

## DEVELOPMENT OF A PERFORMANCE MEASUREMENT FRAMEWORK FOR ADAPTIVE SUPPLY CHAIN

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### ABSTRACT

Over the past few years, analysis of successful manufacturing companies shows that in today's hyper-competitive business environment, supply chain efficiency is a necessary condition for survival. However, as we approach an age of super efficiency, adaptive supply chains, which are more flexible, responsive and re-configurable, are replacing traditional supply chains. Adaptive supply chains possess the flexibility to continually sense and respond to the environment without compromising on operational efficiencies. At the same time, the EMS industry is characterized by fluctuating customer demand, with increasing focus on faster response times and delivery of products at optimal cost. EMS companies therefore need to evaluate their supply chains to adopt adaptive supply chains. For this reason, this research aims to provide a framework for measuring the performance of adaptive supply chain in the context of EMS (electronic manufacturer service) provider. The framework model helps companies to measure and evaluate the performance of their adaptive supply chains. The proposed framework grounds on the methodology of performance measuring frameworks, applying to the measurement of both tangible and intangible assets, and also measuring supply chain performance internally and externally.

### KEYWORDS

Performance, Supply Chain, Manufacturing

### 1. Introduction

In today's ever increasing competition and economy globalization business environment, manufacturers have been exploring innovative technologies and strategies to achieve and sustain competitive advantage. This is aspect, supply chain management (SCM) has gained a tremendous amount of attention from both the academics and practitioners community in recent years, especially

the electronics manufacturing service (EMS) providers in the electronics industry.. The increasing competition, fluctuating demand, reduced price margins, poor visibility and forecasting are few other major factors that affect this industry.

During the last decade, EMS companies in Singapore are facing the challenge to evaluate their supply chains, due to the globalization and outsourcing trend, and the increasing competition between supply chains rather than companies. Their supply chain management involves the coordination or integration of all activities involved in procuring, producing, delivering and maintaining products/services to customers in various geographical locations. And their supply chain's business processes encompasses the full range of intra-company and inter-company activities from material procurement, through manufacturing and distribution, to proper delivery of products to customers.

Currently many EMS companies are implementing lean manufacturing, in order to remove non-value added activities from their operations but the ever changing and uncertain market conditions are pushing these companies to be more adaptive so that they can cope with all kinds of changes in the market circumstances. So there is an urgent need to develop a framework for the performance measurement of adaptive supply chain, to enable EMS companies to evaluate the performance of their current supply chain, compare with their competitors and put them ahead of their competitors.

Over the last decade of evolution of SCM, a steady stream of research have been carried out dealing with the theory and practice of SCM, but unfortunately, the topic of performance measurement of supply chain does not receive adequate consideration. For the performance measurements of supply chain, there are many performance metrics for different types of supply chains.

In this regard, one of the most difficult research areas is that of the performance measurement of adaptive supply chain. Although there are different frameworks developed for performance measurement, with some providing criteria, however, a generally applicable systematic approach to performance measurement has not been developed.

For the performance measurement of the adaptive supply chain, there is currently no performance measurement framework to evaluate the adaptive supply chain. To overcome this research gap, this paper proposes a framework for the performance measurement of the adaptive supply chain. This research develops the performance measurement framework for adaptive supply chain, to enable companies to evaluate their supply chain to meet the current and future market demands. To fulfill this research, there are 4 research objectives to be met and they are 1. Review the literature on the various types of supply chains and their characteristics, 2. Review the literature on the various performance measurement frameworks for supply chains, 3. Develop the definition of adaptive supply chain along with its characteristics, and 4. Develop the framework for performance measurement of adaptive supply chain.

In the following sections, we first review current literature about the previous research on the characteristics and performance measurement framework for various types of supply chain and introduce our definition of the concept of adaptive supply chain, and its key activities & key characteristics, followed by the discussion of the development of performance measurement framework for the adaptive supply chain. Finally, we conclude our work and share the direction of our future research.

## 2. Literature Review

The evolution of supply chains is the inevitable result of the interactions of the ever-changing forces in the market. For example, lean supply chain was developed from the traditional supply chain out of the necessity to substantially cut cost, which was first introduced by Womack [1] as the idea of "lean manufacturing". As the market evolves, the customers are demanding more product variety, better, quicker and more reliable delivery service; service level became the market winner. The agile supply chain strategy, which is less cost effective than the lean strategy but able to provide the customer with a high level of service, was developed and adopted by many EMS companies, especially those whose products have a short product life cycle and unpredictable

market demand [2]. To reap the benefits of both frameworks, Christopher and Towill [3] proposed three approaches to implement the agile supply chain: the Pareto curve approach, the de-coupling point approach and the separation of "base" and "surge" demand approach.

