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Integration of SCOR Model and AHP to Measure the Shipyard Supply Chain Performance: A Case Study

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Abstract: A shipyard is an industry engaged in the construction or repair of ships. A shipyard's ability to complete its production depends on the supply chain. Its suppliers supply all the equipment and materials needed for shipbuilding and maintenance. The shipbuilding sector's supply chain's performance level must be measured to determine how well the existing process flow works. The research was conducted at the PT Dock and a shipyard company in Maluku, Indonesia. The measurement integrates the SCOR and AHP models to determine the existing supply chain performance. The data are collected through questionnaires and from the company archives. The study's findings demonstrate how simple it is to integrate the SCOR model with AHP to assess the shipbuilding sector's supply chain performance. The research proposes 21 KPIs. Those KPIs are constructed from literature studies and interviews with the shipyard management. The one of the AHP findings in this study states that the most important phase in the shipbuilding industry's supply chain is planning.

Keywords: Analytical hierarchy process, collaboration, shipyard, supply chain operation reference, supply chain performance.

Introduction

The improvement in health conditions after the outbreak of the Coronavirus (Covid-19) has improved economic conditions. This condition is indicated by Indonesia's economic growth in 2022, which grew by 5.31 percent, higher than the achievement in 2021, which only experienced growth of 3.70 percent [1]. The shipbuilding industry has also experienced significant growth after the pandemic.

The supply chain that links a shipyard to its suppliers presents its biggest operational challenge [2]. Shipyard supply chains, in particular material procurement initiatives aimed at mitigating unforeseen business risks, are critical to shipyards' capacity to transfer materials [3]. The logistics network and suppliers they work with play a significant role in acquiring the materials required to construct or repair ships. Suppliers, who might be general agents, or direct manufacturers, are a crucial component in the supply chain for materials. Shipyards can make choices about ship component products needed during the ship production process based on the choice of many suppliers who offer their products [4]. To obtain components and materials at a reasonable price, of high quality, and can be delivered on time, the shipyard must be careful in choosing suppliers [5].

Initially, the supply chain was only seen as an extension of traditional contexts such as operations, purchasing, and logistics. Nonetheless, research on supply chain management has grown and covered a wide range of topics, including supplier relationships, supply chain network structures, collaboration within the supply chain, and information sharing procedures [9]–[11]. The foundation of supply chain management (SCM) is information systems. SCM encompasses manufacturing operations, connects with marketing and finance processes, and incorporates several other ideas like risk sharing, strategic resources, business process connectivity, and supplier participation in new product development [12].

The supply chain is a network of companies that work together to manufacture and deliver products to end users. These companies include suppliers, factories, distributors, shops, retailers, and supporting companies such as logistics service companies [13]. Many industries pay attention to supply chain management because of the awareness of the importance of creating integrated relationships with suppliers and customers [14]. Transportation is involved in the supply chain management process when moving goods from the point of origin to the client. Transportation can be essential in the supply chain since nearly every product is produced and

consumed in a different location. Furthermore, transportation contributes significantly to the cost of a supply chain's movement [15]. Additionally, to lessen the effects of environmental degradation, ecological aspects are integrated into the supply chain [16].

The structure of the material supply chain at the shipyard describes the network of parties related to the procurement of materials to the shipyard. As in other supply chain structures, there are three flows in the shipyard supply chain structure: material, money, and information. The material flow starts from the supplier after receiving the order letter from the shipyard. The money flows from the ship owner to the shipyard and then to the supplier as payment for purchased materials. Meanwhile, the flow of information occurs along the chain structure. The ship repair supply chain is a dynamic environment composed of collaborating firms specializing in manufacturing activities. Collaborative relationships with suppliers and developing a culture of trust can provide the same partnership benefits without any formal obligation—collaboration is successful based on mutual benefit rather than agreement [17].

