Lean production in improving supply chain performance through hybrid model SCOR 11.0 – system dynamics

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Abstract. Supply Chain Operation Reference (SCOR) is a method to measure supply chain serving the business process framework, performance indicators and unique technologies to support communication and collaboration among supply chain partners. The objective of this paper is to measure Supply Chain Management performance by using SCOR version 11.0 for production typology of MTS-MTO in Indonesian Batik Industry. This research combines SCOR's model and System Dynamics in order to predict the complex activities on batik industry. The hybrid SCOR-SD could identify the interaction among five attributes with the associated variables simultaneously. The results are obtained after the performance of lean production application is increased and the targets are achieved, even exceeding the target. For reliability attributes that associated with perfect order fulfilment started from 2015 to 2019 respectively are calculated as 80.06%, 103.53%, 105.58%, 93.76%, and 72.17%. Responsiveness attributes associated with the order fulfilment cycle time, respectively 122.45%, 149.10%, 159.26%, 131.53%, and 119.36%. Attributes associated with the total cost of service charge respectively 93.46%, 93.53%, 93.45%, 93.49, and 93.49%. Attributes associated with cash management assets to cash cycle time in a row were 160%, 153%, 146.3%, 150%, and 126.7%. The latter attribute is agility attributes associated with supply chain flexibility upside respectively 100%, 87.2%, 100%, 82%, and 82%.

1. Introduction

Batik is one of the cultural heritages that was firstly created by Indonesian ancestor with certain economic value. Therefore, it should be maintained and preserved. Batik industry becomes one of the earning sources for craftsmen as well as promising business opportunities that can increase the income and the potential tourism object [1]. Batik industry has the opportunity to penetrate the global market with fierce competition among suppliers [2]–[4]. Batik industry has a supply chain started from raw material supply, manufacturing and distribution up to retailers. Hence, the performance of SCM needs to be assessed to preserve the batik industry.

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Supply Chain Operations Reference (SCOR) is a model that is used as a tool to map, set and develop supply chain operations [5]. SCOR's method presents a framework of business processes, performance indicators, a unique technology to support communication and collaboration among supply chain partners. However, SCOR's method is static that cannot perform dynamic analysis and just focus on one-way relationship (linear correlation) [6]. Therefore, it could not predict the performance as well as activities in the future. SCOR's method uses five variables associated with the attribute as the basis of performance measurement of SCM.

To build a dynamic performance measurement in order to correlate between attributes and variables, it is necessary to design SCOR's dynamic models. System Dynamics (SD) is a systems thinking approach that not only based on the data and strategic management. In system dynamics, a problem is considered complex when there is nonlinearity feedback, delay, stock and flow and counterintuitive [7]. SD identifies the attributes and variables and correlates them dynamically. Thus, the hybrid SCORSD will be dynamic with the expected prediction performance in future, which is dynamically and sustain. For encountering this, the mathematical model was built and calculated by using simulation [8]. Once the model is executed, it represents a real system and can measure the performance of the supply chain. Later, next step is to improve supply chain performance. Thus, the lean production and sustainability of batik manufacturing can be developed.

Lean Manufacturing (LM) concept is derived from the concept of Just-in-Time (JIT) production system of Toyota that has been practiced by many manufacturing industries. LM minimizes seven Waste as up time, a reduction in the size of the lot size, the elimination of buffer stock, multifunctional workers, standardization of processes and products, JIT purchasing, etc. [9].

Phenomenon that occurred in the batik industry was less effective and efficient production processes on the factory floor. Then the concept of lean production on the shop floor could be used to improve the performance of the company. Furthermore, the development of supply chain performance measurement using SCOR and hybrid SCOR with others methods have been carried out. [10] An analysis on the value chain by using hybrid simulation and AHP has been conducted. In this study, the simulations were performed using discrete event simulation that merged with SD. However, hybrid of SCOR and SD were obviously less, because they were not based on five attributes of SCOR. In addition, there was no discussion to improve the performance of the lean manufacturing concept that focused on lean production. It did not apply lean on SD models based on the concept of SCOR and there were no results from the five attributes presented. Supply chain performance that is measured using SCOR, can be observed from the interaction among five attributes and associated components called Hybrid SCOR11.0-SD. This research was interesting because it is not only build a model, but also propose the performance improvement through the implementation of lean production supply chain management (SCM).

2. Literature Review
2.1 Supply Chain Operations Reference (SCOR)
SCOR was endorsed by the Supply Chain Council (SCC), which was established in 1996 [11]. This model presents a framework of business processes, performance indicators, best practices as well as unique technologies to support communication and collaboration among supply chain partners, so as to improve the effectiveness of SCM and improvement of supply chain effectiveness. Meanwhile, according to [12] models SCOR is a process reference model, which is intended to make the industry standard that enables SCM in the next generation. Evaluation was done by assessing the performance parameters, such as asset management, cost, reliability, agility and speed responsiveness. SCOR performance consists of two types of elements which is Attribute Performance and Metrics [13]. In the supply chain performance measures through the method of SCOR version 11.0, there are five attributes that used to measure its performance, they are reliability, responsiveness, agility, cost, and assets management [13]. Reliability focuses on the ability to predict the outcome of a process includes: Right time, right quantity, right quality on customers. The main performance indicator of SCOR (metric level 1) is the Perfect Order Fulfilment. The example of its metric is a cycle time. The main SCOR

