Available online at : http://josi.ft.unand.ac.id/

Jurnal Optimasi Sistem Industri

| ISSN (Print) 2088-4842 | ISSN (Online) 2442-8795 |

Research Article

Supply Chain Performance Measurement Framework for Construction Materials: Micro Meso Macro

Moh Nur Sholeh [1], Mochamad Agung Wibowo [2], Naniek Utami Handayani[3]

[1] *Civil and Planning Department, Vocational School, Diponegoro University, Jl. Prof. Sudarto Semarang, 50275, Indonesia*
[2] *Civil Engineering Department, Faculty of Engineering, Diponegoro University, Jl. Prof. Sudarto Semarang, 50275, Indonesia*
[3] *Industrial Engineering Department, Faculty of Engineering, Diponegoro University, Jl. Prof. Sudarto Semarang, 50275, Indonesia*

ARTICLE INFORMATION

Received: June 26, 20
Revised: August 30, 20
Available online: November 20, 20

KEYWORDS

Performance measurement, supply chain, material, micro-meso-macro

CORRESPONDENCE

Phone: +6285640248060

E-mail: mohnursholeh@live.undip.ac.id

A B S T R A C T

Productivity is a challenge in the construction industry, commonly initiated by fragmentation. In addition, some work levels have been identified, including the micro, meso, and macro. However, the construction supply chain is one of the possible solutions adopted to increase productivity. The purpose of this study, therefore, is to develop a framework for measuring supply chain construction performance at the micro, meso, and macro levels. These respective stages are tiered from the bottom to the top level as a supply chain management concept. Furthermore, a design for the supply chain performance measurement framework is created, followed by formulation with KPI, and the consequent application in the project. Therefore, performance is evaluated based on the construction materials, as a large resource. The results identified the supply chain performance at the micro-level as the basis for possible measures between contractor and supplier, using the SCOR. However, the emphasis was made on the strength of construction companies with large suppliers at the meso level. Meanwhile, the macro-level includes the accumulation of related measurements from micro as well as meso, and are consequently used to define the relationship between construction actors at the national level.

INTRODUCTION

High productivity is one of the challenges in construction industries. According to the Lean Construction Institute, the waste generated is up to 57%, while only 10% of activities add value. This sector has acquired significant knowledge from manufacturing industries required to facilitate productivity. In addition, several innovations were equally adopted to strengthen the sectors' development, especially modular systems or fabrication, precisely precast concrete [1]. Furthermore, several countries including Indonesia identify the term construction as a fragmented industry [2], and this has become a big problem faced by construction actors, especially contractors, government, academia, and also suppliers. These discrepancies ensue because specialization levels in employment and supply chains are numerous and varied. Hence, the main contractor is usually overwhelmed to maintain maximum communication and relationships with sub-contractors, suppliers, and project owners.

However, fragmentations are not preventable, being a notable characteristic distinguishing the construction from the manufacturing sector [3]. This challenge is combated through innovation and a good supply chain management, referred to as the control and flow of materials, information, and money between construction actors from upstream to downstream in achieving lean construction [4][5].

Meanwhile, the supply chain is attributed as more important because of technological advancement. Furthermore, improvements from subsequent works are limited due to the short cycle of projects [6]. This condition is different from the manufacturing industry where works are carried out repeatedly in the same place and object. Also, knowledge preservation in the construction supply chain is important and servers as a reference for future projects [7]. This goes a long way to strengthen the relationship between actors and also serves as a guide in project management [8][7].

Presently, numerous approaches and research on supply chain construction are horizontal and are specifically known to flow between actors, including contractors to sub-contractors, suppliers, and owners. Conversely, the vertical aspect deals with projects up to national and multinational levels between construction actors [9][10]. In addition, it is important to evaluate logistics management performance at each level. This research

DOI: 10.25077/josi.v19.n2.p101-110.2020

aims to measure the supply chain construction performance in three different levels, particularly micro (intra-organization), meso (inter-organization), and macro (cross-organization). These activities are generally material-oriented, being one of the largest resources in managing construction projects [11].

Previous studies have disclosed a balanced scorecard as a tool to help managers measure supply chain performance, although there has been a review on the metrics [12]. Furthermore, adequate measurements enable managers to accurately compare the supply chain of competitors as well [13]. Meanwhile, past investigations also stated SCOR as a reference for business orientation, with the intrinsic capacity to improve managerial effectiveness [14]. This simulation was created based on dynamic supply chain analysis and is applied by project managers to determine the allocation of resources in an international production network [15]. Meanwhile, some of these investigations are limited to enlist SCOR a company-wide performance measurement.

This supply chain at the micro-level is defined as the relationship between contractors and suppliers in a project, therefore, regarded as a small scale in the supply chain level. Furthermore, one of the measurements on a project scale uses the Supply Chain Operations Reference (SCOR)to survey the entire process [16]. Meanwhile, the construction supply chain at the meso level is categorized within the company's scope. This is considered an advantage in tender participations, and the presence of stronger management serves as an indicator to determine the winner [17]. However, the performance of the national supply chain at the macro level is measured by those engaged in construction projects, also it reckons supply and demand for the required materials at the national level. Furthermore, performance at this level is assumed to be better measured in terms of vertical and horizontal relationships.

METHOD

Research Method Concept

This research was conducted in several steps to produce a preliminary assessment of the supply chain performance measurement framework at Micro, Meso, and Macro levels. The first step was to design an analysis parameter for these levels, followed by the formulation of a Key Performance Indicator (KPI). Finally, the third step involved implementation of the project. Figure 1 shows the concepts of this research method.

