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# The performance of building construction supply chain: A Case study in building construction project

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**Abstract.** Supply chain is the interconnected hierarchy of supply contracts necessary to procure a built asset. On a traditional building project, design consultants are first tier suppliers, working for the client, and the contractor has a supply chain of sub-contractors and specialist suppliers. The problems in the construction industry are that the first and second tier of the supply chain sign up to impartially difficult arrangements but as the chain develops, so the contractual responsibilities decrease until suppliers at the end of the chain are often not locked in at all. The construction of the Diponegoro University Psychology building began September 29, 2017 with a target of 300 days. The deviation between the realization of project work and the planning timeline is -10.37% in the 7th month. The purpose of this study is to evaluate the supply chain process in building construction project. The Supply Chain Operation References (SCOR) is going to be applied to measures the performance of construction projects based on five material planning processes (plan) and project work schedules, material procurement (source), implementation of construction work (make), material delivery (deliver), and the return process if there is a material return (return). The Matrix (OMAX) and Traffic Light method is going to be used to assess the performance of cement and steel structure as the main material on this building project. The results of the assessment with Omax and traffic light obtained that the supply chain performance of cement material is worth 4.3 of the maximum value is 10. Supply chain performance for iron material worth 5.4 from the maximum value is 10. This shows that supply chain performance is quite good but needs repaired.

## 1. Introduction

Supply chain performance measurement is carried out to observe, control, and integrate relationships between supply chain components, so that it can achieve the same goals and determine the direction of improvement in creating competitive advantage [1]. Based on previous studies, supply chain performance measurements have been carried out in construction on road construction. Supply chains in construction can be measured using the SCOR model but must be validated before being applied to a construction project [2].



The Diponegoro University Psychology Building was built with the target of a building measuring 54 meters high with 13.184 m<sup>2</sup> and 30.100 m<sup>2</sup> of sites and projects. The location of the building was built on Jl. Prof. Soedarto, Tembalang, Semarang. This building is referred to as Undip's First Bioclimatic and Biophilic Green Building. This building will have facilities in the form of class buildings, undergraduate laboratories, postgraduate buildings, deans, libraries, public parks, amphitheater areas, plazas, and so on.

When conducting research observations, based on a time schedule, work should have reached 60.02%. While the realization of the construction work of the Diponegoro University Psychology building reached 49.6%. The deviation between the realization of project execution and the planning timeline is -10.37%. The building construction target is 300 days. However, due to delays in some jobs, the building could have not been completed within 300 days. In accordance with the contents of the Psychology development contract, the contractor will be fined if at the end of the construction period it is not in accordance with the target processing time. If within 300 days the construction of the Psychology building has not been completed, the contractor will be fined 1 / mile of unfinished work multiplied by the contract value.

Measuring the performance of building construction can be done using a model of Supply Chain Operation References (SCOR) as is the case with road construction like previous studies [2]. The dimensions of the SCOR model include reliability, responsiveness, agility, costs, and assets [3]. Performance measurement with the SCOR model is expected to improve construction project work [4]. Some of the objectives of this study were to map the supply chain construction of the Diponegoro University Psychology Building project, identify Key Performance Indicators and apply SCOR to measure the supply chain construction performance of Diponegoro University's Psychology Building project, assessing supply chain performance at Diponegoro University Psychology Building project, recommending improvements supply chain of Diponegoro University Psychology Building project so that the project is not late and carried out as planned.

## **2. Theoretical background of supply chain and performance measurement**

### *2.1. Construction supply chain management*

According to Sukati et al. [1], supply chain is a network of companies that work together to create and deliver a product from suppliers to customers. In the process different processes and activities occur that produce added value to the products or services that consumers will receive. Supply Chain Management plays an important role in construction. Supply Chain Management can be used to analyze, improve, coordinate, and provide constant improvement, and solve problems in the supply chain [5] and [6].

