System Dynamics Approach to Supply Chain Performance Measurement in Small and Medium Enterprise

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Abstract

The concept of supply chain management has today become a tool that both manufacturing and service organizations have been using to help win greater market share. Small-medium enterprises have found it difficult to measure their performance due to the complex external environment. In this paper, analysis of a single case study of an SME through survey and interview is done in order to measure the performance of its responsive supply chain. A system dynamics modeling approach is used to model the variables that have greater influence on the performance system through the development of a causal loop and stock and flow diagrams. Comparisons of the experimental results shows that the domestic purchase of the raw material and quality efficiency will help to reduce the future lead-time and import requirements which will help the company to achieve product availability which is the main competitive strategy of a responsive supply chain.

Keywords
Supply Chain, Performance Measurement, System Dynamics, SME

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1. Introduction

In recent years, Small and Medium Enterprises (SMEs') have contributed greatly to the economies of developed and developing nations. In Australia, they represent 97% of all private business and 47% of private sector employment (Barnes et al., 1998), while in Malaysia, they represent 97% of total companies and contribute 32% to overall GDP in 2012 and projected to around 40% by 2020 (SME Corporation Malaysia: Annual Report 2011/12). Even though SMEs have played major roles in developing and developed economies, they have found it difficult to survive in today's business environment due to the complexity associated with the operating business environment, evolving nature of information technology, rapid changes in customer demands, globalization, outsourcing and many other essential supply chain activities. This difficulty in survival is due to the complex external feedback that also results from business environment in which SMEs are said to operate. Many researchers have found it very difficult to measure the performance of small and medium enterprises as opposed to large enterprises. It is believed that the reasons for difficulties in measuring their performances are due to the fact that majority of the SMEs' do not have the expertise (human resources and capital) to implement an effective measuring system or if they do, majority do not have the technical human resources to implement and purchase some of the performance measure models that are in existence.

From works done by Neely et al., (1995) and Moullin (2003), a more comprehensive definition of performance measurement has been derived: "Performance measurement is defined as the process of quantifying the effectiveness and efficiency of supply chain actions and the idea of evaluating how well organizations are managed so as to provide or create value for their customers and other stakeholders". Performance measurement originated from early accounting systems, "BEFORE and AFTER" the 1980s. According to Kurien and Qureshi (2011), the "BEFORE" phase was based on cost accounting orientations. It was observed that these financial measures failed to measure the factors influencing the success of businesses. This failure however was due to the complexities that existed in organizations and dynamic market in which organizations existed. The second phase of the evolution started in the late 1980s' where many frameworks emerged criticizing the use of financial measures to evaluate firms' performances. Most of the proposed frameworks instituted that both financial and non-financial measures/indicators have to be considered in measuring supply chain performances. In the 1990s' introduction of supply chain performance models to measure supply chain performances emanated. Some of the models that were introduced in the early 1990s' are the Balanced Scored Card (BSC Model), SMART (1998) etc. The most widely cited were SMART (1998), Performance measurement Matrix (1989), BSC (1992) etc.

According to a framework proposed by Gunasekaran et al., (2004), the metrics and measures of a firm can be best evaluated using the following activities or approach: plan, source, make/assemble and deliver. This framework went further to preview that to measure the performance of supply chain we have to consider three different levels; strategic, tactical and operational. Strategic relates to managerial decisions, tactical deals with proper allocation of resources and operational measurement focuses on the real day to day activities in achieving supply chain fit. The balanced score card model developed by Kaplan and Norton (1992), stated that in order to measure the performance of one's supply chain you have to seek balanced measures like customer perspective, financial perspective, internal perspective and innovation. The balanced score card over the years have been considered the most successful model to measure the performance of organizations because it constitutes both financial and non-financial measures. Beamon (1999), went on also to present a framework stating most of the models used persistently utilized cost and combination of cost and customer responsiveness. He stated other performance measures were identified but could not be incorporated into most of the existing quantitative models due to their qualitative nature. Examples were customer satisfaction, information flow and risk management. He went on to conclude that to achieve strategic goals of an organization one has to consider resources output and flexibility. According to the Supply Chain Operations Reference (SCOR) (2010), model employs the concept of process re-engineering, benchmarking and process measurement. SCOR consists of four distinct processes source, make, deliver and plan. According to Neely et al., (2001), that even though several frameworks have been developed over the years to solve performance measurement issues of which Balanced Scored Card being the most widely used and established, but the Balanced Score Card has been seen abused in many organizations. Due to the improvement in technology and idea of "NEW ECONOMY" analysis, there has been an urge for a new generational measurement framework to update scorecards of reputable firms and hence introduction of the performance prism. The performance prism consists of five connected bridges (facets) that helped to answer questions that were not considered by notably the first generation framework proposed in the Balanced Scored Card.

