)/54 = 0.48$
Suppliers - 4	33	33 -24= 9	$R_{N4} = (9 - 0)/54 = 0.17$
	Total	54	1

Table Parameters used in the model scenario 5b

Suppliers	Number of Product procured according to min cost	Normalized risk Values	Number of Product to be transferred	Product to be kept in the supplier	Remaining capacity of the supplier
Suppliers -1	31800	0	0	31800	0
Suppliers -2	30200	0.35	10570	19630	0
Suppliers -3	29450	0.48	14136	15314	0
Suppliers -4	11200	0.17	1904	9296	17600

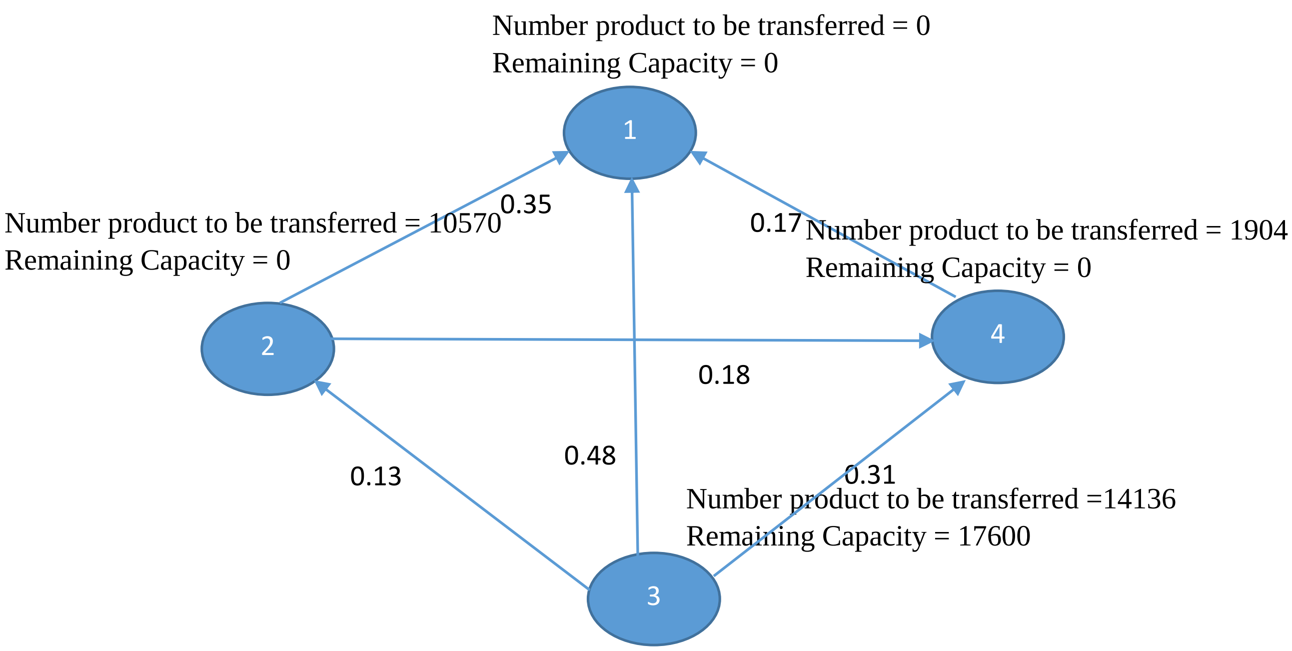

Table Recapitulation The Difference normalized risk values of suppliers (R_{ij})

R_{21}	R_{31}	R_{41}	R_{24}	R_{34}	R_{32}
0.35	0.48	0.17	0.18	0.31	0.13

Objective Function : maximize transfer product according to normalized risk value:

Max Z = $0.35*X_{21} + 0.48*X_{31} + 0.17*X_{41} + 0.18*X_{24} + 0.31*X_{34} + 0.13*X_{32}$

Subject To

$X_{21} + X_{31} + X_{41} \leq 0$

$X_{32} - X_{21} - X_{24} \leq 0$

$X_{21} + X_{24} \leq 10570$

$X_{31} + X_{32} + X_{34} \leq 14136$

$X_{24} + X_{34} - X_{41} \leq 17600$

$X_{41} \leq 1904$

$X_{ij} \geq 0$

The formulation is solved via LINGO and the optimal solution si presented in Table below.

Table Optimal Solution Scenario 3

R_{21}	R_{31}	R_{41}	R_{24}	R_{34}	R_{32}
0	0	0	0	14136	0

In conclusion, the optimal solution was the solution before conducting risk analysis subtracted with solution after conducting risk analysis.

R_{24} = 3464, means that Supplier 2 have to minus 3464 their supply and supplier 4 have to add 3464of their supply.

Supplier 2 = 30200 – 3464= 26736

Supplier 4 = 11200 + 3464= 14664

R_{34}= 14136 means that Supplier 3 have to minus 14136 their supply and supplier 4 have to add 14136 of their supply.