### *2.2. Model supply chain operation reference*

SCOR is a model that is used as a reference for supply chain operations [7]. This model is designed to help from inside and outside the company because it has a sturdy framework and is also flexible so that it can be used in all kinds of industries that have supply chains. Each process is based on process elements and the elements are composed of tasks. Tasks consist of a collection of activities. These activities are standardized to compare supply chains. According to Huan et al. (2004) in the study Pettersson [8] the performance of these metrics is as follows [8]:

**Table 1.** SCOR matrix performances

SCOR Matrix	Operational Definition
Perfect order fulfillment	The percentage of orders for cement materials sent in quality and quantity
Order fulfillment cycle time	The time needed to order cement material until it is received by the contractor on the project
Upside supply chain adaptability	Supplier's ability to adapt to the amount of cement material that can be brought in when the contractor's demand increases
Downside supply chain adaptability	Supplier's ability to adapt in reducing cement orders when the contractor reduces the number of orders
Cost of goods sold	Cost of goods sold incurred to procure covers the cost of labor, materials, and indirect costs associated with supply chain
Supply chain management cost	Costs incurred in managing the procurement of reinforced iron and cement include the costs of planning, procuring, manufacturing, shipping and returning
Inventory days of supply	The average length (in days) of the contractor can survive with the amount of inventory held (if there is no further supply)
Percentage defective inventory	Percentage of defective inventory

### 3. Research Methodology

This research was conducted through the preliminary survey phase, data collection, data processing, and analysis. Data collection was carried out by interviewing and distributing Key Performance Indicator weighting questionnaires. The questionnaire was distributed to one project manager, one project supervisor, one drafter, and one Logistics officer. Data processing is done by calculating the performance of measurement indicators based on data from the building project of the Faculty of Psychology Diponegoro University. Based on previous research and adapted to the SCOR version 10 metric, a SCOR hierarchy model can be developed to measure supply chain performance in construction [9] and [2].

#### 3.1. Analytical Hierarchy Process (AHP)

Analytical Hierarchy Process (AHP) is a measurement method for comparing discrete or continuous paired comparisons [10]. AHP aims to provide weights for each criterion that has been compared. AHP analysis can be done by Software Expert Choice. At this stage the weighting of the SCOR metric is used as an indicator of the supply chain performance assessment of the Diponegoro University Psychology Building construction project. Weighting is done through a paired comparison questionnaire. The questionnaire was filled out by five respondents, namely one project manager, one project supervisor, one drafter, and one logistics officer. The results of the respondent's answers will be calculated using Software Expert Choice 11 to find out the weight value.

#### 3.2. Scoring System with OMAX and Designing Traffic Light

Measurements in this study were conducted using a questionnaire. At this stage of measurement all performance indicators that have been calculated will be measured by Objective Matrix (OMAX) and

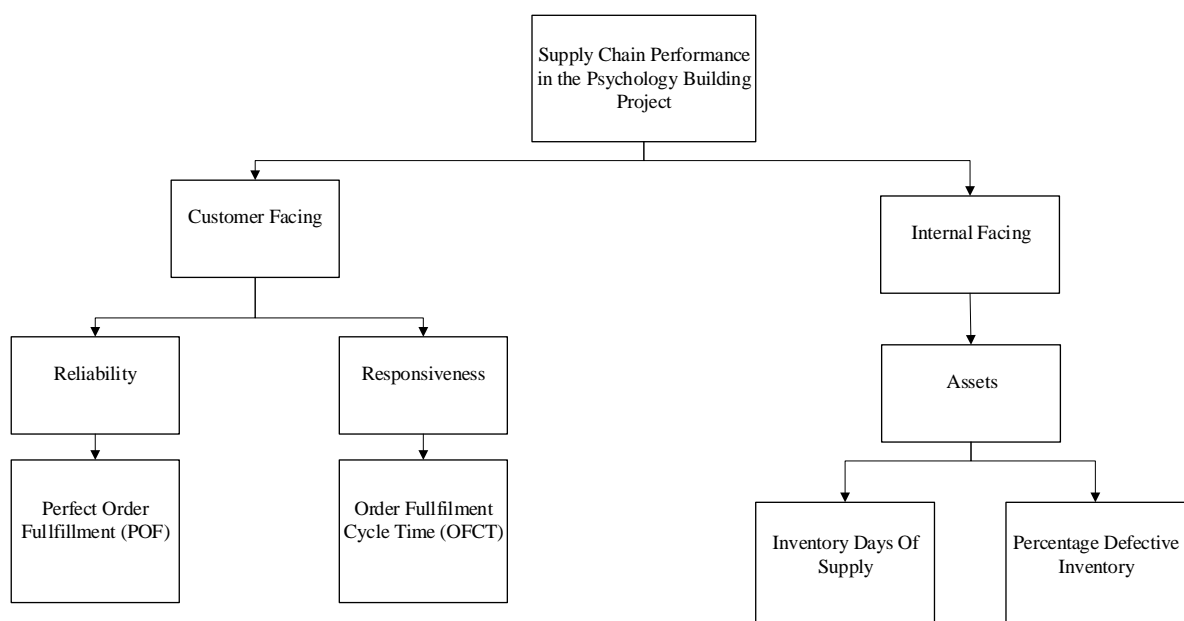
Traffic Light System. Scores on each KPI indicator are obtained from contractor operational data. The weight of the indicators is converted into a conversion of a certain value between 0 and 100.