Many scholarly works have been done on performance measurement of supply chain but few are those on SMEs' and if any, few are those that can suggest procedures for implementation and continuous monitoring due to the characteristics of SMEs'; limited resources and managerial expertise. Scholars have argued regarding the implementation of performance measurement models in SMEs'. Some of them (Jungman et al, 2004) believed that these models are applicable while others (Hvolby and Thorstensun, 2000), said that performance measurement in SMEs has its special characteristics than that of large enterprises. SMEs' are said to have little resources and expertise which makes it difficult to implement these existing models. The difference between large enterprises and SMEs' is the greater external uncertainty of the environment in which SMEs' operates together with greater internal consistency of its motivation and actions. This uncertainty is due to the limited resources and managerial expertise available at SMEs'. The ability of keeping a performance measurement system continuously updated is a challenge for every firm especially SMEs' which need to be extremely flexible and reactive to market changes while characterized by lack of resources and managerial expertise (Paola and Alberti, 2010). Most SMEs have found it difficult to use most of the existing performance measurement system models and frameworks or if they attempt to use one, implementation becomes a problem due to lack of suitable methodologies to guide implementation. Difference between managerial culture and management systems has been observed in SMEs' due to lack of financial and human resources, wrong perceptions of performance measurement system benefits and implementation (Chalmeta et al., 2012). Therefore the primary objective of this study is to develop an assessment approach through system dynamics modeling to help identify the supply chain performance variables that have great influence on the measurement system of SMEs' due to the constant and complex feedback information and model these variables so as to help managers and management make good decisions in measuring the performance of their supply chains.

2. Methodology

A mixed or concurrent design approach was used in this research work. Mixed approach is a methodology that uses both qualitative and quantitative methods to carry out a research. A survey questionnaire, interview and documentation were used to get the qualitative data and some quantitative data from the case study company. Some quantitative data were also achieved from official website of The Ministry Of Agriculture & Agro-Based Industry Malaysia and also from official website of The Malaysian Cocoa Board. The survey included three types of scales but a five point Likert scale was used to help the respondents express the importance of each performance measurement variable. The performance measurement variables of the case study company were identified through interviews with senior management and managers and thorough review of literature from books and journal papers.

Table 1. Definition of performance measurement variables

Variables	Types	Meanings	References
New product development time	Result	Ability to reduce product development time	Handfield (2002), Christopher and Towill (2001)
New product introduction time	Result	Ability to reduce time to introduce new product or new features on existing products	Handfield (2002), Ward *et al* (1996)
Lead time	Result	Time between receiving customer order to product delivery	Towill (1996)
Information technology	Enabler	Software and hardware to empower lead time reduction	Yu, Yan and Edwin chen (2001)
Delivery speed	Enabler	Ability to deliver as planned	Roth *et al.*, (1989), Ward *et al.*, (1996)
Delivery reliability	Enabler	Ability to constantly deliver as scheduled	Roth *et al* (1989), Ward *et al* (1996)
Process integration	Enabler	Working together with suppliers and customers	Christopher and Towill (2001)
Collaborative planning	Enabler	Using resources and facilities of partners	Christopher and Towill (2001)
Market sensitivity	Enabler	Active response to changes in market environment	Christopher and Towill (2001)
Uncertainties	Inhibitor	Unpredictable situations	Prater, Biehl and smith (2001)
Cost	Result	Cost minimization	Manson-Jones,Naylor and Towill (2000)
Quality	Result	Quality is the taste of the customer satisfaction	Christopher and Towill (2001)