performance indicator is Order Fulfilment Cycle Time. While Speed in responding is consumer-focused attributes. Agility stated ability to respond to external changes, the ability to change. External influences include the increase or decrease in demand for the unexpected, supplier or partner who ceased operations, natural disasters, acts of terrorism, availability of finance (economics), or include flexibility and adaptability. Dexterity is the attribute that focuses on the consumer. Cost is an internally focus attribute. Costs generally include the cost of labour, raw materials, transportation. The main SCOR's performance indicator is Total Cost To Serve (TCTS). Total cost to serve is focuses metric on the consumer, because it measures the cost to serve customers. The previous metrics in cost attribute (Cost of Goods Sold and Total SCM Cost) is more oriented to the product. The new metric allows companies to build profits by customers or segments. Asset management attribute expressed the ability to utilize its assets efficiently. Asset management strategy in the supply chain includes inventory reduction as well as the determination of its own production or subcontracting. Examples of metrics are: inventory cycle time and capacity utilization. The main performance indicators SCOR include Cash to Cash Cycle Time and Return On Fixed Assets. Metric in SCOR model includes 134 metrics on level 1 [13]. By using a hierarchical approach as developed in the process of SCOR, metric also has several different levels. Metric level 1 can be decomposed into a metric level 2. Level 2 metrics can be decomposed into level 3 or underneath metric. The metric is a standard of performance measurement process. SCOR recognized three levels of metrics: Metric level 1 is a diagnostic healthcare supply chain as a whole. This metric also known as strategic metrics and key performance indicators (KPI). Benchmarking of metrics level 1 helps companies to set realistic targets to support the strategic direction. Metric level 2 acts as a diagnostic for level 1. Relationship diagnostic metrics helps to identify root causes of performance gaps in the metric level 1. Metric level 3 acts as a diagnostic for the metric level 2.

2.2 *System Dynamics Approach*
SD is a method for studying and managing feedback from the variables containing the complex system. SD can solve a problem up to the level of top management at the macro level, dynamic, and continuously. SD sees the system in terms of flow, both the flow of material and information. [8] It said that the primary method of studying the problem is with a systematic viewpoint, where the system elements interacted with each other in a specific relationship feedback and produce a behaviour. SD model can create a feedback to decision makers about the possible absence of collision on a series of policy by simulating and analysing the system behaviour at different assumptions. In System Dynamics, terms of causa/feedback loop and flow diagrams are familiar. Causal loop diagrams are used to understand the modelling system in order to provide a general overview through causality in the system (system conceptualization). By using it, modellers can quickly create structure model based on assumptions. Flow Diagram is a representation of a detailed depiction of the system. Flow diagram illustrates type of variable and relationships among variables in the system. The main objective of the flow diagram is to represent the flow and detail structure in order to facilitate mathematical modelling.

2.3 *Lean Manufacturing and Production*
The term of lean often interpreted as a collection of tools that help to identify and reduce waste begun with the Toyota Production System (TPS) in Japan and then becomes popular in the US as the companies assess the Japanese method [14]. By reducing waste, product quality will increase and production time as well as the middle of production can be reduced. Lean is not just a tool, but also the reduction of three types of waste that is "young" (work that do not add value), "muri" (work overload) and "mura" (imbalance), to find the problem systematically. Lean production is a systematic approach as process improvement that focuses on removing waste on the factory floor. In the lean approach, Value Stream Mapping (VSM) is used to map the operating conditions at the factory floor and result the ratio of value added time and non-value added time [15, 16]. According to [17], VSM was used to identify sources of waste and tools that will be used to reduce such waste. Waste is not providing benefit to the process transformation from inputs into outputs [18]. There are seven kinds of waste, which are overproduction,

defects, unnecessary inventory, inappropriate processing, transportation, waiting and unnecessary motion [19].

3. Model Development

The model was developed based on the identified problems in batik industry, Solo, Indonesia. It performed by improving the performance of the supply chain. Based on the literature review, SCOR is the best concept in measuring supply chain. However, dynamic business environment becomes the weakness of SCOR, thus it combined with SD. These two concepts are combined and made as a model of integration of SCOR and SD. This model will be known as the Hybrid method SCOR and SD. The development of conceptualization model in form of Closed Loop Diagram (CLD) is described in Figure 1.
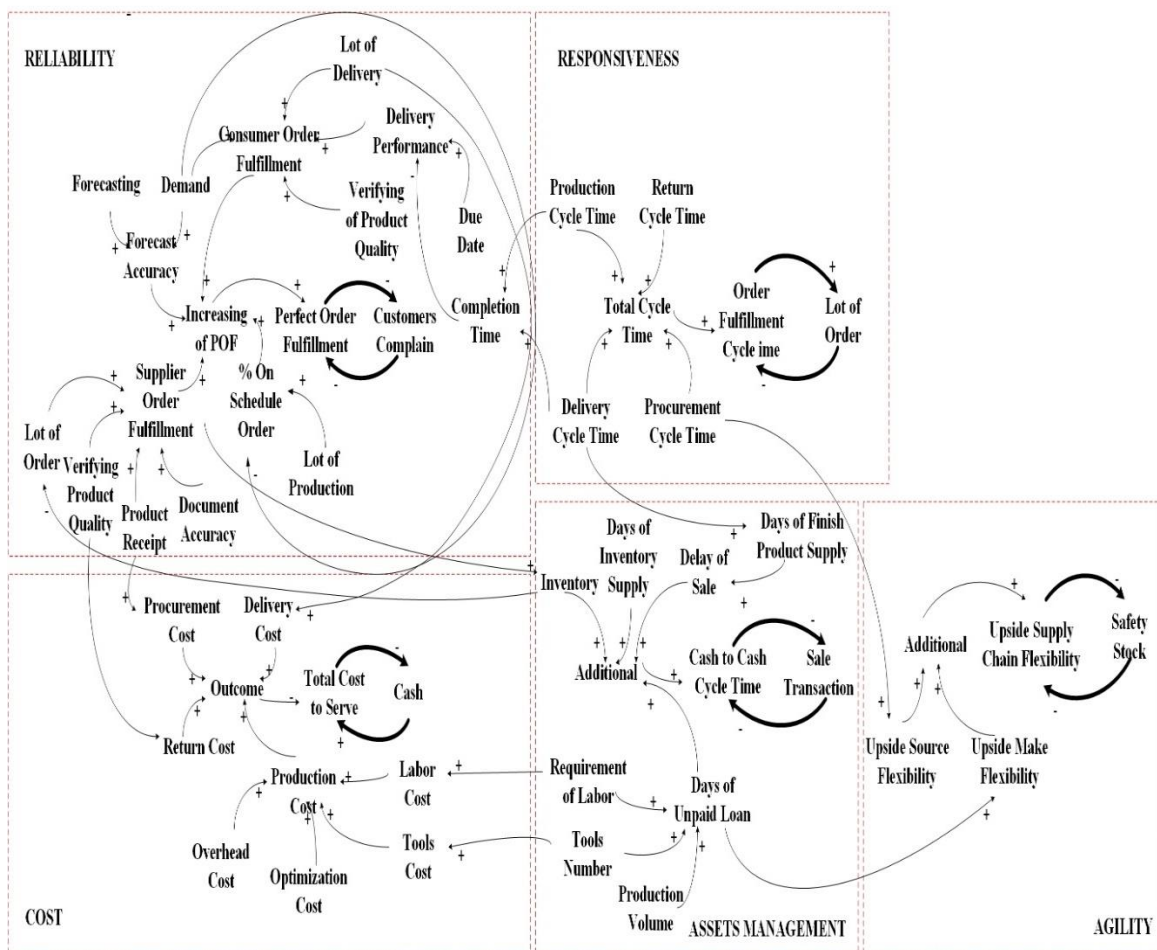

