

Supply Chain Performance Measurement using Hybrid SCOR Model and System Dynamics

Niura Ikasari^{1,a}, Yuniaristanto^{2,b}, and Wahyudi Sutopo^{3,c}

¹ Student of Industrial Engineering Department, Faculty of Engineering
Universitas Sebelas Maret, Indonesia

² Research Group of Industrial Engineering and Techno Economic, Industrial Engineering
Department, Universitas Sebelas Maret, Indonesia

³ Research Group of Industrial Engineering and Techno Economic, Industrial Engineering
Department, Universitas Sebelas Maret, Indonesia

^a niuraikasari14@gmail.com, ^b yuniaristanto@ft.uns.ac.id, ^c wahyudisutopo@staff.uns.ac.id

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Abstract. Production unit of lithium ion battery Sebelas Maret University (UNS) that become Indonesia's first solution to the problem energy in Indonesia, where the need is increased while the source of its acquisition will be increasingly rare. In this case, it is important to supply chain performance rated. Supply Chain Operations Reference (SCOR) is method of supply chain performance assessment based on 5 indicators; reliability, responsiveness, cost, asset management, and agility. Assessment of the SCOR framework presents business processes, performance indicators, best practices and technology to support communications and collaboration among supply chain partners to improve the effectiveness of supply chain management and consummation of the supply chain. SCOR focus on causality measures in the form of a linear correlation. This situation becomes a weakness because the SCOR method cannot continue the steps specific to a future that can predict performance. Study on SCOR combined with system dynamics (SD) can identify 4 perspective and variable interactions associated with causal loop design model. SCOR model and SD gives the value of a more effective and compelling. The initial findings of this study are 27 verified metrics which were then made causal loop diagrams that illustrate the causal relationship between these metrics. The final result of this research in the form of a simulation model at powersim or called flow diagram can show the entire supply chain system and its relevance.

Introduction

Lithium-Ion Battery is one of the solutions for energy problems in Indonesia, especially and the world in general. This is because the needs of renewable energy to replace the fossil energy that has been a source of primary energy in fulfilling of the need for the transportation sector to be the greatest share. For that, Indonesia has devised a strategic plan such as making policy and started research to find alternative land transportation in particular and its energy source [1]. In this case, the government-designated UNS has successfully demonstrated its successful research result which is the National Electric Car (Molina) and SMARTUNS Lithium-ion battery. SMARTUNS-The lithium ion battery has been commercialized, which now has been able to produce 1000 cells per day in the production unit of UNS lithium ion battery [2].

Measurement of supply chain performance, in this case, need to be done to know the company's condition, whether it has decreased or increased and improvements to what to do to improve the company's supply chain performance and to keep product distribution continuing [3,4]. Since its introduction in 1996, the majority of researchers using the supply chain operations reference (SCOR) to measure the performance of the supply company [4]. The supply chain operation reference model (SCOR) is a reference model used as a tool to map, benchmark, and develop the operations of supply chains. SCOR provides companies with a basic process modeling tool, an

extensive benchmark database, and guidelines on how to measure the supply chain operations. However, SCOR is a static tool that does not include any possibilities to do dynamic analyze. In supply chain simulation it is always interesting to analyse lead times and lead time variability, delivery accuracy and delivery speed, and to locate bottlenecks [5].

SD is a methodology for studying and managing the feedback of variables contained in the complex system said the primary method of studying the problem with a systematic viewpoint, where the elements of the system interact with each other in a relationship given feedback to produce a behavior. The interaction in this structure is translated into a mathematical model with the aid of a digital computer simulated to obtain historical behavior. SD models can create feedback to decision makers about the possible absence of the collision of a series of wisdom to simulate and analyze the behavior of the system on different assumptions [8]. Causal loop diagrams or also known as influence diagrams, are used to help modelers to understand the system by providing an overview through causality in the system (the system conceptualization). The Causal loop diagram give simplicity in understanding the structure and behavior of a system, however, the simplicity of it can also make it unclear whether the relationship between variables happened is the relationship or not rate to level [7].