A system dynamics approach was used to measure the performance of the case study company. System dynamics was developed by Jay W. Forrester in 1961. It is a form of computer aided approach for analyzing and solving complex interactions with focus on policy analysis and design. It uses a technique based on information feedback to understand the dynamic behavior of complex, physical and biological systems (Forrester, 1961). There are two sides to system dynamics analysis; causal loop diagram and stock and flow diagram. The causal loop shows the relationship among the various variables of the system through feedback analyses. A positive feedback shows that both the dependent and independent variables move in the same direction while a negative feedback signifies opposite direction. The stock

and flow diagram helps to quantify the causal loop diagram. From the analysis of the survey questionnaire, a causal loop diagram was developed to show the interrelationships and interdependence among the variables. Respondents identified lead-time reduction, quality products and product availability as the main order winning strategies of the case study company. As one of the objectives of this work, these variables were later model to know their effect on the performance of the case study company. The table below gives the various variables for lead-time reduction as the main variable of the performance system.

Table 2. Variables of lead-time reduction

Variable Name	Type	Unit
Domestic cocoa production	Stock	Tonnes
Total cocoa malt demand	Stock	Tonnes
Growth in domestic production	Converter	Tonnes
Growth in cocoa malt demand	Converter	Tonnes
Efficiency of workers	Converter	Percentage
Import requirements	Converter	Tonnes
Import lead time	Converter	Days
Demand accumulation	Flow	Tonnes
Increased production capacity	Flow	Tonnes
Present lead-time	Converter	Days
Future lead-time	Converter	Days
Total lead-time reduction	Converter	Days
Time reduction factor	Converter	Days
Total lead-time reduction	Converter	Days
Time reduction factor	Converter	Days

3. System Modeling

Causal loop diagram are a very simple but powerful ways of visualizing the important part of a system and how they interrelate. The parts of the system are visualized using identifiers. The connection between the parts are shown using arrows pointing in the direction of influence. Causal loop diagrams help the modeler to conceptualize the real world problem in terms of feedback loop. From literature review and initial interview conducted, the performance measurements variables have been divided into enablers, results and inhibitors of which the total sum of the three divisions give the supply chain performance. Since the case study company is focusing on “on-time delivery” (product availability), the supply chain is a responsive supply chain. There are five loops in the Causal Loop Diagram (CLD). In the first loop, to have product always available at the company where the study conducted, the company has to be effective in terms of market sensitivity as it helps to know what the customer wants that could be always made available. Good market sensitivity helps in keeping the company informed about changing demands of customers which could lead to new product development or developing new features on existing product to stay competitive. Increase market sensitivity increases delivery speed. This increase in delivery speed leads to good process integration between the company and its suppliers so as to meet the needs of the customer. This will help increase the performance of the supply chain and it can therefore be ascertain that the feedback loop between market sensitivity, delivery speed, process integration, new product introduction and supply chain performance is (+).