To benchmark and measure the supply chain performance improvements, the Supply-Chain Council (SCC) developed the cross-industry Supply Chain Operations Reference-model (SCOR model), which contains standard process definitions; terminology and metrics, matching supply chain processes against best practices. It uses five performance attributes (Reliability, Responsiveness, Flexibility, Costs & Assets) to model the supply chain by five primary management processes: Plan, Source, Make, Deliver, and Return, and further measures the performance attributes by sub-level performance metrics [4]. For better implementation of the SCOR model, Craig Shepherd and Hennes Gunter [5] provided a comprehensively summarized list of performance metric, and Zhang & Sharifi [6] proposed a layered scoring model for the measurement of current agility level. But all these lack a clear distinction between metrics at the strategic, tactical, and operational levels. And all these performance measurement models or systems are not able to link the measurement with an organization's supply chain strategies. They do not point out which measurement metrics are more important than others to execute or enforce the strategy. Therefore it is difficult for supply chain practitioners to focus on those elements that have significant impacts. Just as Beamon [7] pointed out that "too much emphasis has been placed on cost as the single most important indicator of a supply chain performance".

Through the study of EMS companies in Singapore & Asian region, we found the supply chain's reconfigurability - the ability and speed at which a new supply chain is formed in response to changes made to existing or new products & services opportunities, needs to be brought up from traditional factory level to a higher strategic level to enhance their competitive advantages, and make the supply chain more adaptable to the changing business environment.

We believe that agility alone will not be enough to ensure the supply chain remain competitive; another dimension, re-configurability needs to be added into the supply chain performance system for assessing the adaptive supply chain - a supply chain, which is able to respond to real-time market signals and unexpected market fluctuations, and at the same time possesses the ability to be quickly

redesigned in anticipation of product modifications and new product opportunities.

Some of the major characteristics attributes of adaptive supply chain in terms of its five distinct management processes are summarized in the following Table 1.

**Table 1:** Key Characteristics of Adaptive Supply Chain based on Management processes

Process	Key Characteristics
Plan	<ul style="list-style-type: none"> <li>❖ Ability to take and handle Multiple orders</li> <li>❖ Ability to reduce order lead time</li> <li>❖ Ability to trace Customer Order path</li> <li>❖ Ability to scale orders.</li> </ul>
Source	<ul style="list-style-type: none"> <li>❖ Ability to get order sized changed.</li> <li>❖ Ability to get delivery schedules changed.</li> <li>❖ Ability to influence supplier performance.</li> <li>❖ Ability to change worldwide suppliers.</li> <li>❖ Ability to outsource technology.</li> <li>❖ Ability to source globally.</li> <li>❖ Ability to sustain suppliers on a long term basis.</li> </ul>
Make	<ul style="list-style-type: none"> <li>❖ Ability to change volume.</li> <li>❖ Ability to change product mix.</li> <li>❖ Ability to produce new products quickly.</li> <li>❖ Ability to change manufacturing throughput time</li> <li>❖ Ability to change process characteristics.</li> <li>❖ Ability to change workforce capability.</li> <li>❖ Ability to relocate process among global facilities.</li> </ul>
Deliver & Return	<ul style="list-style-type: none"> <li>❖ Ability to add/delete delivery segments.</li> <li>❖ Ability to add /delete delivery modes.</li> <li>❖ Ability to change delivery policies.</li> <li>❖ Ability to change planned delivery models.</li> <li>❖ Ability to change planned delivery times.</li> <li>❖ Ability to track worldwide shipments.</li> <li>❖ Ability to change total storage capacity.</li> <li>❖ Ability to move products around global storage facilities.</li> </ul>
Customer Service	<ul style="list-style-type: none"> <li>❖ Ability to meet particular customer needs.</li> </ul>

	<ul style="list-style-type: none"> <li>❖ Ability to shorten customer query time</li> <li>❖ Ability to respond customer globally.</li> </ul>
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The aim of our research is to provide performance measurement framework for adaptive supply chain. The next section will describe our systematic approach to develop our framework based on the above management processes.