Supplier 3 = 29450 – 14136 = 15314

Supplier 4 = 14664 + 14136 = 28800

Table Optimal Solution Scenario 5b

Manufacturers/Assemblers (j)					
		1	2	3	Total
Suppliers (i)	1	0	31800	0	31800
	2	0	0	26736	26736
	3	12514	2800	0	15314
	4	25886	0	2914	28800
	Total	38400	34600	29650	102650

Sensitivity Analysis for Price

Sensitivity analysis has also done by raise the price of goods in 5% and 10%. Here are the results of a sensitivity analysis by increasing the price of goods in 5% and 10%.

Scenario 1 : Increase 10% price of soda caustic for supplier 1 and 2 and decrease 10% price for supplier 3 and 4

Table Purchasing price of each supplier 1c

Suppliers	1	2	3	4	Total
Unit Price (P_i)	9130	8910	7560	9515	35115

Using formulations (4-1) by changing level of price, so formulation that used for calculating optimal allocation order are :

Mincost = $(9130 + 63.64)\ y_{11} + (9130 + 55.45)\ y_{12} + (9130 + 70.45)\ y_{13} + (8910 + 97.73)\ y_{21} + (8910 + 102.27)\ y_{22} + (8910 + 95.45)\ y_{23} + (7560 + 65.91 y_{31} + (7560 + 56.82)\ y_{32} + (7560 + 72.73)\ y_{33} + (9515 + 59.09)\ y_{41} + (9515 + 56.82)\ y_{42} + (9515 + 68.18)\ y_{43}$

Mincost = $9194y_{11} + 9228y_{12} + 9200y_{13} + 9008y_{21} + 9012y_{22} + 9005y_{23} + 7626y_{31} + 7617y_{32} + 7633y_{33} + 9574y_{41} + 9572y_{42} + 9583y_{43}$

Subject To

$y_{11} + y_{12} + y_{13} \leq 31800$

$y_{21} + y_{22} + y_{23} \leq 30200$

$y_{31} + y_{32} + y_{33} \leq 29450$

$y_{41} + y_{42} + y_{43} \leq 28800$

$y_{11} + y_{21} + y_{31} + y_{41} \leq 38400$

$y_{12} + y_{22} + y_{32} + y_{42} \leq 34600$

$y_{13} + y_{23} + y_{33} + y_{43} \leq 29650$

In according to data in table below, then obtained optimum results as follows.

Table Optimal Solution Lingo for scenario 1c

Manufacturers/Assemblers (j)					
		1	2	3	Total
Suppliers (i)	1	31800	0	0	31800
	2	6600	5150	18450	30200
	3	0	29450	0	29450
	4	0	0	11200	11200
	Total	38400	34600	29650	102650

Table Parameters used in the model Scenario 1c

Suppliers	Number of Product procured according to min cost	Normalized risk Values	Number of Product to be transferred	Product to be kept in the supplier	Remaining capacity of the supplier
Suppliers -1	31800	0	0	31800	0
Suppliers -2	11750	0.17	1998	9753	18450
Suppliers -3	29450	0.48	14136	15314	0
Suppliers -4	11200	0.35	3920	7280	17600

<u>Objective Function : maximize transfer product according to normalized risk value:</u>

Max Z = $0.35*X_{41} + 0.17*X_{21} + 0.48*X_{31} + 0.18*X_{24} + 0.15*X_{34} + 0.31*X_{32}$

Subject To

$X_{21} + X_{31} + X_{41} \leq 0$

$X_{32} - X_{21} - X_{24} \leq 18450$

$X_{21} + X_{24} \leq 1998$

$X_{31} + X_{32} + X_{34} \leq 14136$

$X_{24} + X_{34} - X_{41} \leq 17600$

$Y_{41} \leq 3920$

$X_{ij} \geq 0$

The formulation is solved via LINGO and the optimal solution is presented in Table 4.13 below.

Table Optimal Solution Scenario 1c

R_{41}	R_{21}	R_{31}	R_{24}	R_{34}	R_{32}
0	0	0	1998	14136	0

In conclusion, the optimal solution was the solution before conducting risk analysis subtracted with solution after conducting risk analysis.

R_{24} = 1998 means that Supplier 2 have to minus 1998 their supply and supplier 4 have to add 1998 of their supply.

Supplier 2 = 30200 – 1998 = 28202

Supplier 4 = 11200 + 1998 = 13198

R_{34} = 14136 means that Supplier 3 have to minus 14136 their supply and supplier 4 have to add 14136 of their supply.

Supplier 3 = 29450 – 14136 = 15314

Supplier 4 = 13198 + 14136 = 27334

Table Optimal Solution Lingo According to Risk Scenario 1c

		Manufacturers/Assemblers (j)			
		1	**2**	**3**	**Total**
Suppliers (i)	**1**	31800	0	0	31800
	2	6600	19286	2316	28202
	3	0	15314	0	15314
	4	0	0	27334	27334
	Total	38400	34600	29650	102650

Scenario 2 : Increasing 15% price of soda caustic for supplier 2 and 4, decrease 15% price for supplier 1 and 3.