Figure 1. Closed Loop Diagram (CLD)

3.1 *Method of Data Collecting*

Primary and secondary data were used in this research. Primary data is obtained from direct observations in the object of study. Primary data can be gathered by direct observations and interviews. While secondary data were obtained by the literature review.

3.2 *SCOR metric development*

The development of SCOR metrics with the following five attributes are adjusted with typology the MTS MTO production. The metric is described in Figure 2 to 6.
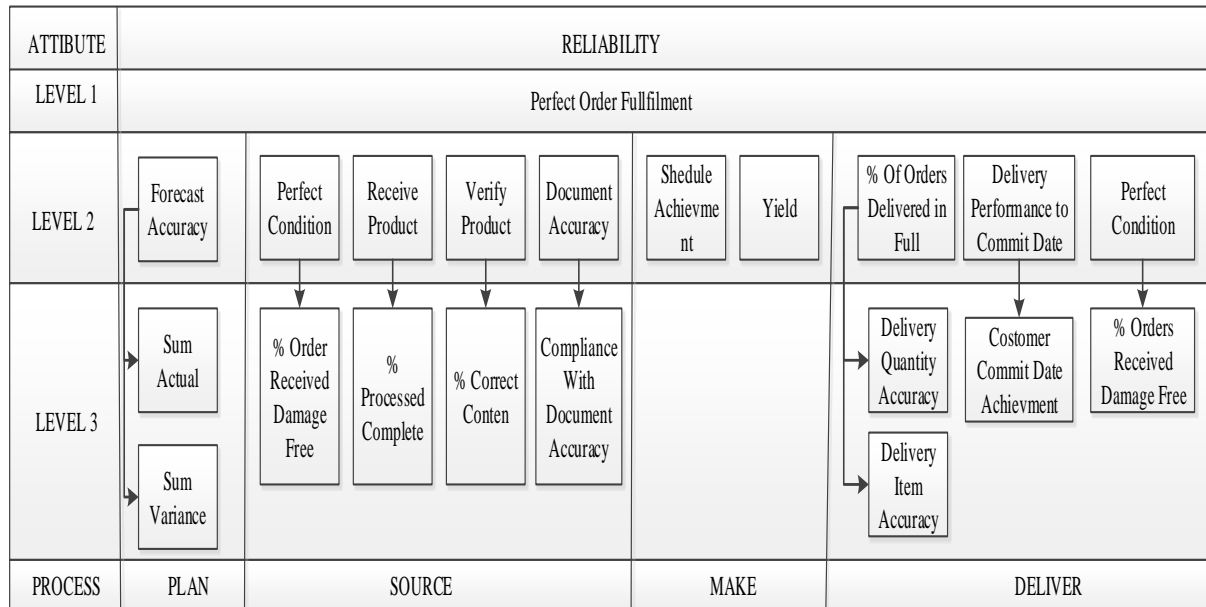
ATTIBUTE	RELIABILITY										
LEVEL 1	Perfect Order Fullfilment										
LEVEL 2	Forecast Accuracy	Perfect Condition	Receive Product	Verify Product	Document Accuracy	Shedule Achievment	Yield	% Of Orders Delivered in Full	Delivery Performance to Commit Date		Perfect Condition
LEVEL 3	Sum Actual / Sum Variance	% Order Received Damage Free	% Processed Complete	% Correct Conten	Compliance With Document Accuracy			Delivery Quantity Accuracy / Delivery Item Accuracy	Costumer Commit Date Achievment		% Orders Received Damage Free
PROCESS	PLAN	SOURCE				MAKE		DELIVER			