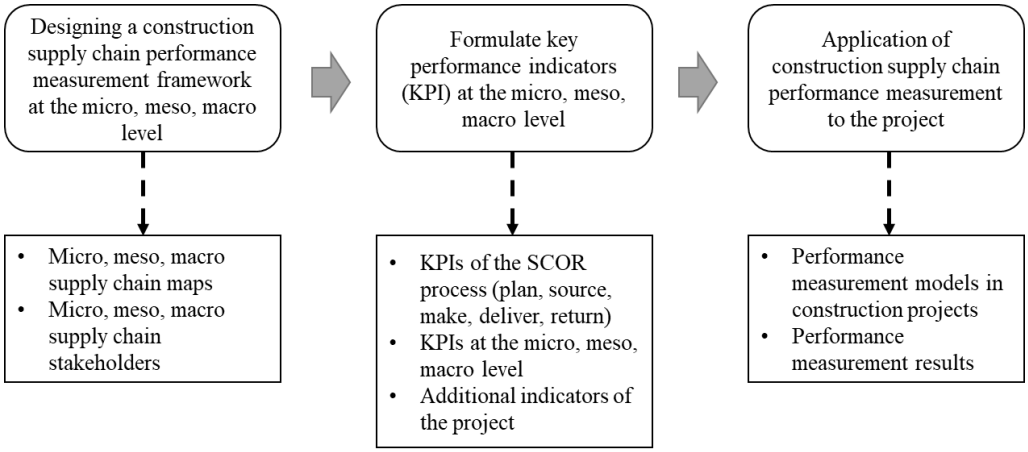

Figure 1. The Research Method Concept

The result of the first step was a construction supply chain map at the micro, meso, and macro levels in correlation with the stakeholders involved and was based on material flow management. The second stage involved formulating a Key Performance Indicator (KPI) adopted from the Supply Chain Operations Reference (SCOR) model. Therefore, the additional indicators from stakeholder input were further explored. Meanwhile, the third step generated examples of project performance measurements based on the SCOR model formula.

The thinking framework provides the most basic perception of any analysis and is, as a result, referred to as the flow of thoughts during research. The thinking framework in Figure 2 explains the rationale, starting from the SCOR model version 12.0, a performance measurement model adopted from the Supply Chain Council. Level one SCOR indicators are adopted for application in construction. Subsequently, validation is conducted by contractors and suppliers of state-owned enterprises to determine the possibility and extent of use in future projects.

Validation and Data Processing

The local conditions influence the validation of a project and supply chain implementation method. For instance, a project's location determines the choice of suppliers and consequently influences sustainability. SCOR indicators are applied to project conditions, before validation while those from other sources are set aside for additional studies.

Table 1 shows that most of the respondents are male (75%). This indicates the construction field to be dominated by men, due to job specifications and difficulty. Furthermore, in terms of educational qualification, DIV/S1 graduates compose the majority, with the minority comprised of DIII graduates with S2/S3 graduates in between, as nearly all employers require DIV/S1 graduates as project workers, while, S2/S3 graduates work as academics on average. In addition, state-owned enterprises held the highest number of respondents, while private

DOI: 10.25077/josi.v19.n2.p101-110.2020

companies and firms owned by the Ministry of Public Works and Housing (PUPR), a government sector, had equal percentages.

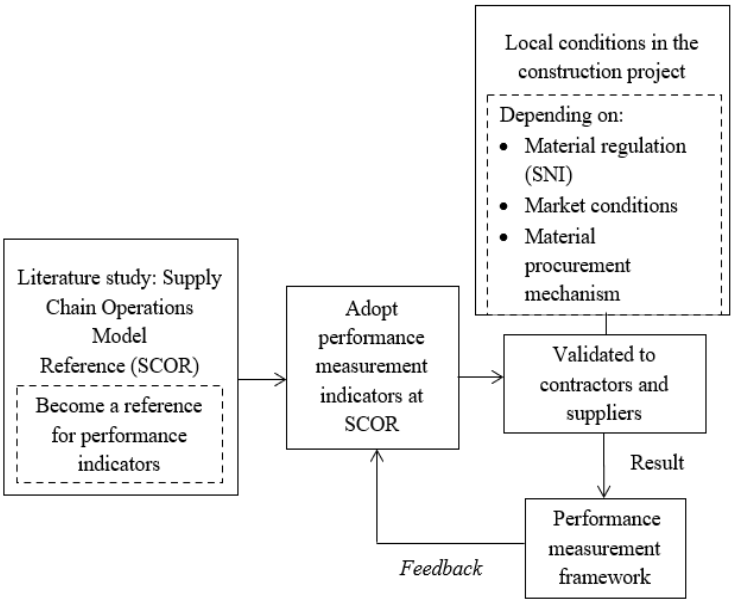

Figure 2. Research Thinking Framework

Table 1. Composition of Respondents based on Gender, Education, and Company Scale

Criteria	Sub Criteria	Number of respondents	%
Gender	Male	15	75
	Female	5	25
Level of education	DIII	2	10
	DIV/S1	13	65
	S2/S3	5	25
Company scale	Government	5	25
	State-owned enterprises	10	50
	Private	5	25

The next stage involved the construction supply chain performance measurement, with indicators designed based on the SCOR model, local conditions, and other suitable sources to validate the project and suppliers. This process aims to measure KPI implementation. Furthermore, a questionnaire was filled by the project manager or the head of material procurement at this stage to elucidate the data analysis process and ensure a successful formulation.

The SCOR model measures projects through performance criteria [18], and each has a major indicator. These include *reliability*: perfect order fulfillment, *responsiveness*: order fulfillment cycle time, *agility*: flexibility and adaptability of the reverse and downside supply chains, overall risk value; *costs*: costs of supply chain management and goods sold, *asset management efficiency*: cash to cash cycle time as well as return on fixed assets and working capital. Therefore, these KPIs serve as tools to measure activities at the project or the micro-level.