The Flow diagram is a representation of a form of the detailed depiction of the system. The main objective of the flow diagram is to represent the flow and structure of the system in detail to facilitate mathematical modeling. A diagram describing the relationship between variables made in the loop diagram case and effect with clear, where used symbols in certain variables. In the flow diagram distinguished between the flow of physical and the flow of information. Change in a variable in this subsystem will change physical quantity. Otherwise, the flow of information is not the flow of a convertible. The information derived from one source could be a variable that transformed into another without reducing the amount of information that is in the source [4].

In research conducted by Immawan and partners say the managerial implication from their result is the SCOR parameter hybrid with dynamic model make the model of system dynamics can equip the result of SCOR having the character of static. Hybrid SCOR-SD it helps the manager of the company understand interactions among SCOR, of the parameters of so that by improving one or two of the variable will affect the whole of the variable. The manager just looking for variables that have potential biggest then fix it. The result is the fifth variable will also change [4]. Research conducted by Persson and Partner using SCOR Version 3 and Level 3 are hybrid with simulation using Arena software says the SCOR Template version 3 requires further development to be useful, *e.g.* to incorporate the processes *Return* and *Plan*. Still, the use of SCOR Template, for each level 3 process, can save time when analyzing a supply chain. The time to build up a company's supply chain into a simulation model can be reduced significantly compared to modeling every process every time a company should be mapped [5].

In this case study, issues occurring in the Lithium Ion battery production Unit occur in various processes, starting from the source or supply of raw materials. Some times there are out of raw materials that cause plants to not produce during a certain period time. In the process of *make*, there is a human error in machine settings that resulted in the formula of lithium ion battery is not appropriate, less dense *press* process, a winding machine that is occasionally damaged so that the rolling process is not perfect. Then, the *grading* process where charge-discharge is not optimal, the final product is pretty much problematic in terms of capacity and internal resistance that causes battery drop. The *enable* process is experiencing issues in data management that is centralized only in one person. Last is enough high waste rate.

Methodology

Production unit of lithium ion battery Sebelas Maret University (UNS) uses the Make To Order (MTO) production type. This Plant produces 2 types of batteries namely Lithium Ferrophosphate Battery (LFP) and Lithium Nickel Cobalt Aluminum Oxide Battery (NCA). The battery supply chain has 3 entities or links, namely suppliers of all raw materials derived from 1 supplier namely imports from China, production unit of lithium ion battery Sebelas Maret University (UNS) that

performs the production process of lithium battery, and customer. Customer is divided into two regular customers and end customers. The relationship between the three groups is as follows.

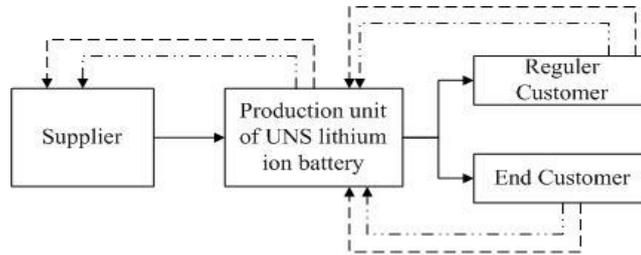


Figure 1. Battery Supply Chain

The raw materials of lithium ion batteries consist of NCA, AB, PVDF, KS-6, NMP, aluminium foil, graphite, CMC, SBR, copper foil, separator, plastic cover, upper isolator, lower isolator, tube cell, cardboard pack. All the raw materials are ordered by the lithium ion Battery production unit to suppliers from China shipped directly to the warehouse belonging to the Production unit of lithium ion battery Sebelas Maret University (UNS). Afterward the production unit of lithium ion battery Sebelas Maret University (UNS) produces the batteries ordered by the buyer through the management team under the Business Management Agency UNS (BPU UNS) and PT. Pertamina in cooperation with UNS. The production process starts from electrode preparation, cell assembly, container sealing, battery testing, then packing. The battery is then shipped by the production unit of lithium ion battery Sebelas Maret University (UNS) to the buyer.