Figure 2. Metric Reliability MTS MTO

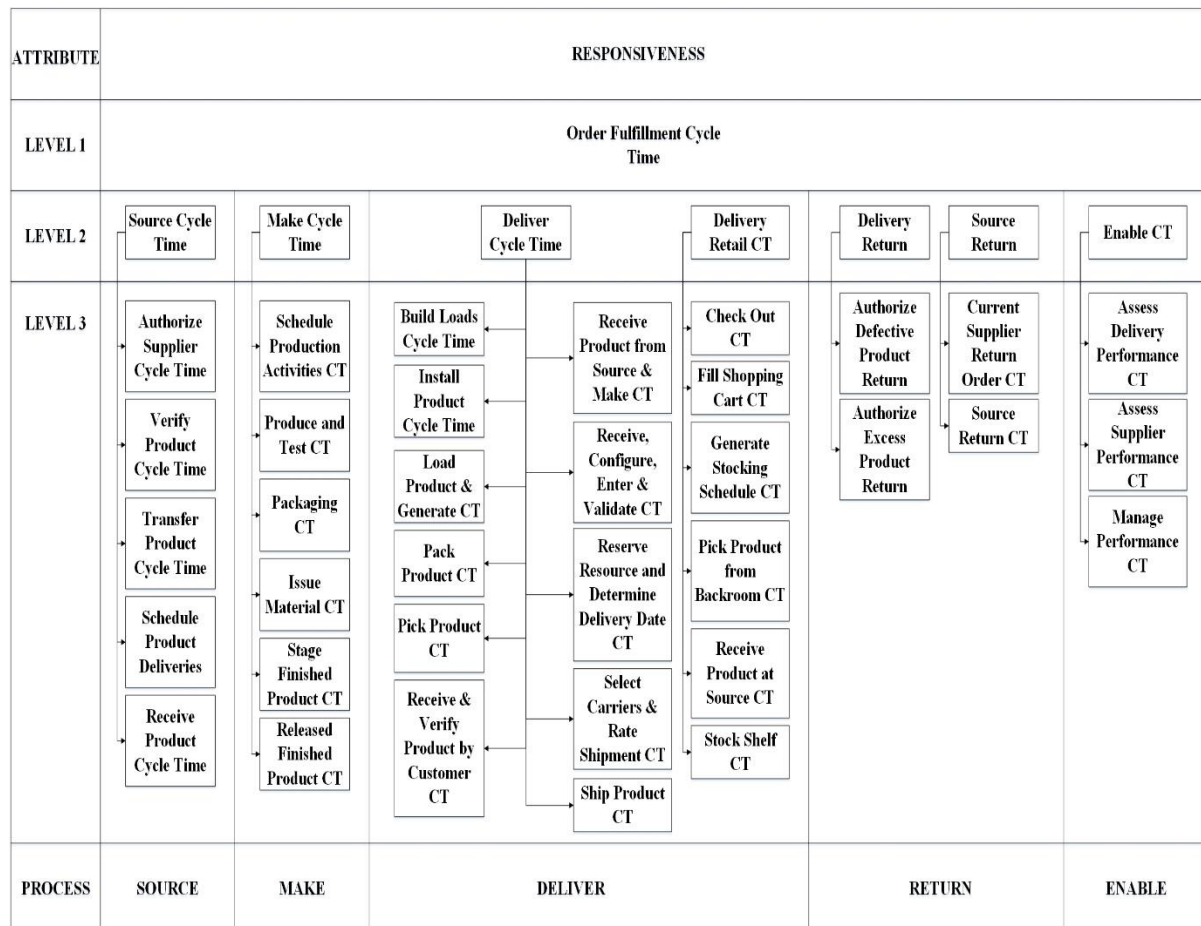| ATTRIBUTE	RESPONSIVENESS						
LEVEL 1	Order Fulfillment Cycle Time						
LEVEL 2	Source Cycle Time	Make Cycle Time	Deliver Cycle Time	Delivery Retail CT	Delivery Return	Source Return	Enable CT
LEVEL 3	Authorize Supplier Cycle Time; Verify Product Cycle Time; Transfer Product Cycle Time; Schedule Product Deliveries; Receive Product Cycle Time	Schedule Production Activities CT; Produce and Test CT; Packaging CT; Issue Material CT; Stage Finished Product CT; Released Finished Product CT	Build Loads Cycle Time; Install Product Cycle Time; Load Product & Generate CT; Pack Product CT; Pick Product CT; Receive & Verify Product by Customer CT — Receive Product from Source & Make CT; Receive, Configure, Enter & Validate CT; Reserve Resource and Determine Delivery Date CT; Select Carriers & Rate Shipment CT; Ship Product CT	Check Out CT; Fill Shopping Cart CT; Generate Stocking Schedule CT; Pick Product from Backroom CT; Receive Product at Source CT; Stock Shelf CT	Authorize Defective Product Return; Authorize Excess Product Return	Current Supplier Return Order CT; Source Return CT	Assess Delivery Performance CT; Assess Supplier Performance CT; Manage Performance CT
PROCESS	SOURCE	MAKE	DELIVER		RETURN		ENABLE

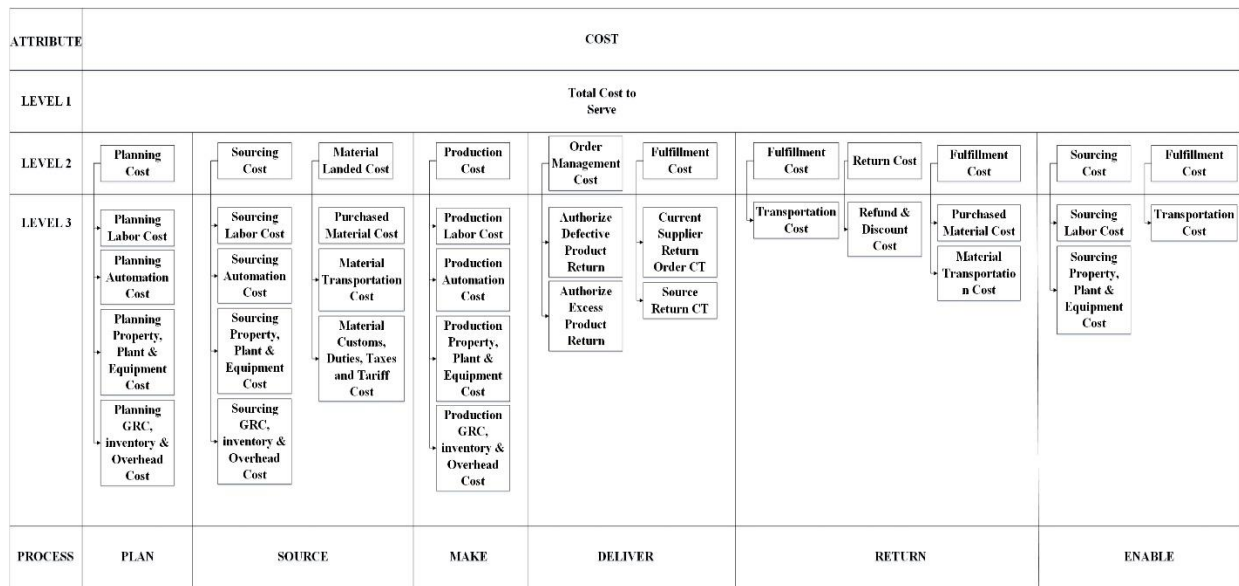Figure 3. Metric Responsiveness MTS MTO
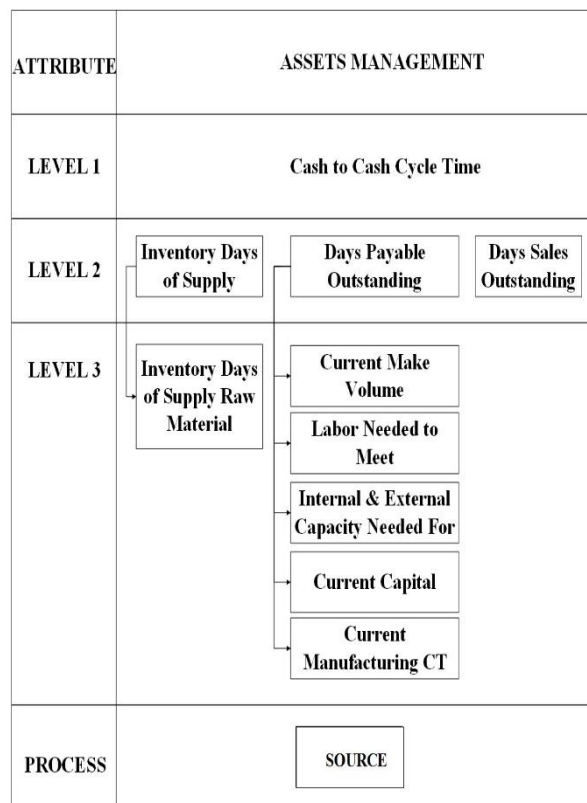
Figure 4. Metric Cost MTS MTO