It is currently critical to measure supply chain performance to determine the advantages and disadvantages of each supply chain process [18]. Regardless of strategy, product type, or scale of operation, supply chain performance will dictate a company's capacity to create customer value [19]. Several models and methods are available for evaluating the performance of supply chains, such as the Supply Chain Operation Reference (SCOR) model [23–25], big data analytics [22], hybrid fuzzy MCDM technique [21], and balanced scorecard [20]. A model known as SCOR clarifies, evaluates, communicates, and points out chances to boost workflow effectiveness [26]. The SCOR model was developed by the Supply Chain Council (SCC), a global non-profit consortium with methodologies, diagnostics, and benchmarking tools to help companies formulate rapid improvements in supply chain activities [27]. The SCOR model is a conceptual model developed as a cross-industry standard. Standardization aims to facilitate understanding the supply chain as a first step in obtaining adequate and efficient management to support corporate strategy [28]. The SCOR model is constructed on the entire supply chain process, which is mapped as interrelated flows from the highest level (strategic level) to the elemental level (nano-level) [29].

Achieving the best possible supply chain performance will yield multiple objective functions from the SCOR model. The task of selecting the appropriate objective function is complex. Analytical Hierarchy Process (AHP) is commonly employed to address this multipurpose condition [25] Some authors suggest applying AHP [30]–[32]. Utilizing the Analytic Hierarchy Process (AHP), decision-makers can identify the most critical variable and take action to affect the situation's outcome [33], [34].

The SCOR model has been used to measure supply chain performance in the shipyards industry [35]–[37], pangasius sp. Agroindustry supply chain [38], the global flight catering supply chain [29], or the automotive industry [23]. Meanwhile, the integration of the SCOR model with the AHP model has also been used in various studies [39]–[43]. The present study applies the SCOR model to AHP and examines shipyards in Maluku. While integrating the AHP and SCOR models has been done many times, it has never been used in shipbuilding facilities. The shipbuilding industry is a large one that involves several sectors. It has a complex job orientation, affects multiple industries, and is a highly competitive industry. It also requires many skilled workers and workspaces. This research is different from earlier investigations.

This study aims to measure the performance level of the shipbuilding industry supply chain with the SCOR and AHP models. Furthermore, this article is organized in the following order: research methods, results and discussion, and conclusions.

Methods

Research Locations

The study was carried out from January to April 2022 at the PT Dock and a shipyard company in Ambon. The Shipyard is not a shipbuilding facility; it can only perform ship repairs. The company occupies five hectares of land and uses a three-line docking system with a slipway capacity of 500 tons and airbags with a capacity of 1500 DWT. A supply chain underpins all the Shipyard's activities. This supply chain provides all the materials needed to repair ships and cargo support equipment.

SCOR Model

The SCOR model divides each organizational link in the chain into its constituent core processes—plan, source, make, deliver, and return. The scheduled task is associated with the shipyard's production planning procedure,

precisely the ship repair procedure. The supply of raw materials for ship repair and facilitating the connection between businesses and their suppliers are examples of source activities. Ships that have been repaired are examples of manufacturing processes that transform raw materials into completed goods. Deliver refers to returning the ship to the ship owner after it has been repaired, while return refers to the ship owner's complaints or returns if the ship has an issue.

The primary process at level 2 is divided into the following characteristics: Cost, efficiency, responsiveness, adaptability, and dependability. Furthermore, at level 3, attributes are described as key performance indicators. The shipyard industry business processes are shown in Table 1. The process is divided into three levels, namely core processes (level 1), attributes (level 2), and Key Performance Indicators (KPI) (level 3).