The construction supply chain maps at the meso and macro levels focus on the pre- and post-project stages. However, there is limited related research these days. This analysis technique has no attained good performance at the micro level [16], although the concept forms the basis of the construction supply chain at the national level.

RESULT AND DISCUSSION

This study aims to design the concept of supply chain performance measurements in construction. Hence, it is important to create the concept of a framework, as shown in Figure 3. The outcome is assumed to be good on instances where materials, costs, and information are properly handled. These considerations follow the project stages and are initiated by an idea or concept, design, material procurement, implementation, and up to the finished building, before submitting to the customer.

Moreover, a good construction supply chain is observed from the problems in the projects. Hence, the assessment ought to be based on performance. Therefore, several steps were carefully drafted, including the execution level measured, detailed to the method, and indicator. This evaluation is conducted properly on instances where the performer's performances are also assessed. Furthermore, three main parties are involved in the evaluation at each level in the construction supply chain, consisting of the micro, meso, and macro. The parties referred comprise (1) construction, as well as material and heavy equipment companies as the main actors in the project, (2) materials and heavy equipment suppliers, assumed to support the work progress, (3) the Ministry of Public Works and Housing as policymakers in determining the supply chain in Indonesia.

The concept of performance measurement is needed to determine the extent of operational capabilities in maintaining the supply chain. However, the micro-meso-macro aspect is considered an interesting topic of conversations amongst contractors, suppliers, academics, and the government. In addition, each stakeholder has a personal opinion and view, particularly because of the

respective interest to be achieved as a target. This is considered especially by contractors and suppliers assumed to observe the supply chain or procurement from a business perspective [19]. Consequently, an efficient set up is estimated to increase company profits.

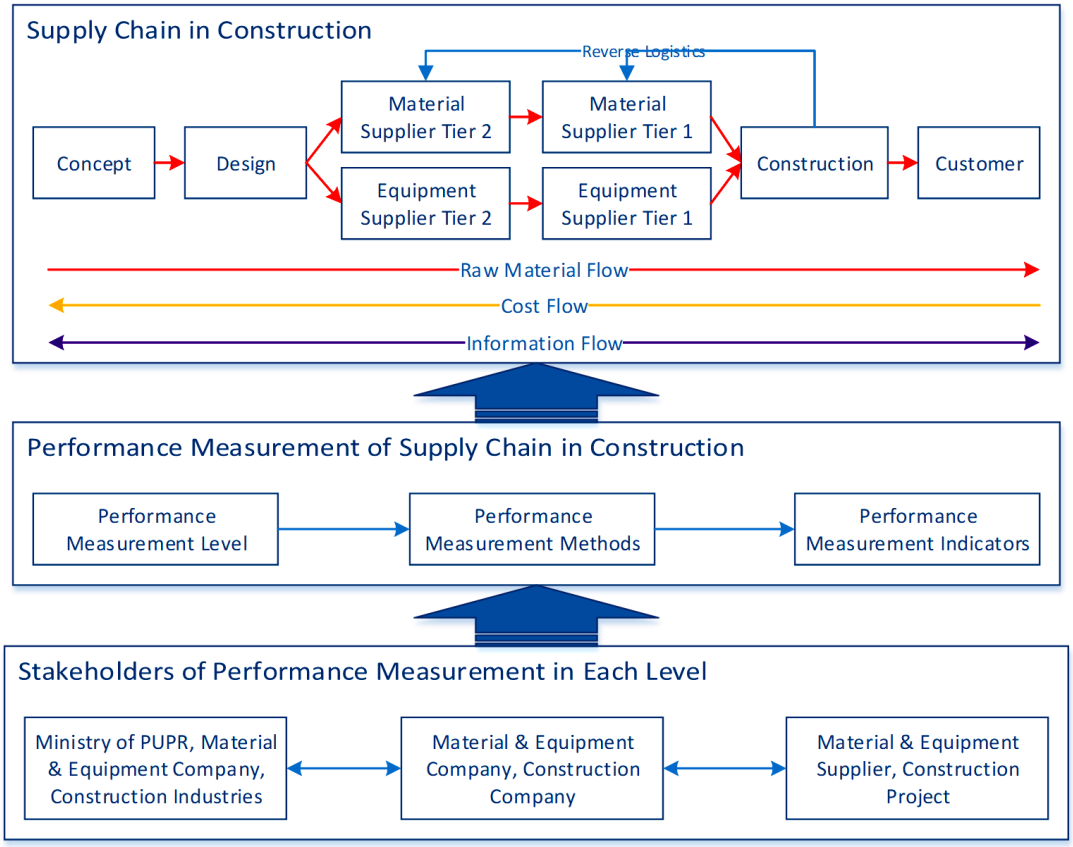

Figure 3. Concept of Supply Chain Performance Measurement Framework in Construction

Critical questions have been raised by stakeholders in the construction sector bothering on the effectiveness of the supply chain required to generate several benefits. However, the perception of government and academic community is built on a predefined model and standard in managing projects. Generally, construction stakeholders recognize the need for each level (micro-meso-macro) to specify the material inflow and technique adopted to measure appropriate performance.

The construction supply chain covers the project work cycle from conception, design, material procurement, implementation, and user experience. Several workflows are to be managed during this stage, including material flow, finances, and information. However, three parties are involved in the measurement of supply chain performance at each construction phase. The first category comprises the Ministry of Public Works and Housing, construction materials, and equipment companies, as well as the industry. In addition, the second group involves the construction materials and equipment companies as well as construction companies, while the third party refers to the suppliers, as well as the projects. Therefore, evaluating supply chain performance at each level (micro, meso, and macro) is very significant. Large and fragmented construction industry requires adequate support in terms of effective supply chain at every phase. In this study, the measurement of construction supply chain performance is consistently focused on the micro stage at the project scale as few contractors and local suppliers are employed. This is indeed different from meso and macro levels, where the company and national scales were consulted to formulate supply chain policies. However, preliminary studies on performance evaluation were also performed to determine the patterns and challenges.