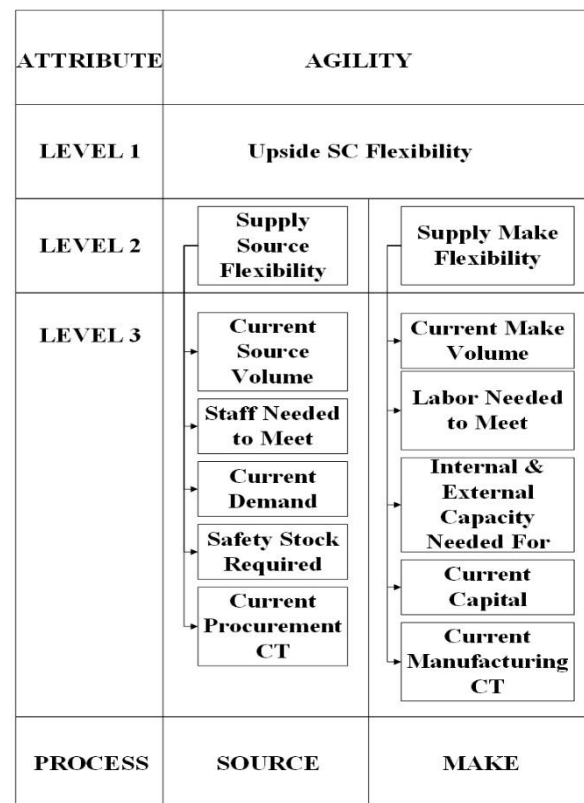Figure 5. Metric Assets Management MTS MTO

Figure 6. Metric Agility MTS MTO

3.3 System Dynamics Modelling

Causal loop has been created (Figure 1) and will be converted into the flow diagrams and further being processed using software PowerSim 9. Flow diagram is the variable containing a mathematical model of the data processing. The flow diagram is formed as described in Figure 7.

3.4 *Simulation and Validation*

Simulations are carried out in several steps as follows:1) System dynamics model test, aimed at equalizing the dimensions, to test the dimensions so that the entire system is a model to simulate the same dimensions. 2) Performing data input 3) Running simulation. Then, validation of the model is a necessary to ensure that the models are made behaves just like the real system. If the model is not similar to the real system, the next step will not be conducted. In this case, the validation will be performed by the validation causal loop based on structural validation approved by experts/specialists.