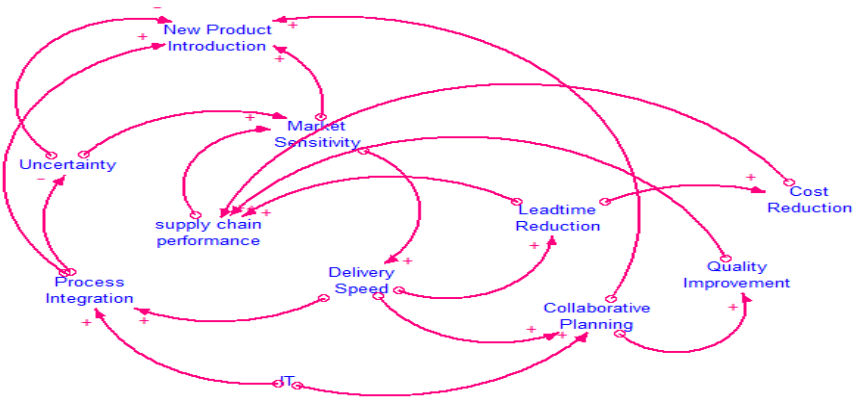

Figure 1. Causal loop diagram for supply chain variables

In the second loop, we see that increase in market sensitivity increases delivery speed which in turn improves process integration. A very sensitive market will help to reduce greater uncertainties and therefore the company will be able to better forecast to avoid stock out. The feedback loop between market sensitivity and uncertainty is (-). In the third loop, increased in delivery speed reduces the lead time for replenishment. This reduced lead time will result to lower cost and hence more orders will be received from customers because respondents identified reduced lead-time as one of the order winning strategies which will increase the supply chain performance. The loop between delivery speed, lead time reduction and cost is a (+ve) loop. On the other hand, poor market sensitivity leads to high uncertainties about customer demands. In the fourth loop, Uncertainty in customer demand results to decrease in process integration and collaboration as suppliers may not know the actual situation of what is required which increases the lead time for product availability. Long lead time leads to decrease in customer orders which will seriously affect the supply chain performance. The best solution to oversee uncertainties in supply chain operations is to have a good IT tool or tools that can be used for better forecasting. The feedback loops between uncertainty, new product introduction, process integration, collaborative planning and IT is (-ve). In the fifth loop, Collaborative planning helps to improve the quality of the products and also reduce cost that could improve the supply chain performance. The feedback loop between collaborative planning, quality, cost and supply chain performance is (+ve). Reduce lead time will help to increase delivery reliability, reduce cost and will lead to winning more customer orders as the main competitive strategy of the case study company is product availability. This will then increase supply chain performance or surplus. The feedback loop between reduced lead time, delivery reliability, cost and supply chain performance is positive.

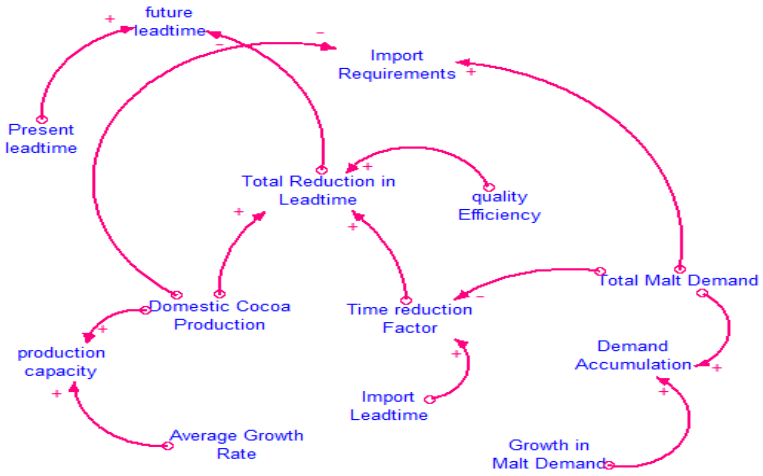

Figure 2. Causal loop diagram of lead-time reduction

There are several connecting loops in the diagram. It starts by explaining that the when there is growth in domestic production, there will be an increase in the capacity of production which will increase the domestic stock available. Therefore the loop between domestic cocoa production, production capacity and growth in domestic rate is (+). When there is growth in demand of malt drink, demand may tend to accumulate as customers make their orders to the case study company. This however increases the total demand of malt drink leading to increase in importation. The loop

between the four variables is said to be (+). When there is increase domestic production of cocoa there will be a decrease in the import requirements as the company tends to purchase raw materials locally instead of importing while increase in total malt demand increases importation. Hence the loop between domestic cocoa production import requirements is (-ve) while it is (+ve) for the case of total malt demand. Three factors are said to reduce total leadtime of the company; Quality, domestic cocoa production and time reduction factor. Quality products reduces rework by saving time, domestic production allows increase in domestic availability of raw materials and time reduction factor reduces the effect of import leadtime and total malt demand on the total leaddtime. Hence the loop between total leadtime and the three variables is positive (+ve). As the total leadtime reduces to purchase cocoa powder for production so does the future leadtime reduces. The future leadtime increases with increase in present leadtime, and therefore the loop between total leadtime and future leadtime is (-ve) will it is (+ve) for the case of present leadtime.

4. Results and Discussion

The result of the various simulations that were investigated using a what-if-analysis in order to study the behavior of the selected variables on the model over a period of five years look ahead. Fifteen (15) scenarios were investigated with five scenarios each of the three parts. Three variables were investigated for part one (domestic cocoa production, future lead-time and import requirements), three for part two (total malt demand, future lead-time and import requirements) and one variable for part three (future lead-time). Figure 3 shows the current operating conditions of the case study company.