The next step after creating a concept of construction supply chain management and measuring the performance is to develop a model for the micro-meso-macro level. This depiction is illustrated horizontally to ensure the concept map is easier to comprehend, as observed from low to high level or conversely (Figure 4).

Basically, the level on the left encapsulates the right. Therefore, the meso summarizes the events at micro, while the macro reviews the occurrences at the micro and meso. The supply chain at micro is referred to as intra-organization and is measured at the project work phase. The meso stage, also called the inter-organization, links the micro and macro. This level is quantified at the scale of construction companies and suppliers. Meanwhile, the macro shows an accumulation of meso or several construction companies commonly referred to as cross-organizational on the national scale. Furthermore, consideration of the supply and demand for national construction materials is necessary to become a variable in the supply chain [20].

Figure 5 broadly describes the performance measurement at all levels, where the micro stage or construction project scale focused on small to large projects. However, the assessment method as well as the applied indicators were adopted from the

DOI: 10.25077/josi.v19.n2.p101-110.2020

SCOR model. Meanwhile, attention is on small to large companies at the meso or company scale, and the performance assessment method also originated from SCOR. At the macro or the national scale, the effort is on national construction companies where the performance measurement method applied input-output analysis.

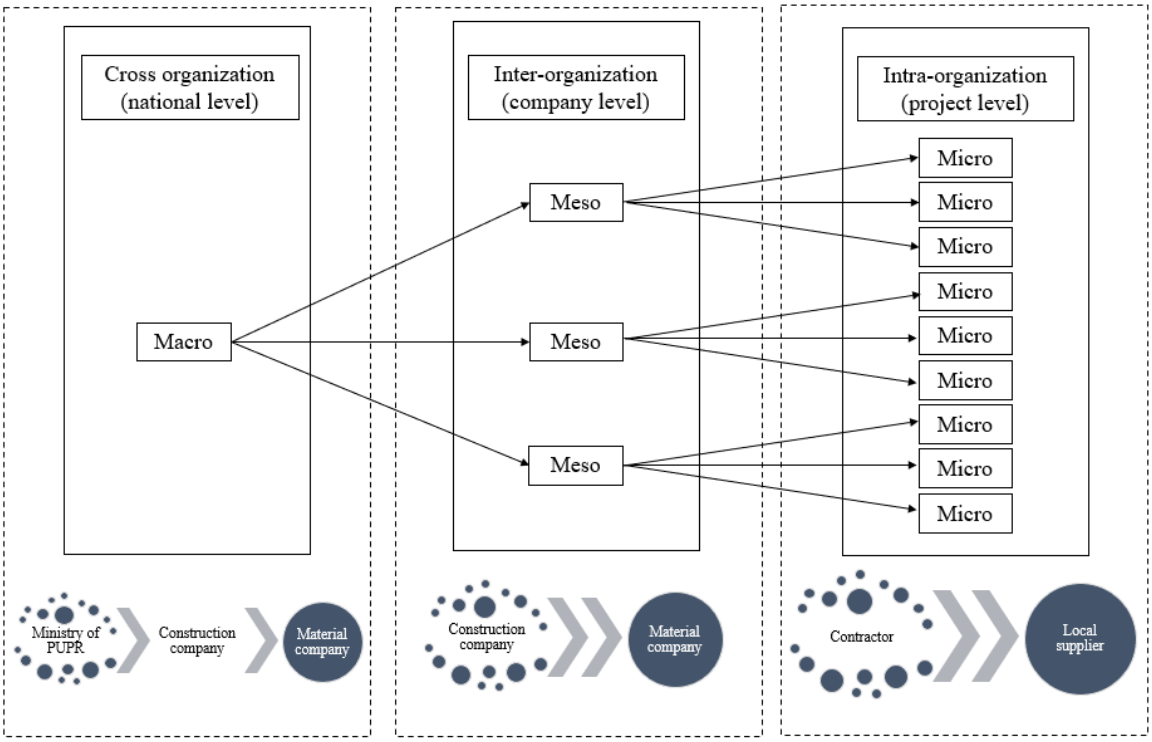

Figure 4. The Concept of Micro-Macro-Macro and Stakeholders in the Construction Supply Chain