3.5 *Performance Improvement Trough Lean Production*

Based on the five attributes, Batik Company has a good performance. However, to maintain business competition, it is required an increase on the values of these attributes. The observation data through VSM then identifies unproductive time workers, especially on the production floor. VSM is used to map the operating conditions at the company's current production. The mapping process was carried out by conducting observation and interview. The result is shown in Figure 8 and Figure 9. Batik industry produced two types of batik, batik "tulis" and printing. The production process was based on the typology of MTS MTO, the production cycle time takes 35- 125 days for one production lot with 350 peaches batik (batik printing 240 and 110 batik "tulis").
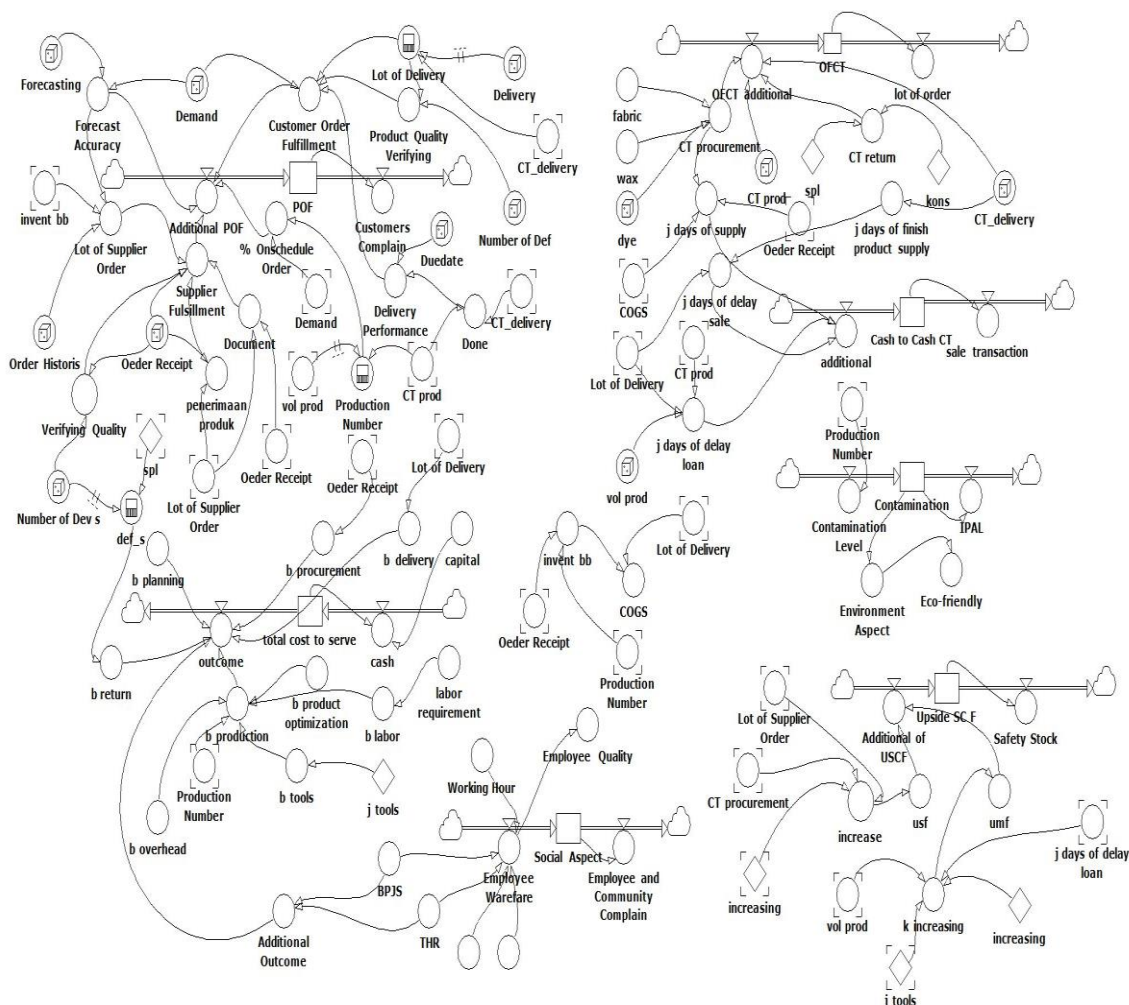

Figure 7. Flow diagram model of SCOR attributes

VSM that is shown in Figure 8, illustrates the production lead time for 110 batik "Tulis", which is 125 with value added time of 107 days. Meanwhile, Figure 9 shows the production lead time for 240 printing batik, which is 35 days with 30 days added value with this added value with ratio of 85.17% to 85.4% of batik "tulis" and printing" batik. The value added ratio indicated that there was no unproductive activity causes waste such as overproduction, defect, unnecessary inventory, inappropriate processing, transportation, waiting and unnecessary motion.
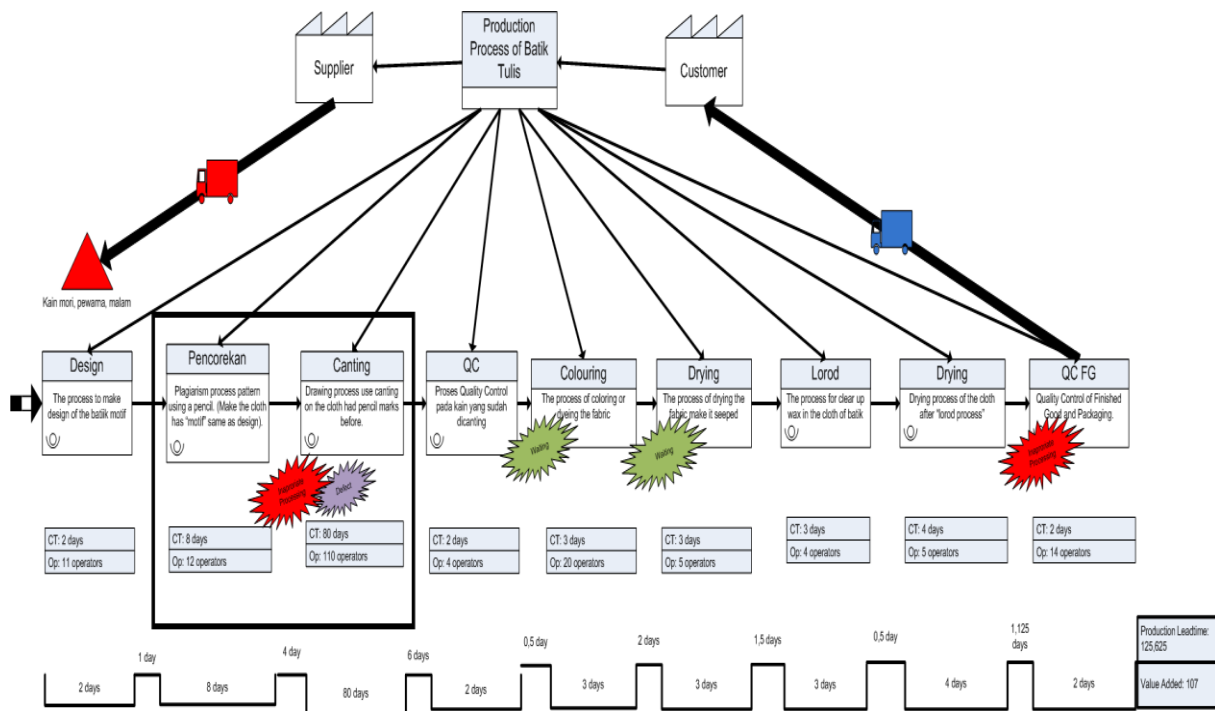

Figure 8. Value Stream Mapping "Batik Tulis"

Overproduction is occurred in production process due to the process "mencanting" and printing process take longer time than next process of Quality Control (QC). QC process often waits for previous activity to be finished. From the observations and interviews, product defect occurs in process "mencanting" and printing. QC process often waits for previous activity to be completed. From observations and interviews, product defects occur in "mencanting" and printing resulted in a cascading pattern. Colouring process by the operator is considered as inappropriate process since there are two groups of operators. The first group consists of very experienced operators, while the other group consists of workers who are just in the learning process as the worker. Operators with imbalance skill will cause many errors in colouring.