OMAX has 10 levels whose values are the result of interpolation. A value of 0 is a minimum value and a value of 10 is the maximum value provided by stakeholders. While Traffic Light divides into 3 colors namely red, yellow, and green. If the results of bad measurements will be grouped in red, yellow enough, and good for blue. The limit of each color for evaluation with a traffic light is applied based on the results of the achievement of each indicator.

#### 4. The case study: supply chain in building construction project

The supply chain process of the Diponegoro University Psychology building construction project begins with the purchase of material procurement. Relationships that occur in the supply chain of the building of the Psychology building include the flow of information, the flow of money, and the flow of goods and services. The project owner (owner) plays a role in forming the supply chain for project development. The owner is the final consumer of the supply chain building project of the Faculty of Psychology Diponegoro University. If the construction has been completed, the building will be handed over to the building owner to be used.

The calculation of the actual value of supply chain aims to determine the current condition of the project. Achievement is calculated based on data obtained from the project. The results of data processing will be used to determine the achievement of project performance. **Figure 1** shows a comparison between the SCOR metrics used for project supply chain measurements. Some metrics are omitted because there is no data in the field that matches the operational definition for measurement. The following is the final weighting result of the SCOR metric that is used to measure the supply chain performance of a construction project. Several metrics from the eight metrics that were previously set were eliminated because they were not in accordance with the project conditions and no data was found in the project location that represented the definition of the metric.



**Figure 1.** SCOR hierarchy model supply chain performance measurement

**Table 2.** SCOR matrix weight of project supply chain performance measurement

Indicator	Local Weight	Performance Attributes	Local Weight	SCOR Matrix	Local Weight	Global Weight	Description
Customer facing	0.344	Reliability	0.589	Perfect Order Fullfillment	1	0.203	Larger is better
		Responsiveness	0.411	Order Fullfillment Cycle Time	1	0.142	Low is better
		Total	1				
Internal Facing	0.656	Assets	1	Inventory Days of Supply	0.641	0.420	Low is better
				Percentage Defective Inventory	0.359	0.236	Low is better
Total	1			Total	1	1	

Performance assessment indicators that have been assessed will be observed based on the traffic light. The green indicator means it's good, yellow is enough, and red means bad so repairs are needed.

**Table 3.** Monitoring supply chain performance indicators with traffic light (cement material)

KPI	POF	OFCT	Inventory Days of Supply	Percentage Days of Inventory
Actual	10.61%	38	21	5
Score	10	40.00	9.00	5
	9	37.14	16.86	7.29
	8	34.29	24.71	9.57
	7	31.43	32.57	11.86
	6	28.57	40.43	14.14
	5	25.71	48.29	16.43
	4	22.86	56.14	18.71
	3	20.00	64.00	21
	2	13.33	82.33	26.33
	1	6.67	100.67	31.67
	0	0.00	119.00	37
Actual Value	2	7	3	7
Weight	0.203	0.142	0.42	0.236
Value	0.406	0.994	1.26	1.652

Based on **Table 3** above it is known that two SCOR metrics are red and two are yellow. The perfect order *fulfills* and inventory days of supply metrics have poor performance that needs to be fixed.