Questionnaires and company data are the two methods used to measure the performance of the shipyard supply chain. Five employees deemed knowledgeable about supply chain issues in the shipbuilding industry were among the chosen respondents to gather questionnaire responses. The five staff members comprise three production workers, a technical manager, and a senior production manager. These individuals are thought to understand the supply chain issues facing the shipbuilding industry, having worked in the field for at least five years. The Scores of KPIs collected through questionnaires were KPI_3 – KPI_6, KPI_10, KPI_13, KPI_14, KPI_17, KPI_19, and KPI_20. Respondents were asked for assessments regarding existing KPIs and provided ratings based on their work experience so far. Respondents' responses were in the form of ratings between 0 and 100, where a value of 0 indicated that the KPI's performance was terrible, and a value of 100 indicated that the KPI's performance was excellent. Other KPI assessments, namely KPI_1, KPI_2, KPI_7 – KPI_9, KPI_11, KPI_12, KPI_15, KPI_16, KPI_18, and KPI_21 is obtained from company data. Ratings are also given with a range of 0 to 100. A value of 0 is if the performance is far below the target, and a value of 100 is if the performance meets or exceeds the target set by the company.

Analytical Hierarchy Process

The structural hierarchy of the shipyard's performance is composed starting from level 0, namely the supply chain performance of the shipyard. Level 1 has five attributes, i.e., plan, source, make, deliver, and return is shown in Figure 1.

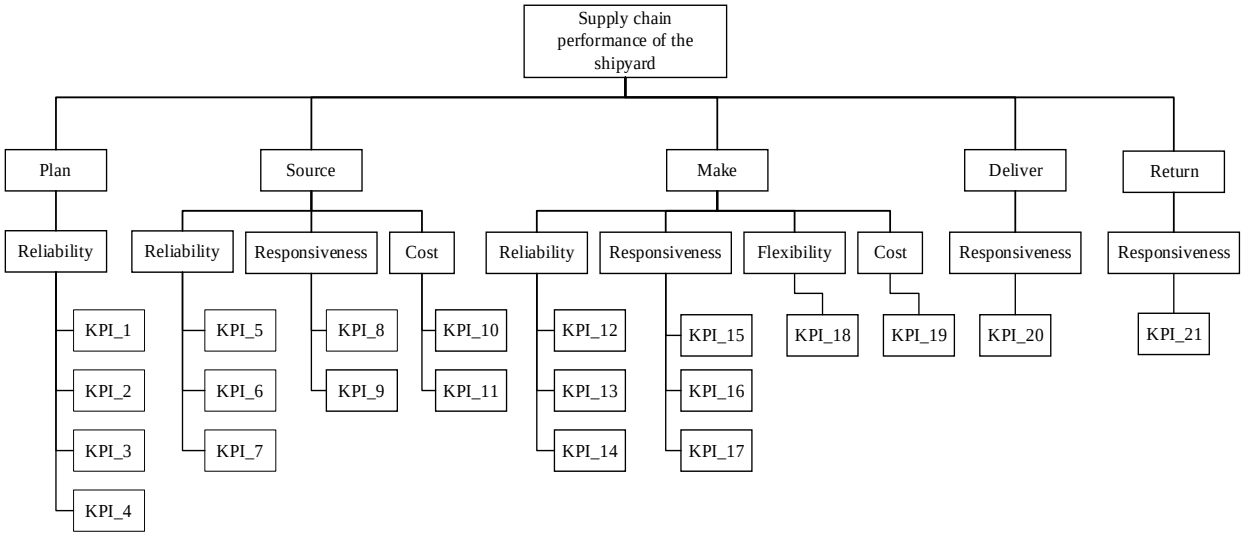

Figure 1. Structural hierarchy of supply chain performance of the shipyard

Validity and Reliability Test

A validity test is conducted to assess how accurate KPIs are at gauging supply chain performance. As the shipbuilding industry's supply chain's performance is being measured, the reliability test is utilized to ascertain whether the chosen KPI is consistent and dependable. Many staff members knowledgeable about supply chain problems are given questionnaires to complete to conduct the evaluation.

Results and Discussions

Production Process Flow

Process flow consists of three main stages: input, process, and output. Customers who wish to repair their ships receive orders during the input process. Individuals or businesses can be considered consumers. Next, the engineering, finance, materials, and inventory warehouse departments handle orders. The delivery procedure is currently in the output phase. The ship is returned to its owner once it has been repaired.