While the QC waits from previous activity, the useless communication will be encountered among workers and causes unfocused works hence there will be waste time. Waste of transportation does not occur because the facilities have good production line layout. Nevertheless, the waste is occurred in the production process because of the waiting activities from the previous process. Wasting time also occurred in the QC process on the "mencanting" and in the drying process after the colouring process. From the wastes that have been identified, the most significant waste is inappropriate waste processing and waste of waiting. These wastes are able to be reduced or eliminated by proposing the recommendation for waste reducing in order to improve the efficiency of production processes that may implicate on the performance of the companies' supply chain.
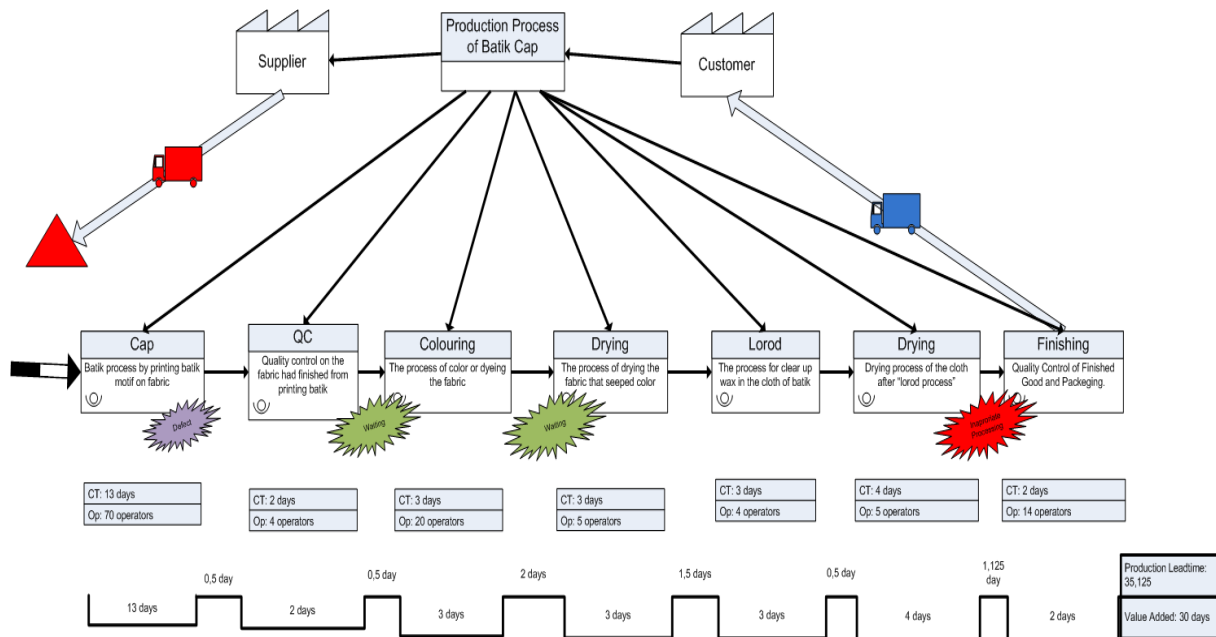
Figure 9. Value Stream Mapping "Batik Printing"

Furthermore, this research proposes several actions to Eliminate waste (1) waste reduction, waiting time in the design process that called as "pencorekan", describes as the process of pattern drawing by pencil in part of *batik tulis* process. (2) Hybrid Innovation process between "Pencorekan" and "Pencantingan" in batik tulis. Process of "pencantingan" is a process of "waxing" in the surface of batik cloth and executed after the process "pencorekan". This process was carried out directly without waiting time between both processes. Process combining would provide more effective and efficient process. (3) Elimination of processing waste in batik printing.

This waste is emerged due to the not optimal activities of the workers and much negligent behaviours experienced in works due to the uncomfortable work environment. (4). QC process of the intermediate product takes up to 6 days to 3 days, hence it needs to be eliminated (5) Waste of waiting occurs when choosing colors for batik. Then, colour selection is carried out manually by visual. It is proposed to use information technology (6). Elimination of delay between the colouring process and the drying process (7). Waste reduction on inappropriate Processing for the QC Process Finished Goods. From observations and interviews in this process, it can be resumed that workers often perform unnecessary activities such as: Chatting and showing fabric disability to each other among operators. Therefore, a lean time QC process is proposed

4. Discussion and Conclusion

Supply chain performance measurement was conducted by building the SCOR metrics version 11.0 on production typology MTS MTO. Furthermore, assessment of the five attributes. The Company has Reliability of 85.58%, 86.22% responsiveness, cost of 94.09%, Agility of 61.11%, and 90.90% Asset management. Furthermore, the assessment of the five attributes separately, because SCOR metrics provide discrete resulted without involving the relationship between the attributes with other attributes. The results achieved sequentially are Reliability 85.58%, 86.22% responsiveness, cost 94.09%, Agility 61.11%, and 90.90% Asset management. In reality, the five attributes are interconnected and able to contribute to the company performance. Hence, the necessary system dynamic involving two-way relationship (feedback).

The result is used to develop causal loop diagram shows in Figure 1. Then flow diagram is developed based on causal loop and simulated (Figure 2). These models are simulated for the next five years and the results could be seen in Table 1 below.