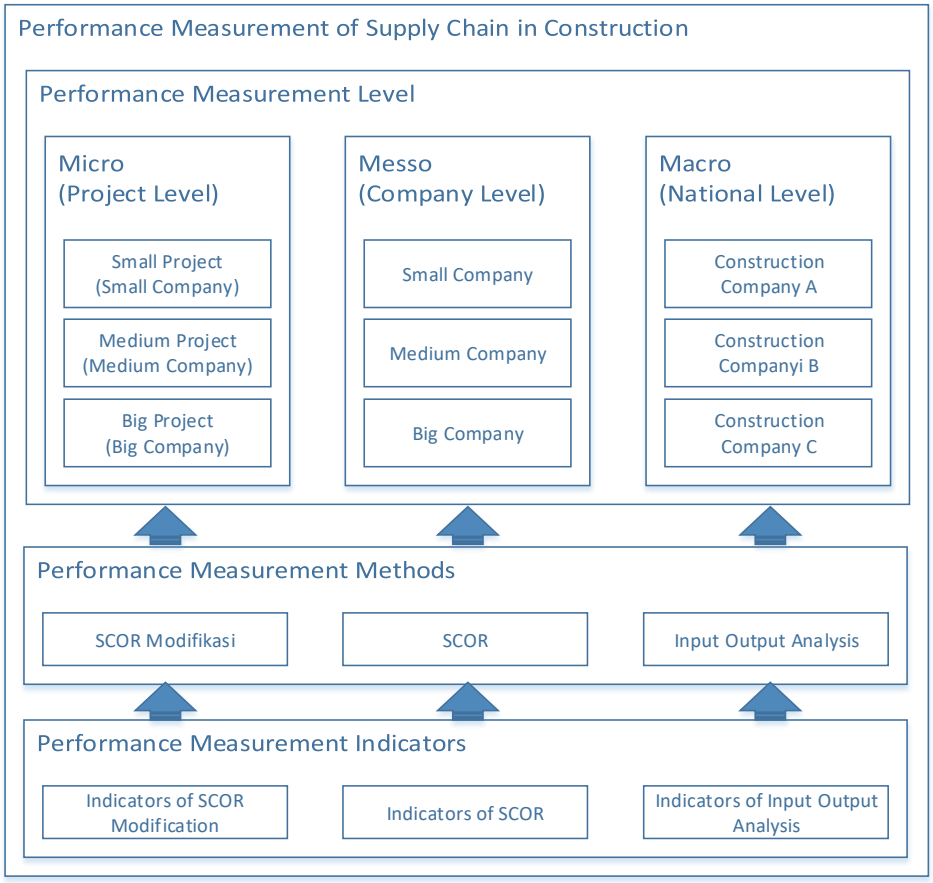

Figure 5. The Concept of Measuring the Construction Supply Chain Performance at Each Level (Micro, Meso, Macro)

Supply Chain Performance Measurement at the Micro Level (Intra-Organizational)

Supply chain construction at the micro-level is the principal basis in the flow. The strength at this phase is observed from the relationship between contractor and supplier, where performance measurement is analyzed, and also adopted from the SCOR model. In addition, a case study was conducted on an apartment project in Semarang. Furthermore, the concept of performance measurement framework is based on the work attributes of the SCOR model version 12.0.

Explanation of each performance attribute based on the Supply Chain Council [21], including:

- *Reliability*: the ability to complete tasks as expected. This focuses on the ability to predict the results of an activity. The metrics on reliability attributes include punctuality, quantity, and quality. In addition, the attribute measures delivery time, material quantity, and quality according to specifications in a construction project.
- *Responsiveness*: speed of performing supply chain tasks required to provide customers the desired products. This comprises the speed cycle time metrics for tasks performed.
- *Agility*: ability in responding to external influences and market changes to gain or maintain a competitive advantage. SCOR's agility metrics include flexibility and adaptability.
- *Costs*: operational costs of the supply chain process, including labor, material, management, and transportation. The typical cost metric covers the price of goods purchased.
- *Asset management efficiency (assets)*: The ability to utilize assets effectively and efficiently. Asset management strategies include inventory reduction and in-sourcing vs. outsourcing. Also, the metrics consist of inventory periods and capacity utilization.

Reliability, responsiveness, and agility are all focused on the customer. The costs and asset management efficiency (assets) are considered as an internal focus. In addition, all SCOR metrics are grouped under one performance attribute, where each possesses one or more levels or strategic metrics. This calculation is employed by organizations for performance evaluation in a competitive market space. The Key Performance Indicator (KPI) adopted while assessing the supply chain from SCOR, as captured in Table 2.

Based on Table 2, KPI from perfect order fulfillment to return on working capital is an indicator adopted from SCOR model 12.0. Additional indicators, including technology application and the supplier's activeness, were based on project questionnaires and validation. Performance indicators of information technology calculate its utilization by ready mix concrete suppliers in supporting supply chain activities. According to Simchi-Levi and Zhao [22], the purpose of information technology is to provide openness and availability of information, allow single data contact, formulate decisions based on overall supply chain details, and ensure enabling collaboration with supply chain peers.

The suppliers' activeness is an additional KPI criterion at the project as it becomes a reference in providing the best service to customers. According to Lu *et al*. [23], effective communication and supplier activity influences supply chain with customers. Also, the level of activeness is the initiative to request for and offer material needs, provide delivery information, and updates on new material types, as well as to generate feedback from contractors. These five (5) components are used as references in measuring supplier performance from an active point of view.

Table 2. Micro-level Supply Chain Performance Indicators

Performance type	KPI	Assessed Party
Reliability	Perfect order fulfillment	Contractors and suppliers
Responsiveness	Order fulfillment cycle time	Contractors and suppliers
Agility	Upside supply chain adaptability	Contractors and suppliers
	Downside supply chain adaptability	Contractors and suppliers
	Overall value at risk	Contractors and suppliers
Cost	Total supply chain management costs	Supplier
	Cost of goods sold	Supplier
Asset management efficiency	Cash-to-cash cycle time	Supplier
	Return on supply chain fixed assets	Supplier
	Return on working capital	Supplier
Additional indicators	Application of technology	Contractors and suppliers
	Supplier activity	Contractors and suppliers

DOI: 10.25077/josi.v19.n2.p101-110.2020

Supply Chain Performance Measurement at Meso Level (Inter-Organizational)

Meso level is an intermediate phase in the structure of the supply chain concept. This focuses on supply chains in construction companies and suppliers. However, the activity is more pronounced in contractors, with the role to serve as a middle-man between suppliers and project owners. Figure 6 illustrates the supply chains of the two companies in contrast. It represents the concept of measuring supply chain performance from two separate companies. The concept shows the connection between two construction companies with major concrete and steel material suppliers, with each linked to the raw materials dealer. Although the concrete and steel supplier relationship chain varies in the supplier company operations, it usually depends on the project location and is similar to the raw material. This condition is the difference between supply chains in construction and manufacturing, due to changing locations and supply partners [24]. Therefore, every construction company has its ability to manage its supply chain based on the project experience (micro-level) of the company.