Validity and Reliability Test

Questionnaires containing KPIs (Table 1) were circulated to five respondents, namely company employees. The validity test was carried out by comparing the corrected item's total correlation value with the R value for N=5, df=5-2, and α=0.05. The results show that all KPIs have a corrected item total correlation value of more than 0.88, so it is concluded that all KPIs are valid and can be used for further testing.

Reliability testing was carried out using the Cronbach Alpha coefficient. The result shows that the Cronbach Alpha value of 0.983, indicates that the selected KPIs are very consistent.

Table 1. Core business process, Attribute, and the KPIs

Level 1	Level 2	Level 3 (KPI)		Source
Plan	Reliability	1.	Forecast accuracy of raw materials	[44]
		2.	Forecast accuracy of supporting materials	[44]
		3.	Communication with suppliers	Company
		4.	Supplier reliability	Company
Source	Reliability	5.	Delivery performance	[36]
		6.	Source lead time	[45]
		7.	Deviation material arrival schedule	[44]
	Responsiveness	8.	On-time delivery of raw materials	Company
		9.	On-time delivery quality	Company
	Cost	10.	Supplier costs for sending raw materials	Company
		11.	Cost of on-time delivery	Company
Make	Reliability	12.	Improved employee performance	Company
		13.	The initial process of ship repair	Company
		14.	Ship repair process	Company
	Responsiveness	15.	Efficiency in the use of raw materials	Company
		16.	Machine's efficiency	Company
		17.	Make employee reliability	[44]
	Flexibility	18.	Flexibility in the ship repair process	Company
	Cost	19.	Ship repair costs	Company
Deliver	Responsiveness	20.	Deliver Cycle Time	[45]
Return	Reliability	21.	Number of customer complaints	[44]

Analytical Hierarchy Process (AHP)

Pairwise Comparison Matrix and Consistency Test

We conducted pairwise comparisons on the core processes (level 1), attributes (level 2), and KPIs (level 3). The PT Dock and the shipping company's senior production manager completed the pairwise comparison questionnaire. This procedure is in line with the senior production manager's responsibilities, which make sure that everything runs smoothly during the ship repair process, the necessary supplies are on hand, and all machining equipment is kept in good working order. We employed Super Decision Software for the decision analysis. Table 2 shows the pairwise comparison matrix of plan, source, make, deliver, and return components. Additionally, Table 3 and Table 4 show the pairwise comparison matrix for the attributes and KPI's respectively.

Table 2. Results of pairwise comparison matrix of core process

Participant	Plan	Source	Make	Deliver	Return	CI	CR (CI/1.12)
1	0.3002	0.2488	0.1312	0.2273	0.0925	0.0478	0.0427

The Consistency Ratio (CR) is 0.0427; since it is less than 0.1, we can conclude that the comparison between the core processes is consistent.

Table 3. Results of pairwise comparison matrix of the attribute

Core process	Attribute	Weight	CI	CR
Plan	Reliability	1.0000		
Source	Reliability	0.6370	0.03703	0.063845
	Responsiveness	0.2583		
	Cost	0.1047		
Make	Reliability	0.5024	0.04971	0.055233
	Responsiveness	0.1538		
	Flexibility	0.2265		
	Cost	0.1173		
Deliver	Responsiveness	1.0000		
Return	Reliability	1.0000		

Table 4. Results of pairwise comparison matrix of the KPIs

Attribute	KPI	Weight	CI	CR
Reliability	KPI_1	0.46234	0.03044	0.0338
	KPI_2	0.20488		
	KPI_3	0.18838		
	KPI_4	0.14440		
Reliability	KPI_5	0.44343	0.01759	0.0303
	KPI_6	0.16920		
	KPI_7	0.38737		
Reliability	KPI_12	0.25992	0.05156	0.0889
	KPI_13	0.41260		
	KPI_14	0.32748		
Responsiveness	KPI_15	0.44343	0.01759	0.0303
	KPI_16	0.38737		
	KPI_17	0.16920		

Table 3 and Table 4 show that the Consistency Ratio (CR) is smaller than 0.1, so it is concluded that the results of the comparison are consistent.