### 3. Proposed Measurement Framework for Supply Chain Performance

In this section, we presents our performance measurement framework & its performance metrics in the context of following supply chain management processes by dividing the metrics into Flexibility and Responsiveness, which measures the corresponding key characteristics of the adaptive supply chain based on the management processes as follow:

1. Plan
2. Source
3. Make
4. Delivery & Return
5. Customer Service & Satisfaction

#### 3.1. Metrics for Evaluating Plan

Planning is the first crucial part of any supply chain as it defines the dimension of organization. In adaptive environment, planning plays a vital role in combining all the other management processes of the supply chain.

We use the supply chain order planning fulfillment to evaluate the plan process, and measure it in the following three key areas: (a) order entry method; (b) order lead-time, and (c) customer order path. See Table 2 below.

**Table 2:** Metrics for Evaluating Plan

Responsiveness	Flexibility
❖ Total Supply Chain response time.	❖ Flexibility of Order processing for new & existing products.
❖ Total Supply Chain cycle time.	❖ Flexibility of handling the multiple orders.
❖ Order lead-time.	❖ Flexibility to alter (Up/Down) the planned order.
❖ Order fulfillment lead-time.	❖ Flexibility of inventory planning for new & existing orders.
❖ Customer response time.	❖ Flexibility of manufacturing capacity for new & existing orders.
❖ Product development cycle time.	❖ Flexibility of Vehicle routing capacity for new & existing orders.
❖ Total cash flow time.	

**Table 3:** Metrics for Evaluating Source

Responsiveness	Flexibility
❖ Supplier lead time against industry room/	❖ Supplier ability to respond to quality problems
❖ Supplier's booking-in procedures.	❖ Range of order size (min, max, number or states)
❖ Efficiency of purchase order cycle time.	❖ Range of delivery frequencies
❖ Upside source adaptability.	❖ Number of different parts.
❖ Outsourcing technology.	❖ Level of strategic linkage between purchasing and manufacturing
❖ Effective Risks management to minimize the risk.	❖ Number of suppliers.
	❖ Upside source flexibility.
	❖ Supplier response to quality problems.
	❖ Downside source adaptability.
	❖ Upside Source return adaptability

### 3.2. Metrics for Evaluating Source

For many years, the selection of suppliers and product choice were mainly based on price competition with less attention to other criteria like quality & reliability etc. More recently, the whole approach to evaluating suppliers has undergone drastic change. The evaluation of suppliers in the context of the supply chain (efficiency, flow, integration, responsiveness and customer satisfaction) involves the measurement at the following three different levels:

- ❖ Strategic level - measure the lead-time against industry norm, Quality level, Cost saving initiatives, and supplier pricing against market etc.
- ❖ Tactical level - measure the efficiency of purchase order cycle time, booking in procedures, cash flow, quality assurance methodology and capacity flexibility etc.
- ❖ Operational level - measure the ability in day to day technical representation, adherence to developed schedule, ability to avoid complaints and achievement of defect free deliveries etc.

We use the Supplier Link to evaluate the Source activity as the following Table 3

### 3.3. Metrics for Evaluating Make

After the order is planned and goods sourced, the next step is to make or assemble the products. This is the activity carried out by organizations that own production sites, and their performance has a major impact on product cost, quality, speed of delivery and delivery reliability, and flexibility.

We evaluate the Make activity on the Production Level in the following three areas (See Table 4 below):

1. Range of Product and Services
2. Capacity Utilization
3. Effectiveness of Scheduling Techniques

**Table 4:** Metrics for Evaluating Make

Responsiveness	Flexibility
❖ Planned process cycle time.	❖ Product flexibility.
❖ Manufacturing lead time.	❖ Capacity flexibility.
❖ Time required to produce.	❖ Volume Flexibility.
❖ Time required to produce new product mix	❖ Number of tasks worker can perform.
❖ Upside make adaptability	❖ Upside makes flexibility.
❖ Product life cycle.	❖ Downside make flexibility..
	❖ Point of customization.
	❖ Number of methods available to increase capacity.
	❖ Number of different manufactured products.
	❖ Number of product changeover.
	❖ Range of workforce capabilities.
	❖ Number of available processes to manufacture product.

### 3.4. Metrics for Evaluating Delivery & Return

Delivery & Return is the link in a supply chain that directly impacts customers, which is a primary determinant of customer satisfaction. Hence, measuring and improving delivery is always desirable to increase competitiveness.