After identifying the battery supply chain, the next step identifies the supply chain performance metrics based on the SCOR model. Metrics are standards for performance measurements from a supply chain or a verifiable size process, which is realized in both quantitative and qualitative form, and is defined against a specific reference point. Each metric must have a clear name, purpose, target, scope, unit, way of measurement, measurement frequency, data source, the person in charge, and other related attributes [6]. The supply chain performance metrics used are 10 strategic metrics (level-1 metrics) and 42 strategic metrics on level 2 organized by SCOR performance attributes. The performance attribute is a metric grouping or categorization used to express a specific strategy. SCOR recognizes five performance attributes namely *reliability*, *responsiveness*, *agility*, *cost*, and *asset management efficiency*. *Reliability*, *responsiveness*, and *agility* are important attributes for a customer's viewpoint (customer-facing). While the *cost* and *asset management efficiency* attributes are important attributes for internal monitoring but are not directly a customer's concern (internal-facing).

Performance metrics level 1 and Level 2 of SCOR that have been identified are then verified by observation to the field. Verification is done to determine the supply chain performance metrics that correspond to the company's conditions related to the battery supply chain. This verified level 1 SCOR performance metric will be referred to as the Key Performance Indicators (KPI) for the associated company. As for determining the value of the Level 1 performance metric, it used calculation considerations also on each level 2 performance metric. However, the performance assessment results seen are the value of accumulating each level 2 metric assessment on each level 1 metric. This KPI is an indicator of the success of the battery supply chain performance for the production unit of lithium ion battery Sebelas Maret University (UNS).

After verified metrics, the next step is to combine the process of this SCOR model with a dynamics system that begins by creating a causal loop diagram. The causal loop diagram is created by linking attributes along with its metrics to the metric or other factors affecting each other (relating to causation) to the battery supply chain system. And the interconnectedness markers are a positive sign (+) and a negative sign (-).

A positive sign indicates if the cause rises, the result will increase (growth, reinforcement), if the cause drops, the result will decrease. While a negative sign indicates if the cause rises, the result will drop, if the cause drops, the result will rise.

Once CLD is created, the system is visually depicted into the Powersim software after this called a flow diagram. In the Powersim there are tools that can support interconnectedness between factors, ie tools to create new auxiliary, create new level, make a constant, create link between two variables, create a flow with a certain rate, create a flow without rate, create snapshots of variables, make the graph to display time series control, create time table control, create data charts, create data tables, and perform running in time.

Results and Discussion

The following is the result of identifying and verifying metrics called KPI (Metric level-1).

Table 1. Key Performance Indicators

Performance Attributes	Metric Level-1	Metric Level-2	Units
Reliability	Perfect Order Fulfillment	% of Orders Delivered In Full	%
		Delivery Performance to Customer Commit Date	
		Accurate Documentation	
		Perfect Condition	
Responsiveness	Order Fulfillment Cycle Time	Source Cycle Time	Days
		Make Cycle Time	
		Delivery Cycle Time	
Agility	Upside Supply Chain Flexibility	Upside Source Flexibility	Days
		Upside Make Flexibility	
		Upside Deliver Flexibility	
	Upside Adaptability	Upside Source Adaptability	%
		Upside Make Adaptability	
		Upside Deliver Adaptability	
	Downside Adaptability	Downside Source Adaptability	%
		Downside Make Adaptability	
		Downside Deliver Adaptability	
Cost	Total Cost to Serve	Planning Cost	%
		Sourcing Cost	
		Order Management Cost	
		Production Cost	
		Fulfillment Cost	
		Delivery Cost	
Asset Management Efficiency	Cash-to-Cash Cycle Time	Days Sales Outstanding	Days
		Days Payable Outstanding	
	Return on Fixed Assets	Supply Chain Fixed Assets	%
	Return on Working Capital	Accounts Payable	%
		Accounts Receivable	