Weighted Matrix

The weights for each core process, attribute, and KPIs are compiled using the pairwise comparison matrix (see Table 5).

Table 5. KPIs weighting

Level 1	Weight	Level 2	Weight	Level 3	Weight
Plan	0.3002	Reliability	1.0000	KPI_1	0.46234
				KPI_2	0.20488
				KPI_3	0.18838
				KPI_4	0.14440
Source	0.2488	Reliability	0.6370	KPI_5	0.44343
				KPI_6	0.16920
				KPI_7	0.38737
		Responsiveness	0.2583	KPI_8	0.25000
				KPI_9	0.75000
		Cost	0.1047	KPI_10	0.25000
				KPI_11	0.75000
Make	0.1312	Reliability	0.5024	KPI_12	0.25992
				KPI_13	0.41260
				KPI_14	0.32748
		Responsiveness	0.1538	KPI_15	0.44343
				KPI_16	0.38737
				KPI_17	0.16920
		Flexibility	0.2265	KPI_18	1.0000
		Cost	0.1173	KPI_19	1.0000
Deliver	0.2273	Responsiveness	1.0000	KPI_20	1.0000
Return	0.0925	Reliability	1.0000	KPI_21	1.0000

Supply Chain Operation Reference (SCOR)

Two methods are used in the SCOR model to acquire data: distributing surveys and gathering information about the firm. KPI_1 is derived from corporate information. Table 6 displays the KPI_1 measurement result. The accuracy of the forecast is evaluated by comparing the requirements. The average value obtained is used to determine the score.

Table 6. Score calculation for KPI_1

Main Material	Requirement	Provided	Forecast accuracy
Marine plate (sheet)	10	15	67%
Shaft material (pcs)	2	10	20%
Paint (pail)	10	11	91%
Main/Auxiliary engine (set)	2	2	100%
Pump (set)	5	5	100%
Pipe (staff)	10	10	100%
Valves (pcs)	5	5	100%
Navigation equipments (set)	5	5	100%
Life safety equipment at sea (set)	10	10	100%
	Average		86%

KPI_2 measures supply of supporting materials's level in the company. KPI_2 is obtained from company data (see Table 7).

Table 7. Score calculation for KPI_2

Supporting material	Requirement	Provided	Forecast accuracy
Welding electrode (kg)	100	150	67%
Oxygen gas (tubes)	100	200	50%
LPG (tubes)	100	150	67%
Paint/chalk (litre)	2	10	20%
	Average		51%

KPI_3 and KPI_4 obtained from the results of the questionnaires given to 5 employees of PT Dock and the shipyard company (see Tables 8 and Table 9)

Table 8. Score calculation for KPI_3

Resp.	Communication	Cooperation	Work environment	Average
1	80	100	60	80.0
2	60	100	60	73.3
3	80	20	100	66.7
4	100	80	60	80.0
5	40	80	100	73.3
		Average		75

Table 9. Score calculation for KPI_4

Resp.	Education	Internal Motivation	Work Discipline	Attitude and work ethic	Skill	Average
1	80	60	100	60	100	80.0
2	80	40	60	80	80	68.0
3	60	40	80	100	100	76.0
4	80	60	60	80	100	76.0
5	60	80	40	100	100	76.0
			Average			75

Table 10 displays an overview of the SCOR score. Once the KPI score for each attribute is multiplied by the KPI weight, the attribute score is the total of the results. One can determine the final attribute score by multiplying the attributes by weight. The exact computation is calculated to get the process score. Combining the outcomes of all the processes yields the final SCOR score.