In part one of the experimental analyses, a “what-if analysis” was taken to vary the growth in domestic Cocoa Production so as to observe the behavior on other variables of the model overtime. From results shown in Figures 4, Figure 5, and Figure 6, it is evident that as the growth in domestic production of cocoa increases, the stock value of domestic production increases followed by a decrease in the import requirements and future lead-time. From the respondents of the questionnaire survey, it takes about 30 days to import and about 7 days to deliver the cocoa powder domestically. Therefore increasing domestic growth increases domestic availability of cocoa powder which will reduce import requirements and hence reduce lead time. Part two of the analyses was based on varying the growth in demand for total malt drink by the customers of the company.

From results shown in Figure 7, Figure 8 and Figure 9, it is also evident that as the company tends to receive more orders from the customers, demand continues to accumulate which could prompt more import requirements because the total demand of malt drink of the company increases. If however the growth in domestic production remains constant, then we will observe an increase in import requirements and hence there will be increases in the future lead-time.

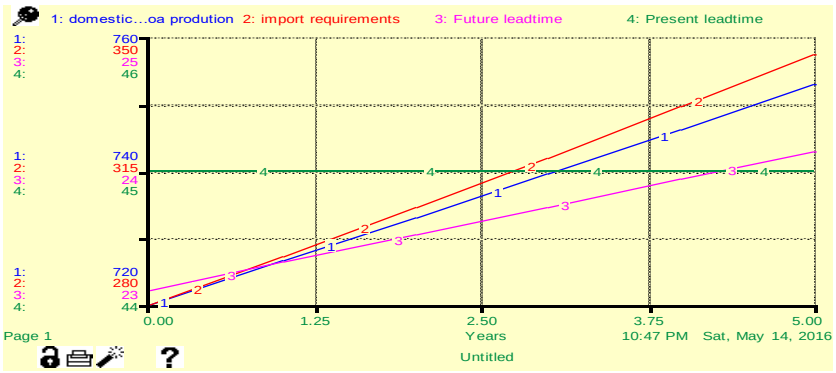

Figure 3. Current operating conditions of the case study company

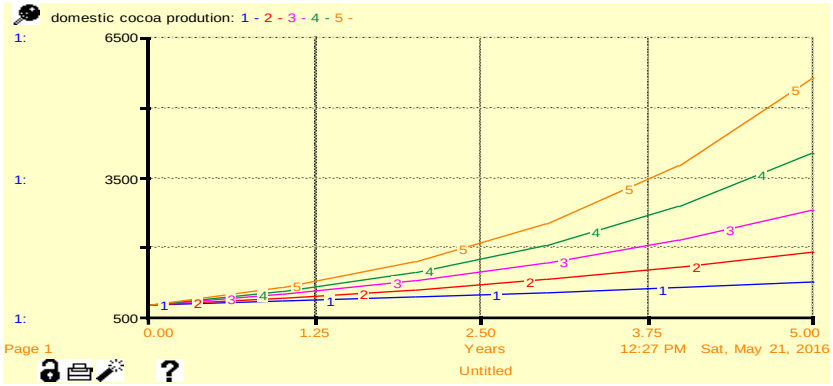

Figure 4. Scenario results for domestic cocoa production

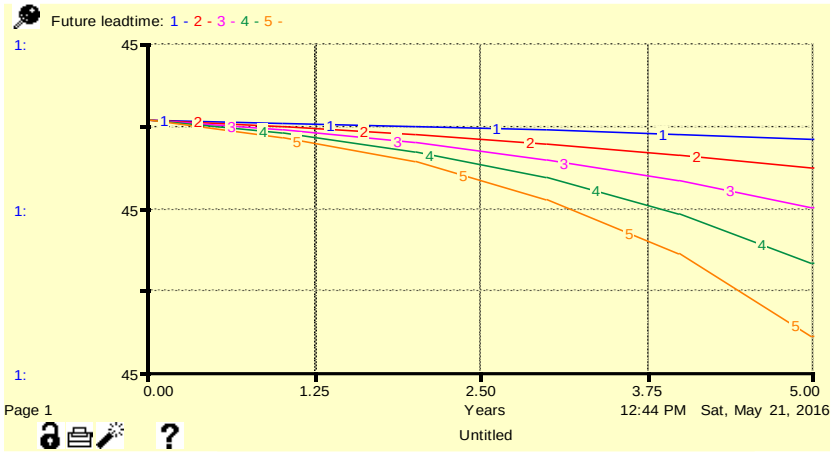

Figure 5. Scenario results for future lead-time of domestic cocoa production

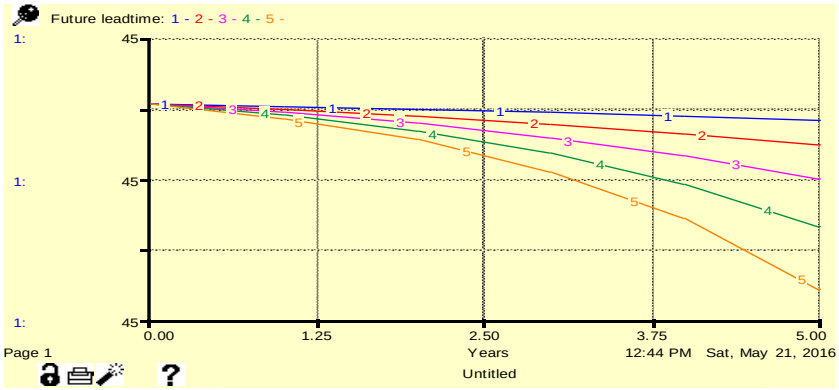

Figure 6. Scenario results for import requirements of domestic cocoa

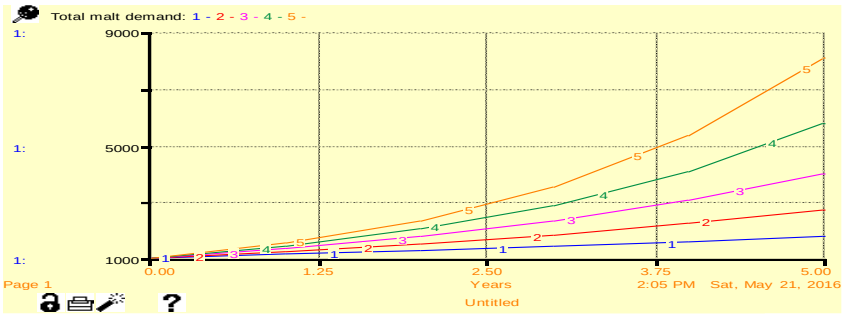

Figure 7. Scenario results for total malt demand

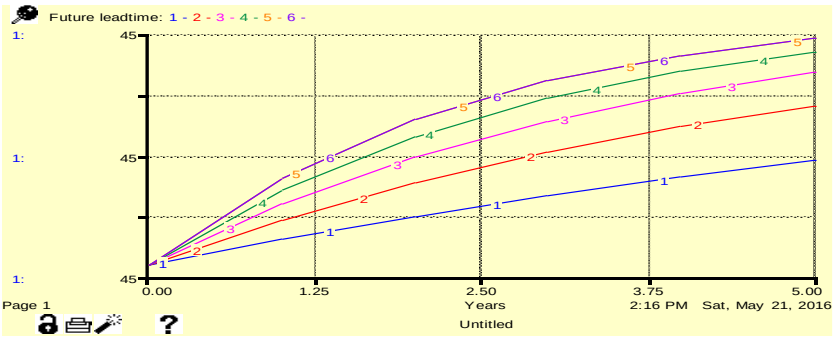

Figure 8. Scenarios results for future lead-time of malt

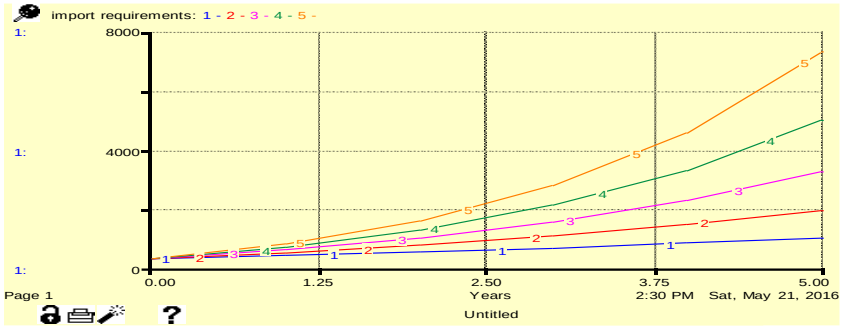

Figure 9. Scenarios Results for Import Requirements of malt

5. Conclusion

This study has investigated that domestic purchase of the principal raw material (cocoa powder) and producing quality products will help to reduce the lead-time by making products available at all times meeting customer demand, which is the main focus of a responsive supply chain and hence will improve the performance of the company. This study did not focus on cost involved in making the supply chain of the company responsive. From the analysis of the questionnaire, it is gathered that the