Delivery by its very nature takes place in a dynamic and ever-changing environment, making the study and subsequent improvement of a distribution framework difficult. We measure the Delivery & Return by the following major elements within a distribution structure will affect the framework as a whole (See Table 5 below):

- Measures for Delivery Performance Evaluation
- Measures for Transit Goods and Returns from Customers
- Flexibility of Delivery Frameworks to meet Particular Customer Needs
- Total Distribution Cost

**Table 5:** Metrics for Evaluating Delivery & Return

Responsiveness	Flexibility
❖ Delivery lead time	❖ Delivery lead time
❖ Frequency of delivery.	❖ Frequency of delivery.
❖ Product lateness	❖ Product lateness
❖ Average lateness of orders	❖ Average lateness of orders
❖ Average earliness of orders	❖ Average earliness of orders
❖ Percent of on-time deliveries.	❖ Percent of on-time deliveries.
❖ Upside deliver adaptability	❖ Upside deliver adaptability
❖ Upside deliver return adaptability.	❖ Upside deliver return adaptability.
❖ Total order-to-delivery lead time	❖ Total order-to-delivery lead time
❖ Distribution lead-time to specific geographical location.	❖ Distribution lead-time to specific geographical location.

### 3.4. Metrics for Evaluating Customer Service & Satisfaction

Since customers come from all over the world, without a satisfied customer, the whole exercise of applying the supply chain strategy could be costly and futile. For effective performance measurement, supply chain metrics must be linked to customer satisfaction. This measurement is needed to integrate the customer specification in design, to set the dimensions of quality, for cost control, and as a feedback for the control of process.

We measure the Customer Service & Satisfaction by the following areas, which could be summarized in the following Table 6.

- Flexibility of Supplier-Customer Relationship
- The Customer Query Time
- Post Transaction Measures of Customer Service
- Customer Perception of Service

**Table 6:** Metrics for Evaluating Delivery & Return

Responsiveness	Flexibility
❖ Satisfaction with knowledge transfer	❖ Pre-Transactions Flexibility.
❖ Customer query time	❖ Transactions Flexibility
❖ Supply Chain & Logistics Cost	❖ Post Transactions Flexibility.
❖ Cost associated with assets and Return on investment	❖ Flexibility of service system to meet particular requirements.
❖ Customer assistance in solving problem.	❖ Warranty/return processing costs.
❖ Customer complaint.	❖ Flexibility of reverse logistics network.
❖ Rate of complaint.	
❖ Product quality which requires customer	

In summary, these are the performance metrics that target broader functional areas of supply chain as well as its total attributes such as supply chain response time. For instance, a firm that is interested in benchmarking and performance evaluation must first analyze its performance using the metrics discussed. Once strong and weak areas are identified, and then other metrics can be employed to gain greater insights into achieving the objectives as underlined in the study.

Taken together, these representations of performance metrics can give a clear picture of which metric should be used for the performance assessment study, where it can be used, and who will be responsible for that. Such a representation is a step closer to bridging the gap between the need for a model with which performance of an Adaptive Supply Chain can be assessed, and the potential areas of improvement can be identified.

#### 4. Conclusions

In this paper, we explore the importance of performance measurement system for adaptive supply chain for fulfilling the demand of current dynamic and ever-changing market needs; review the development in the area of supply chain performance measurement. We have found out that although there are quite a number of publications that stressed the importance of the measurement and proposed approaches and methods,

there is still a lack of a holistic system that can links strategy and performance measurement.

After identifying the most important characteristics attributes & activities of a supply chain has and the performance metrics that contribute the attributes, we propose a performance measurement framework which is used to evaluate the performance of adaptive supply chain and helps the companies to identify, evaluate and monitor the key areas which can help them to maintain their pace and speed of their success.

This research is not intended to prescribe “the best performance measurement framework” for companies to evaluate their supply chain performance. Indeed, it has been argued throughout this research that the complex nature of the supply chain process means that any attempt to do this will be almost impossible. The framework provides the first step to the managers to identify, articulate & explore their company’s key areas of supply chain, which are use to achieve competitiveness in the market. Since, this is the general framework, which targets mainly some key areas of any Adaptive Supply Chain.

In short, throughout this research, we have developed a concepts, metrics and framework for measuring performance of Adaptive Supply Chain processes. There are several ways in which the various concepts exposed in this research can be extended in the future. For example, further conceptual and development work in identifying more tangible and intangible areas of supply chain management should be carried out which also plays an important role.

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