Table 10. The final score of SCOR

Process	Attribute	KPI	KPI's Weighting	Score	Weight* KPI Score	Attribute score	Attribute Weighting	Weight* Attribut score	Process score	Process Weight	Weight* Process score
Plan	Reliability	KPI_1	0.46234	86	39.7612	75.169	1.0000	75.17	75.17	0.3002	22.5634
		KPI_2	0.20488	51	10.4489						
		KPI_3	0.18838	75	14.1285						
		KPI_4	0.14440	75	10.8300						
Source	Reliability	KPI_5	0.44343	70	31.0401	81.621	0.6370	51.99	87.77	0.2488	21.8387
		KPI_6	0.16920	70	11.8440						
		KPI_7	0.38737	100	38.7370						
	Responsiveness	KPI_8	0.25000	100	25.0000	100.000	0.2583	25.83			
		KPI_9	0.75000	100	75.0000						
	Cost	KPI_10	0.25000	80	20.0000	95.0000	0.1047	9.95			
		KPI_11	0.75000	100	75.0000						
Make	Reliability	KPI_12	0.25992	70	18.1944	92.202	0.5024	46.32	94.95	0.1312	12.4563
		KPI_13	0.41260	100	41.2600						
		KPI_14	0.32748	100	32.7480						
	Responsiveness	KPI_15	0.44343	91	40.3521	92.625	0.1538	14.24			
		KPI_16	0.38737	100	38.7370						
		KPI_17	0.16920	80	13.5360						
	Flexibility	KPI_18	1	100	100	100	0.2265	22.65			
	Cost	KPI_19	1	100	100	100	0.1173	11.73			
Deliver	Responsiveness	KPI_20	1	100	100	100	1.0000	100.00	100.00	0.2273	22.7280
Return	Reliability	KPI_21	1	100	100	100	1.0000	100.00	100.00	0.0925	9.2540
										SCOR	**88.8404**

Discussion

This study found the supply chain performance of PT Dock and the shipyard company is 88.8404. This value is in the range of 70 – 90, which is in the excellent category [24]. AHP can be easily applied to the SCOR model to obtain weights of core processes, attributes, and KPIs.

One weighting technique frequently combined with other models to speed up the process of making decisions involving a variety of attributes and criteria is the Analytic Hierarchy Process (AHP). Flood risk can be evaluated by integrating AHP with Grey-Dematel [46] or TOPSIS [47], and renewable energy priority can be evaluated using VIKOR [48] or Delphi [49].

Several researchers have also carried out AHP integration with the SCOR model before[42], [43], [50]. This study proves that AHP can be integrated into the SCOR model to assess the performance of the shipbuilding industry supply chain.

This study differs from several other earlier investigations. By adding a quality criterion to the SCOR model, research [37] focuses more on ranking suppliers according to their performance. The pairwise comparison findings showed that quality was the most essential aspect, and agility was the least important. Researchers [36] use the conventional shipbuilding industry as their study subject, dividing the supply chain performance into internal and external supply chain performance. This procedure is not done in the current research because the focus of this research is only on external suppliers who support the ship repair process in the company.

Managerial Implication

The research's managerial implications include the ease with which any industry can integrate the SCOR model with AHP. The organization's management team can more easily identify the standards and KPIs crucial to enhancing the performance of the supply chain thanks to this integration. With this understanding, the management team can concentrate on achieving these KPIs and Criteria while promoting higher value for other KPIs and Criteria.

Conclusion

The study demonstrates how simple it is to integrate the SCOR model with AHP to assess the supply chain performance of the shipping sector. We suggest 21 KPIs to measure the supply chain performance for the shipping building industry. Those measurements are implemented at PT Dock and a shipbuilding company in Maluku, as the result the supply chain performance of PT Dock and the shipbuilding firm is 88.8404. In this

study we limited to a single shipyard in which the main business is only repairing ships and not constructing new ships. Subsequent investigations will broaden this analysis to encompass bigger shipbuilding facilities capable of building new vessels.

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