There are 5 attributes, 9 levels-1 metric and 27 levels-2 metrics verified from observations made to the suitability of SCOR process metrics with enterprise conditions. In the reliability attribute that serves to discuss the ability of the company to perform the necessary task, consisting of 1 metric level 1 is *perfect order fulfillment* and 4 metric levels 2 namely *% of orders delivered in full, delivery performance to customer commit date, accurate documentation, and perfect condition*. Perfect Order Fulfillment is the percentage of orders that meet the delivery performance with complete and accurate documentation and no delivery breakdowns. Orders are considered perfect if the product ordered is the product provided and the amount ordered matches the amount available (*% of orders delivered in full*). A shipment is considered perfect if the location, specified customer entity and delivery time are met (*delivery performance to customer commit date*). Documentation is considered perfect if all is accurate, complete, and timely (*accurate documentation*). Product conditions are considered perfect if the product is shipped with the correct configuration, with no damage, customer ready, and accepted by the customer (*perfect condition*).

On the *responsiveness* attribute describes the speed of the tasks performed. This attribute focuses on customers as it relates to the speed of response time to customer requests. There are 1 metric level 1 that is Order fulfillment cycle time and 3 metric level 2 is source cycle time, make cycle time, and deliver cycle time. OFCT or order fulfillment waiting time is the average actual cycle time is consistently achieved to fulfill customer order or order fulfillment waiting time. The source cycle time is the average time associated with the sourcing process. Make cycle time is the average time associated with the making process. Delivery cycle time is the average time associated with the process of delivery.

On the attributes of agility describe the ability to respond to external influences that include: increase or decrease in demand, suppliers or partners that will be out of business, natural disasters, acts of terrorism, availability of financial resources, labor issues. There are 3 metric levels 1 and 9 metric level 2. The first Level 1 metric is the upside supply chain flexibility and has three level 2 metrics namely upside source flexibility, upside make flexibility, and upside deliver flexibility. The Upside supply chain flexibility or supply chain flexibility is the number of days it takes to respond to a 20% increase or decrease in the unplanned product request at no additional cost or service. Upside source flexibility is the number of days required to respond to a 20% increase or unplanned reduction in the fulfillment of raw material quantities. Upside make flexibility is the number of days required to respond to a 20% unplanned increase or continuous reduction in production assuming there is no restriction of raw material. Upside deliver flexibility is the number of days required to respond to a 20% increase or unplanned ongoing reduction in delivery quantity assuming that there is no other limit.

The second Level 1 metric is upside adaptability and has 3 levels 2 metrics namely upside source adaptability, upside make adaptability, and upside deliver adaptability. Upside adaptability or adaptability of the top supply chain is the maximum quantity increase that can be shipped within 30 days or the ability to increase the quantity of anticipation in case of excess order. Upside source adaptability is the maximum sustained percentage to increase the number of raw materials that can be obtained/received. Upside make adaptability is the maximum sustained percentage to increase the quantity delivered which can be achieved within 30 days assuming there is no restriction of raw material. Upside deliver adaptability is the maximum sustained percentage that increases the quantity delivered which can be achieved within 30 days assuming there is not limited availability of finished goods.

The third Level 1 metric is the downside adaptability and has 3 metric levels 2 namely downside source adaptability, downside make adaptability, and downside deliver adaptability. Downside Adaptability or adaptability of the bottom supply chain is a reduction in the maximum quantity that can be shipped within 30 days or the ability to lower the quantity when there is no order. Downside source adaptability is a reduction in the quantity of sustainable raw materials at 30 days before shipment without supply or cost of fines. Downside make adaptability is a continuous production decline at 30 days before delivery without supply or cost fines. Downside deliver adaptability is a

reduction in the quantity of continuous delivery at 30 days before shipment without supply or penalty fee.