The problems of changing project location greatly affect the supplier relationship as the source of the materials and tools required by the contractor to implement an innovation strategy. One key approach is to instigate framework contracts with suppliers. This is an agreement with the service provider or supplier by setting a unit price with terms and conditions for purchase transactions during the agreed period. However, the strategies implemented in the meso phase involves improving enterprise resource planning (ERP). This is an integrated and automated system required to manage business processes in companies regarding the more effective operation, production, and distribution to and from other companies [25].

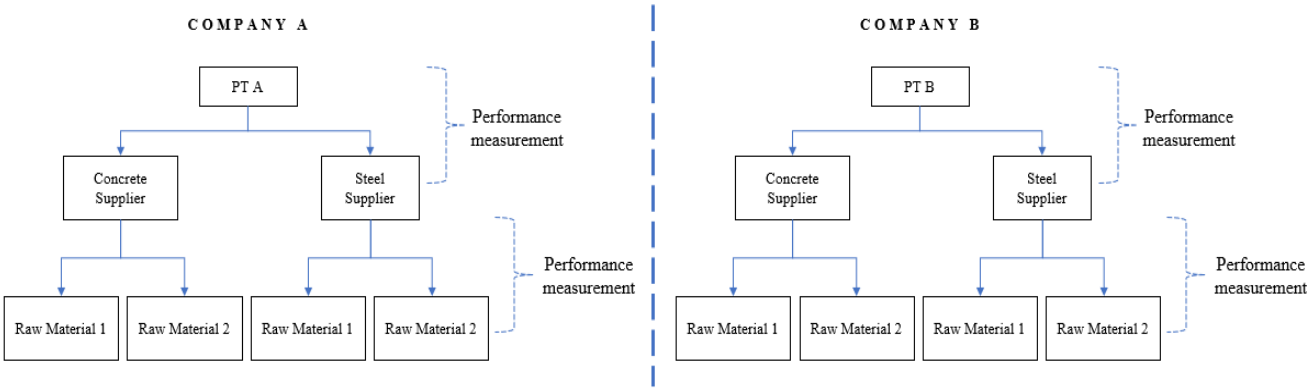

Figure 6. The Concept of Measuring Supply Chain Performance in the Company

Performance Measurement of Supply Chain at the Macro Level (Across Organizations)

The supply chain at macro phase extends to the top level in the hierarchy. This requires the integration of various parties, from performers in the field to the government, specifically assigned to the Ministry of Public Works and Housing, with an important role in the national supply chain for policymaking. This agency also has the power to formulate policies, by assembling suppliers and contractors to discuss the procurement of national construction materials. As a simple illustration, the macro-level refers to the accumulation of micro and meso supply chains.

The challenge faced by Indonesia in the material distribution is associated with the numerous islands, despite the even distribution of development. The current condition of the supply source remains centralized on Java Island. Hence, there is always a possibility of increased cost and time of material procurement due to the uneven material demand. The challenge to balance supply and demand per region is potentially resolved using an approach, to properly meet the material needs from the prepared supply.

Another problem encountered is the non-transparent supply and demand. Hence, the government needs to take sides with the national construction supply chain using instituted policies. The strategies adopted at this level requires the harmonization & collaboration of various parties involved. However, the national construction supply chain in Indonesia is faced with the challenge of how to connect the distribution of the material between islands [26]. For example, the price of cement in Java is very different from Papua. This basically makes sense as distribution costs are incurred, hence developing a means to minimize these variations is highly necessary.

The concept of inter-island supply chain integration is to be developed to improve national performance. The strategy adopted involves ensuring a good distribution pattern of construction materials and equipment, therefore enhancing the ease for contractors to procure materials. This concept needs to be supported by optimizing the main ports in Indonesia, as an infrastructure for the distribution of materials between islands. Therefore, the quality of the main ports outside Java Island has to be considered, and an effective strategy is also needed in material procurement. Subsequently, materials prone to price fluctuation are increased.

Example of Measuring Supply Chain Performance

This research focuses on the quantitative measurement of supply chain performance at micro level or a project scale. This includes a construction job involving samples of steel material, while the KPI used was perfect order fulfillment. In addition, the steel

ordering system in Project A as a case study was performed through a centralized framework contract between PT. X (Persero) Tbk, with the designated reinforcing steel supplier. Therefore, after an agreement on the unit price, a purchase order (PO) is required according to the needs in the field.

PT. K as one of the steel suppliers can accommodate the contractor's request with a total volume of 18,250 kg. This amount is possibly fulfilled as long as the delivery is timely, with the right quality and quantity of 17,450 kg. Under this circumstance, K is considered to demonstrate a fulfillment percentage of:

$$= \frac{The\ goods\ arrived\ perfectly}{Total\ order}\ x\ 100\%$$

$$= \frac{17.450\ Kg}{18.250\ Kg}\ x\ 100\%$$

= 95,62%

Perfect order fulfillment of 95.62 indicates 4.38% of the steel material is defective, damaged, or deficit of the specifications. This value is probably achieved by performing several tasks, including an improvement in communication with suppliers, using facilities, including telephone, email, and the WhatsApp application. Furthermore, quality control was also tightened by taking steel samples every delivery time for tensile and bending tests in the laboratory.

The second example is the indicators of order fulfillment cycle time. This refers to the time taken by a supplier to complete a delivery. As observed in project A, the following time was required to meet the steel needs:

- PT. X = 5 days
- PT. Y = 7 days
- PT. Z = 6 days

The average estimated time for 3 suppliers to deliver reinforcing steel to project A in Semarang was 6 days. These supplies were executed after the framework contract was created, and the purchase order (PO) was completed as well as legalized by PT. A, and forwarded to the supplier. There are several considerations made by project A team to achieve these values, including by overseeing the process, initiated by the administration, and followed by production as well as delivery. In addition, it is also necessary to improve communication and coordination between the project and the supplier logistics team.