Table 1. Simulation Result during 5 Years (2015-2019)

No	Atributes (%)	Years					Average
		1	2	3	4	5	
1	Reliability	79,89	87,96	69,88	72,32	**68,43**	75,70
2	Responsiveness	112,80	58,91	73,41	**48,92**	78,73	74,55
3	Cost attribute	93,51	93,49	93,34	93,36	93,42	93,42
4	Asset management	83,33	96,67	82,33	**51,67**	155,67	93,93
5	Agility	74,44	100	92,22	**68,33**	100	86,99

It shows that batik industry has enough *reliability* since the average reliability value is 75,70%. Yet it still has not accomplished 100% as planned. The result shows that *responsiveness* in batik industry is still lack. It can be concluded from the lowest value of 48,92% which still far from 100%. The result shows that the company is good based on *cost attribute* because the average value almost reaches 100%. From these results, it can be analyzed that the level of *asset management* batik industry is good. It can be seen from the simulation results that the level of *asset management* companies approaches the target of 100%. However, it should be increased to avoid the results below 60% as in 2018 in the simulation. In average, it almost reaches 100%, means that the condition of the company is good enough. While the average of Agility over five years reaches up to 86.99%

Based on system dynamics simulation, if the result is compared with the target, it achieves unsatisfied result. So, an improvement is required by employing lean production. The result will be discussed as follows: For reliability attribute, the result after being improved are respectively 80,06%, 103,53%, 105,58%, 93,76%, and 72,17%. It shows that the implemented lean has increased up to 100% even above. Responsiveness attribute, the companies target for cycle time is 80%, start from production to customer's delivery.

The implemented lean has resulted 32,59 days or equal to 159,26% compared the target. Cost attribute, the companies target for cost attribute is 1.400.000.000. IDR. While, from the implemented lean production it obtained on 93% of target. Asset management attribute, the target for cash cycle inside the company is 30 days. While the real system need more than 30 days of it. The implemented lean production is only takes 12 days. It means that the company could exceed the target. Agility attribute, tolerated additional time to supply and production during additional demand is 20% in 1,8 days. The implemented lean production simulation could reach 82-100%.

Table 2. Simulation lean production using system dynamics for next 5 Years (2015-2019)

No	Atributes (%)	Years					Average
		1	2	3	4	5	
1	Reliability	80,06	103,53	105,58	93,76	72,17	91.02
2	Responsiveness	122,45	149,10	159,26	131,53	119,36	136.34
3	Cost attribute	93,46	93,53	93,45	93,49	93,49	93.48
4	Asset management	160	153	146,2	150	126,7	147.18
5	Agility	100	87,2	100	82	82	90.24

5. Acknowledgments

6. References
[1]   S. Novani, U. S. Putro, and P. Hermawan, "Value Orchestration Platform: Promoting Tourism in Batik Industrial Cluster Solo," Procedia - Soc. Behav. Sci., vol. 169, no. August 2014, pp. 207–216, 2015.

[2]   T. Borshalina, "Marketing Strategy and the Development of Batik Trusmi in the Regency of Cirebon which Used Natural Coloring Matters," Procedia - Soc. Behav. Sci., vol. 169, no. August 2014, pp. 217–226, 2015.

[3]   L. Mayangsari, S. Novani, and P. Hermawan, "Batik Solo Industrial Cluster Analysis as Entrepreneurial System: A Viable Co-creation Model Perspective," Procedia - Soc. Behav. Sci., vol. 169, no. August 2014, pp. 281–288, 2015.

[4]   T. Ismail, L. S. Wiyantoro, and M. Muchlish, "Strategy, Interactive Control System and National Culture: A Case Study of Batik Industry in Indonesia," Procedia - Soc. Behav. Sci., vol. 65, no. ICIBSoS, pp. 33–38, 2012.

[5]   H. Stadtler and C. Kilger, Supply Chain Management and Advanced Planning. Berlin, Heidelberg: Springer Berlin Heidelberg, 2008.

[6]   F. Persson, "SCOR template—A simulation based dynamic supply chain analysis tool," Int. J. Prod. Econ., vol. 131, no. 1, pp. 288–294, May 2011.

[7]   Y. Barlas, R. Chapters, and B. Sketch, "System Dynamics : Systemic Feedback Modeling for," pp. 1–29.

[8]   J. W. Forrester and P. M. Senge, "Test For Building Confidence In System Dynamics Model." 1979.

[9]   N. R. Ramaswamy, V. Selladurai, and a. Gunasekaran, "Just-in-time implementation in small and medium enterprises," Work Study, vol. 51, no. 2, pp. 85–90, 2002.

[10]   L. Rabelo, H. Eskandari, T. Shaalan, and M. Helal, "Value chain analysis using hybrid simulation and AHP," Int. J. Prod. Econ., vol. 105, no. 2, pp. 536–547, 2007.

[11]   SCC, "SCOR Model," Supply Chain Council, 1996. [Online]. Available: http://www.apics.org/sites/apics-supply-chain-council.

[12]   S. H. Huang, S. K. Sheoran, and H. Keskar, "Computer-assisted supply chain configuration based on supply chain operations reference (SCOR) model," Comput. Ind. Eng., vol. 48, no. 2, pp. 377–394, Mar. 2005.

[13]   P. John, Transformasi Rantai Suplai dengan Model SCOR. PPM, Jakarta Pusat, 2014.

[14]   K. D. Zylstra, "Lean distribution," Appl. lean Manuf. to Distrib. Logist. supply Chain. Hoboken, NJ, 2006.

[15]   D. Gracanin, B. Buchmeister, and B. Lalic, "Using cost-time profile for value stream optimization," Procedia Eng., vol. 69, pp. 1225–1231, 2014.

[16]   C. Saleh, F. H. Astuti, M. R. A. Purnomo, and B. M. Deros, "Fuzzy identification of value stream analysis tools in lean manufacturing," in Proceeding of 2012 International Conference on Uncertainty Reasoning and Knowledge Engineering, URKE 2012, 2012, pp. 74–77.

[17]   F. a. Abdulmalek and J. Rajgopal, "Analyzing the benefits of lean manufacturing and value stream mapping via simulation: A process sector case study," Int. J. Prod. Econ., vol. 107, no. 1, pp. 223–236, 2007.

[18]   S. Gao and S. P. Low, "The Toyota Way," in Lean Construction Management, Springer, 2014, pp. 49–100.

[19]   P. Hines and N. L. Rich, "The Seven Value Stream Mapping Tools," vol. 17, no. 1, pp. 46–64, 2000.