The cost attribute describes the cost of the operation. There are 1 metric level 1 namely total cost to serve and 6 metric level 2 namely planning cost, sourcing cost, order management cost, production cost, fulfillment cost, and delivery cost. Total cost to serve or total cost of delivery of products is the sum of the supply chain cost of the delivered product and service for the consumer. Planning cost is the total cost of the cost of workers, automation, and overhead in the planning supply chain process. Sourcing Cost is the total cost associated with the management of orders, receipts, inspections and warehouses of materials, products, and services. The order management cost is the cost of governance, risk management, fulfillment, and overhead allocated for the order management process. Production cost is the total cost associated with managing and conducting the manufacturing process. Fulfillment Cost is the total cost of the cost of workers, automation, assets, and overhead associated with order fulfillment. Delivery cost is the total cost associated with the product delivery process.

The asset Management efficiency attribute illustrates the ability to leverage assets efficiently, an asset management strategy in the supply chain including reduced inventory. There are 3 metric levels 1 and 5 metric Level 2. The first Level 1 metric is cash to cash cycle time (CCCT) and has two level 2 metrics that are days sales outstanding and days payable outstanding. CCCT is the time it takes for investments to be made to flow back to the company after it has been issued to raw materials or metrics that measure the supply chain speed that turns the supplies of raw materials or products into money. Days sales Outstanding is the length of time when sales are made until cash for it is received from customers. Days payable outstanding is the length of time of purchase of materials, labor and/or conversion resources until the cash payment must be made stated in the day.

The second Level 1 metric is return on fixed assets and has 1 metric level 2 that is supply chain fixed assets. Return on fixed assets measures the return of a company accepting invested capital in a fixed asset supply chain. Supply chain Fixed Assets ie the number of costs associated with fixed assets plan, source, make, deliver. The third Level 1 metric is the return on working capital and has two levels 2 metrics that are accounts payable and Accounts receivable. Return on working capital or work capital return is a measurement that assesses the amount of investment relative to the position of the company's working capital compared with the revenue generated from the supply chain. Accounts payable constitute the number of materials purchased, labor and/or conversion resources to be paid or obligations to other parties that must be fulfilled in a short period time. Accounts receivable is the number of receivables in circulation and is expressed in rupiah.

The connectedness of causation between attributes, metrics and other factors will be illustrated in the causal loop of the diagram below in figure 2 and then flow diagram in figure 3.

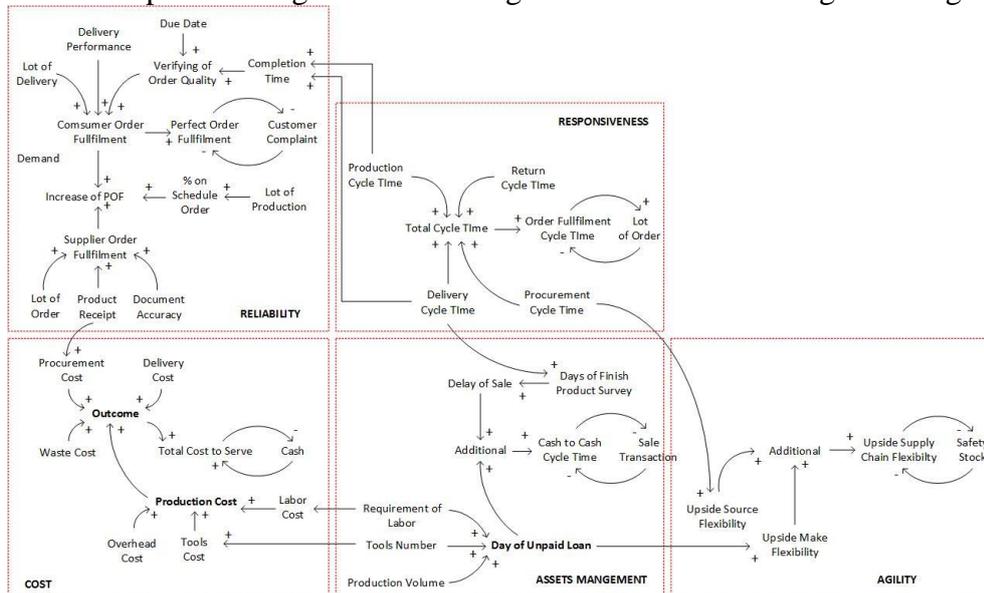


Figure 2. Causal Loop Diagram

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