Performance of cement material supply chain flow is 4.3. Supply chain performance level is at level 4.3 of the total 10.

**Table 4.** Monitoring supply chain performance indicators with traffic light (steel material)

KPI		POF	OFCT	Inventory Days of Supply	Percentage Days of Inventory
Actual		77.70%	174	19.36	0
	10	100	9.00	4.67	0.00
	9	97.62	16.86	7.93	0.00
	8	95.24	24.71	11.18	0.00
	7	92.86	32.57	14.44	0.00
	6	90.48	40.43	17.69	0.00
Score	5	88.10	48.29	20.95	0.00
	4	85.72	56.14	24.20	0.00
	3	83.34	64.00	27.46	0.00
	2	77.78	82.33	35.06	0.00
	1	72.23	100.67	42.65	0.00
	0	66.67	119.00	50.25	0.00
Actual Value		3	0	6	10
Weight		0.203	0.142	0.42	0.236
Value		0.609	0	2.52	2.36

Based on the table above it is known that two SCOR metrics are red, one red metric and one yellow metric. The perfect order fulfilment and order fulfilment cycle time metrics have poor performance that needs to be corrected. The performance of the supply chain flow of cement material is 5.4. The value of supply chain performance is at the level of 4.3 of the total 10.

The assessment of supply chain performance on the project using steel material for the OFCT indicator uses the best and worst scale of supply chain performance in cement materials. This happens because iron material only occurs once in a single order or shipment of material. The best scale percentage defective inventory indicator is 0% because there is no defective steel material which cannot be used anymore.

Based on the results of the study obtained several performance indicators that require improvement. These performance indicators are shown in the following table.

**Table 5.** Performance indicators on supply chains of cement and steel materials needing improvement

Performance Attributes	SCOR	Cement	Monitoring	Steel	Monitoring
Reliability	Perfect order fulfillment	0.406	Red	0.609	Red
	Order fulfillment cycle time	0.994	Yellow	0	Red
Assets	Inventory days	1.260	Red	2.520	Yellow
	Percentage defective inventory	1.652	Yellow		

The score value in the table above is the result of the global weight of each metric and the value of the level of performance achievement in the Omax table. Each metric is known to need to make improvements based on achieving metric values at the OMAX level and Traffic Light. In this study, levels 0-3 are red, levels 4-6 are yellow and levels 7-10 are green.

## 5. Conclusion

Based on the research, four matrices were used to measure the supply chain performance in the construction of the Psychology Faculty building, Diponegoro University. Measurements are made to determine the performance attributes of reliability, responsiveness, and assets. The metrics used include perfect order fulfilment metrics, fulfilment cycle time orders, inventory days of supply, and percentage defective inventory.

Performance assessment of supply chain performance is carried out by weighting metrics with AHP then scoring using OMAX and Traffic Light. In this study the supply chain assessment of building construction projects was carried out by analyzing cement material and reinforcing steel material. The performance of the supply chain flow of cement material is 4.3 with an overall value of 10. The average level of supply performance of cement material is 4.75. This average level is in the yellow category. The performance of supply chain flow of iron material is worth 5.4 with a total value of 10. The average level of supply chain performance of steel material is 4.5. Thus, it is necessary to improve the measurement metrics to improve supply.

Recommendations for improvements made to improve supply chain performance are as follows. First, the need for SOP planning that is in accordance with the conditions in the field, the need for a special team to supervise work in the field, the importance of trust to maintain the relationship between suppliers and contractors, and the existence of cost management by adjusting the materials used and the appropriate use of labor with needs in the field.

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