The third example is the indicator of upside supply chain flexibility. This features the ability for reinforcing steel suppliers to be flexible on the days number required, particularly on instances where the contractors' request changes or is not planned. Based on project A, the time required by suppliers involved in meeting the steel needs to increase the volume include:

- PT. X = 14 days
- PT. Y = 16 days
- PT. Z = 18 days

The duration for steel shipments for Project A in Semarang is highly dependent on the supplier's production capacity, a number of expeditionary fleets, and road traffic conditions. Therefore, the time required for additional requests was stipulated at 16 days. Meanwhile, there is a need for several considerations before this value is achieved. This includes simplifying the administrative process if the addendum contract and overseeing the project to completion.

The three examples of measuring supply chain performance at the micro-level are possibly used as a reference during the assessment suppliers' performance quality in dealings with contractors. In addition, the contractors are expected to create a track record of suppliers used. This is to serve as a selection reference for future projects in nearby locations.

CONCLUSIONS

The supply chain in Indonesian construction is a very interesting study topic. This is because the country's geographic location is different from others, based on the presence of various islands, from Sabang to Merauke. The development projects in all regions require an even distribution of materials. However, numerous problems have been identified, which lead to an increase in implementation costs, delays, poor quality of work, and ultimately inefficiency in the overall project. These challenges are possibly initiated by inadequate supply chain management; hence the identification of performance indicators is necessary to help measure the suppliers' activities. Moreover, associated difficulties ought to be addressed immediately. In addition, the performance of the supply chain concept is possibly measured based on micro, meso, and macro levels, illustrated horizontally from left to right. Specifically, the micro phase is at the project level, and is directly carried out by the contractor.

This micro-level is possibly measured using an indicator from Supply Chain Operations Reference (SCOR). Furthermore, an example used in Project A, with KPI for perfect order fulfillment on steel material obtained a value of 95.62%. Moreover, the meso level is intermediate, comprising some innovations on the supply chain conducted by construction companies. These include framework contracts and Enterprises Resource Planning (ERP), estimated to be quite effective, and capable of reducing costs. In addition, the assessment involved comparing the supply chain performance of several companies. Meanwhile, the macro level is assumed to be more directed at joint operation in meeting the supply and demand for national construction materials. The governments' alignments in policy and harmonization between parties ought to be promoted for better output. Furthermore, it is essential to create regional divisions for fair distribution.

This research has created the concept of performance measurement at the micro meso and macro levels. However, it is possible to develop future research opportunities in more detail, especially at the meso and macro levels. This study used SCOR as a reference for the indicators adopted in construction.

DOI: 10.25077/josi.v19.n2.p101-110.2020

Therefore, there is need to explore more models, in order to obtain more complete concept at all levels.

ACKNOWLEDGEMENT

The authors are grateful to PT Pembangunan Perumahan and PT Adhi Karya as respondents in this study, as well as the Ministry of Public of Works and Housing, in the Sub-Directorate of Construction Materials and Equipment, Directorate of Construction Services Institutions and Resources for providing access to several projects within the ministry and the interactive discussions granted regarding this research.

REFERENCES

[1] P. S. Nugroho, "Peningkatan Produktivitas Konstruksi Melalui Pemilihan Metode Konstruksi," J. Ilm. Din. Rekayasa, vol. 8, no. 1, pp. 25–30, 2012. https://doi.org/10.20884/1.dr.2012.8.1.56.

[2] C. Sun, S. Jiang, M. J. Skibniewski, Q. Man, and L. Shen, "A literature review of the factors limiting the application of BIM in the construction industry," Technol. Econ. Dev. Econ., vol. 23, no. 5, pp. 764–779, 2017. https://doi.org/10.3846/20294913.2015.1087071.

[3] A. M. Alashwal, H. A. Rahman, and A. M. Beksin, "Knowledge sharing in a fragmented construction industry : On the hindsight," vol. 6, no. 7, pp. 1530–1536, 2011.

[4] I. N. Pujawan, Supply Chain Management. 2005.

[5] R. D. Broft and L. Koskela, "Supply chain management in construction from a production theory perspective," in 26th Annual Conference of the International Group for Lean Construction: Evolving Lean Construction-Towards Mature Production Across Cultures and Frontiers, 2018, pp. 271–281. https://doi.org/10.24928/2018/0538.

[6] P. Behera, R. Mohanty, and A. Prakash, "Understanding construction supply chain management," Prod. Plan. Control, vol. 26, no. 16, pp. 1332–1350, 2015. https://doi.org/10.1080/09537287.2015.1045953.

[7] M. K. Lim, M.-L. Tseng, K. H. Tan, and T. D. Bui, "Knowledge management in sustainable supply chain management: Improving performance through an interpretive structural modelling approach," J. Clean. Prod., vol. 162, pp. 806–816, 2017. https://doi.org/10.1016/j.jclepro.2017.06.056.

[8] M. A. Wibowo and R. Waluyo, "Knowledge management maturity in construction companies," Procedia Eng., vol. 125, pp. 89–94, 2015. https://doi.org/10.1016/j.proeng.2015.11.014.

[9] X. Xue, Y. Wang, Q. Shen, and X. Yu, "Coordination mechanisms for construction supply chain management in the Internet environment," Int. J. Proj. Manag., vol. 25, no. 2, pp. 150–157, 2007. https://doi.org/10.1016/j.ijproman.2006.09.006.

[10] M. N. Sholeh, Manajemen Rantai Pasok Konstruksi. Yogyakarta: Pustaka Pranala, 2020.