lead-time, quality and product availability are the three main order winning strategies of the customers of the company. Most Small and medium sized companies do not have an effective or a performance measurement system due to the fact that most cannot identify their internal strength and weaknesses but more focus on external opportunities and threat. There are lots of competitors in the beverage market in Malaysia who are also trying to gain greater market share by producing quality products to the customers and also trying to make products always available. Therefore since the case study company has identified the various strategies they can use in winning customer orders, they must strive to be efficient and effective in their activities. In trying to purchase a raw material locally which is the best decision, the case study company needs to have good collaboration with its supply chain partners so as to integrate well to enhance on-time delivery. The use of IT in planning the operations of suppliers and customers in terms of deliveries is very important in a responsive supply chain. IT will increase collaboration,

process integration and delivery speed by making product available to the customers. From survey, it is evident that the current operating system of the case study company is not effective in terms of using IT systems. The company does not have a specialized type of software that can improve the ordering system of the supply chain and in most cases orders are done manually and in person.

Two causal loop diagrams were developed from the questionnaire analyses. The first causal loop explained the inter-relationship between each of the selected performance measurement variable helping to achieve the first objective of this research. The second causal loop diagram was developed after identifying the three main variables that have greater influence on the performance measurement system of the company. A system dynamics model is developed from the causal loop diagram of lead-time reduction. One of the main importance of system dynamics is to model the way in which information, actions and consequences interact to generate dynamic behavior. The system dynamics model can help develop a solution approach for small and medium sized enterprises that cannot effectively measure and maintain or continuously update their performance system due to the constant feedback they experience on regular bases because of the dynamicity of their operating environment. This SD approach can help managers and top management to know where and on what to make decisions to achieve their responsive supply chain objectives.