Table Purchasing price of each supplier 2c

Suppliers	**1**	**2**	**3**	**4**	**Total**
Unit Price (P_i)	7055	9315	7140	9948	33458

Using formulations (4-1) by changing level of price, so formulation that used for calculating optimal allocation order are:

Mincost = (7055+ 63.64) y_{11} + (7055 + 55.45) y_{12} + (7055 + 70.45) y_{13} + (9315+ 97.73) y_{21} + (9315+ 102.27) y_{22} + (9315+ 95.45) y_{23} + (7140+ 65.91y_{31} + (7140+ 56.82) y_{32} + (7140+ 72.73) y_{33} + (9948+ 59.09) y_{41} +(9948+ 56.82) y_{42} + (9948 + 68.18) y_{43}

Mincost = $7119y_{11} + 7110y_{12} + 7125y_{13} + 9413y_{21} + 9417y_{22} + 9410y_{23} + 7206y_{31} + 7197y_{32} + 7213y_{33} + 10007y_{41} + 10004y_{42} + 10016\, y_{43}$

Subject To

$y_{11} + y_{12} + y_{13} \leq 31800$

$y_{21} + y_{22} + y_{23} \leq 30200$

$y_{31} + y_{32} + y_{33} \leq 29450$

$y_{41} + y_{42} + y_{43} \leq 28800$

$y_{11} + y_{21} + y_{31} + y_{41} \leq 38400$

$y_{12} + y_{22} + y_{32} + y_{42} \leq 34600$

$y_{13} + y_{23} + y_{33} + y_{43} \leq 29650$

In according to data in table below, then obtained optimum results as follows.

Table Optimal Solution Lingo for scenario 2c

		Manufacturers/Assemblers (j)			
		1	**2**	**3**	**Total**
Suppliers (i)	**1**	0	31800	0	31800
	2	550	0	29650	30200
	3	26650	2800	0	29450
	4	0	0	11200	11200
	Total	27200	34600	40850	102650

The optimal solution above is the optimal solution before considering risk aspect which in this research risk aspect is explained in the form of risk profile. Because in scenario 1c is only changing price factor then for risk profile using the same value as in table 4.8. So we can know the model parameters based on risk profile as follows.

Table Parameters used in the model Scenario 2c

Suppliers	Number of Product procured according to min cost	Normalized risk Values	Number of Product to be transferred	Product to be kept in the supplier	Remaining capacity of the supplier
Suppliers -1	31800	0	0	31800	0
Suppliers -2	30200	0.17	5134	25066	0
Suppliers -3	29450	0.48	14136	15314	0
Suppliers -4	11200	0.35	3920	7280	17600

<u>Objective Function : maximize transfer product according to normalized risk value:</u>

Max Z = $0.35*X_{41}+ 0.17*X_{21}+ 0.48*X_{31}+ 0.18*X_{24}+ 0.15*X_{34} + 0.31*X_{32}$

Subject To

$X_{21} + X_{31} + X_{41} \leq 0$

$X_{32} - X_{21} - X_{24} \leq 0$

$X_{21} + X_{24} \leq 5134$

$X_{31} + X_{32} + X_{34} \leq 14136$

$X_{24} + X_{34} - X_{41} \leq 17600$

$Y_{41} \leq 3920$

$X_{ij} \geq 0$

The formulation is solved via LINGO and the optimal solution si presented in Table below.

Table Optimal Solution Scenario 2c

R_{41}	R_{21}	R_{31}	R_{24}	R_{34}	R_{32}
0	0	0	5134	12466	0

In conclusion, the optimal solution was the solution before conducting risk analysis subtracted with solution after conducting risk analysis.

R_{24} = 5134 means that Supplier 2 have to minus 5134 their supply and supplier 4 have to add 5134 of their supply.

Supplier 2 = 30200 – 5134 = 25066

Supplier 4 = 11200 + 5134= 16334

R_{34} = 12466 means that Supplier 2 have to minus 12466 their supply and supplier 4 have to add 12466 of their supply.

Supplier 3 = 29450 – 12466 = 16984

Supplier 4 = 16334 + 12466 = 28800

Table Optimal Solution Lingo According Risk Scenario 2c

		Manufacturers/Assemblers (j)			
		1	**2**	**3**	**Total**
Suppliers (i)	**1**	0	31800	0	31800
	2	10216	2800	12050	25066
	3	16984	0	0	16984
	4	0	0	28800	28800
	Total	27200	34600	40850	102650

AUTHOR’S BIOGRAPHY

Cindy Revitasari was born in Kediri, March 1993. Her nickname is Cindy and she is a moslem. She got her Bachelor Degree of Industrial Engineering from Brawijaya University (UB) in 2015 with cumlaude predicate. In her undergraduate study, she have been active in Organization especially in entrepreneur department of Industrial Engineering Student Association and also active to join some committee. She also has been selected to be an assistant at Simulation and Industrial Application Laboratory that concern about software Arena and Promodel. She has completed her master degree program with cumlaude predicate in Department of Industrial Engineering, Sepuluh Nopember Institute of Technology (ITS), concern on Operations and Supply Chain Engineering in 2017. For further information, it allows to contact the author through email revitasaricindy@gmail.com.

“ Learn from yesterday, live for today and always hope for a better tomorrow ”

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