[11] S. Kaushik, "Material Supply Chain Practices in the Construction Industry," Int. Res. J. Eng. Technol., vol. 5, no. 7, pp. 543–554, 2018.

[12] R. Bhagwat and M. K. Sharma, "Performance measurement of supply chain management: A balanced scorecard approach," Comput. Ind. Eng., vol. 53, no. 1, pp. 43–62, 2007. https://doi.org/10.1016/j.cie.2007.04.001.

[13] F. Persson, "SCOR template - A simulation based dynamic supply chain analysis tool," Int. J. Prod. Econ., vol. 131, no. 1, pp. 288–294, 2011. https://doi.org/10.1016/j.ijpe.2010.09.029.

[14] P. Taylor, M. A. Sellitto, G. M. Pereira, M. Borchardt, R. Inácio, and C. V. Viegas, "A SCOR-based model for supply chain performance measurement: application in the footwear industry," Int. J. Prod. Res., vol. 53, no. 16, pp. 4917–4926, 2015. https://doi.org/10.1080/00207543.2015.1005251.

[15] M. Thunberg and F. Persson, "Using the SCOR model's performance measurements to improve construction logistics," Prod. Plan. Control, vol. 25, no. 13–14, pp. 1065–1078, 2014. https://doi.org/10.1080/09537287.2013.808836.

[16] M. A. Wibowo and M. N. Sholeh, "The analysis of supply chain performance measurement at construction project," Procedia Eng., vol. 125, pp. 25–31, 2015. https://doi.org/10.1016/j.proeng.2015.11.005.

[17] D. Luu and W. Sher, "Construction tender subcontract selection using case-based reasoning," Constr. Econ. Build., vol. 6, no. 2, pp. 32–43, 2006. https://doi.org/10.5130/AJCEB.v6i2.2982.

[18] Supply Chain Council, "Supply Chain Operations Reference Model," Supply Chain Oper. Manag., pp. 1–976, 2012.

[19] K. Lamba and S. P. Singh, "Big data in operations and supply chain management: current trends and future perspectives," Prod. Plan. Control, vol. 28, no. 11–12, pp. 877–890, 2017. https://doi.org/10.1080/09537287.2017.1336787.

[20] H. A. Rahardjo and H. Bermawi, "Strategi Pengelolaan Rantai Pasok Industri Konstruksi dalam Mendukung Pembangunan Infrastruktur Nasional," in Seminar Nasional Teknik Sipil V, 2015.

[21] APICS, Supply Chain Operations Reference (SCOR) Version 12.0. 2017.

[22] D. Simchi-Levi and Y. Zhao, "The value of information sharing in a two-stage supply chain with production capacity constraints," Nav. Res. Logist., vol. 50, no. 8, pp. 888–916, 2003. https://doi.org/10.1002/nav.10094.

[23] W. Lu, K. Ye, R. Flanagan, and C. Jewell, "Developing Construction Professional Services in the International Market: SWOT Analysis of China," J. Manag. Eng., vol. 29, no. 3, pp. 302–313, 2013. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000144.

[24] J. Gosling, D. R. Towill, M. M. Naim, and A. R. J. Dainty, "Principles for the design and operation of engineer-to-order supply chains in the construction sector," Prod. Plan. Control, vol. 26, no. 3, pp. 203–218, 2015.

[25] M. Misita, N. Lapcevic, and D. Tadic, "New model of enterprises resource planning implementation planning process in manufacturing enterprises," vol. 8, no. 5, pp. 1–15, 2016. https://doi.org/10.1177/1687814016646263

[26] M. N. Sholeh and M. A. Wibowo, "Aplikasi Rantai Pasok: Pengadaan Material Konstruksi Antar Pulau," Proceeding SENDI_U, pp. 978–979, 2015.

AUTHOR(S) BIOGRAPHY

Moh Nur Sholeh is a teaching staff at the Department of Civil and Planning, Vocational School, Diponegoro University. He earned a Bachelor Degree (B. Eng) and Master Degree (M. Eng) in Civil Engineering from Diponegoro University. His research areas are construction supply chain management and Building Information Modeling (BIM). (mohnursholeh@live.undip.ac.id)

Mochamad Agung Wibowo is a Professor in Construction Management at the Department of Civil Engineering - Faculty of Engineering - Diponegoro University. He earned a Bachelor Degree in Civil Engineering from Diponegoro University, Semarang, Master Degree in Management from Diponegoro

University, Semarang, Master Degree (M.Sc.) and Doctoral Degree (Ph.D.) in Construction Management, Civil Engineering from Nottingham University, UK. He is Dean of Faculty of Engineering, Diponegoro University. He has published journal and conference papers in Civil Engineering especially in Construction Management. His research interests are lean construction, sustainable construction, supply chain management in construction industry, risk management, quality of construction project, project management, knowledge management, higher education performance modeling, and engineering education. (agung.wibowo@ft.undip.ac.id)

Naniek Utami Handayani is an Assistant Professor in Industrial and Systems Engineering at the Department of Industrial Engineering - Faculty of Engineering - Diponegoro University. She earned a Bachelor Degree in Mathematics from Brawijaya University, Malang, Master Degree and Doctoral Degree in Industrial Engineering and Management from the Bandung Institute of Technology (ITB), Bandung. She is a member of the Institute of Supply Chain and Logistics Indonesia, Head of Optimization and Industrial System Design Laboratory, and Head of Quality Assurance Team of Faculty of Engineering, Diponegoro University. She has published journal and conference papers in Industrial Engineering. Her research interests are industrial clusters, SME's management, disaster logistics, performance measurement, quality systems, higher education performance modeling, and engineering education. (naniekh@ft.undip.ac.id)

 DOI: 10.25077/josi.v19.n2.p101-110.2020