However, it can then be recommended that the company must focus on getting raw materials locally than importing because lead-time is the greatest weapon in a responsive supply chain. In trying to achieve this goal, there have to be other factors that could aid this goal; process integration (good supplier and customer relationship), planning in collaboration with local suppliers to help them know the demand trend and forecast of customers of the company, training of workers to improve quality thereby avoiding reject/rework, good information technology structure, market sensitivity as a responsive supply chain so as to know the changes in the taste of customer desires..

6. Limitations and Future Research

There are lots of other performance measurement variables that can be used to measure supply chain performance, but the variables selected in this study which were reviewed from literature and approval by some expert managers of the case study company are based on the concept of a responsive supply chain. However, if we are considering a cost effective supply chain, then most variables like delivery speed, delivery reliable may not be of significance (Chopra and Miendl, 2010). The variables; lead-time reduction, quality and availability that were selected as main variables that have influence on the performance system were based on the analysis of the respondents. Every enterprise, small, medium or large may have its own competitive strategy and what may be suitable for one may not be suitable for another.

To the future analysis of this study, the present study is limited to a single case study company. The analysis is based on respondent from a case study company and hence future work could be done on multiple case study companies to know the most important variable or variables especially on a responsive perspective. Comparison could be done from multiple analyses before a conclusion can be manifested for application to various SME in Malaysia.

There are several other approaches to measuring the performance of supply chains; strategic, practical and operational, but this work is limited to strategic approach because the model developed is meant to help managers take good decisions due to the complex and dynamic environment in which SMEs revolve. Future work can be done using either of the other two approaches to measure the performance of SMEs operating on a responsive supply chain.

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