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Implementing the Theory of Constraint to Optimize the Marine Transportation System Productivity: A Case Study of Company 'X'

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Abstract: Sea transport cost is one of prominent components in terms of macro and micro economy. It has also a huge impact on global economic growth and business competitiveness. Many researchers have been involving to define new methods in order to gain the productivity and efficiency of marine transportation system. However, several researches merely focus on local optimum solution, short-term orientation and incomprehensive integration of strategic variables and operational aspects. Therefore, in order to accommodate those criteria into a new system, we should take into account all factors which influence on the whole of marine transportation system. Theory of Constraint (TOC) is a multi-faceted methodology that views the system as a series of processes or events that are interconnected. Even though it has been widely used in manufacturing sector, the application of TOC in the marine transportation system is still limited. This research aims to implement the concept of TOC to develop new tools and methods to resolve the issue of marine transportation as well as to formulate a good strategy at the level of strategic, operational and tactical in order to improve the performance of marine transportation system. The study is conducted at PT.X as one of the providers of sea transport services. Three scenarios are applied to analyse the changing of performance for each constraint when the capacity constraint will be increased by 50, 100 and 150%, respectively. As a result of the Investment Efficiency Ratio, the greatest impact derived from investment activities was obtained from elevation constraint of jetty, the second largest ratios is the elevation constraint of onshore pump capacity and the last is port draft constraint.

Key words: Ratio, efficiency, develop, sector, jetty

INTRODUCTION

Sea transport cost is one of prominent components in terms of macro and micro economy. From the macro perspective, increasing sea transport cost by 10% could affect the decreasing in the global trade volume by 20% (Limao and Venables, 2001). Moreover, it could also influence on declining of export and domestic product growth in one country (Radelet and Sachs, 1998). From the micro point of view, sea transport cost could impress on creating the product price which would stipulate on the business competitiveness in the company.

Regarding a huge impact on sea transport cost towards global economic growth and business competitiveness, many researchers have been involving to define new methods in order to gain the productivity and efficiency of marine transportation system. However, several researches merely focus on local optimum solution, short-term orientation and incomprehensive integration of strategic variables and operational aspects on the marine transportation system. Therefore, in order to accommodate those criteria into a new system, we should take into account all factors, which affect on the whole of marine transportation system.

According to Mabin and Balderstone (2003), one of the multi-faceted methods that could analyze the organization problems as well as could provide its solutions was called Theory Of Constraint (TOC). TOC itself has a role that performance on the system could be limited by a constraint. By improving the constraint performance would directly influence on the entire system outcomes. Hence, improving performance based on the TOC could be focused on identifying and managing constraint of the system.

In addition, TOC framework that provides guidance to manipulate the system and improve the system capacity is expected to be utilized in the marine transportation system to produce optimal solutions in both the short and long term. Lastly, TOC which provides the stages to define the global performance measures expected to be utilized in the marine transportation system to align with performance improvement at the operational

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level to the strategic. Overall, TOC could be fitted to solve organization problems by providing global optimum solution not only in short term but also in long term, which is also in line with strategic and operational solution.

Research question: Generally, the objectives of this study can be described as follows:

- To develop new tools and methods to resolve the issue of marine transportation with TOC
- To improve the productivity and efficiency of the marine transportation system by applying the concept of TOC into the system

Therefore, in order to identify the problems properly, two research questions are formulated as follows:

- How big is the marine transportation system constraints must be addressed so that the performance of the system can be optimal?
- How big is the impact on the improvement based on TOC to increase the cost efficiency of marine transportation system?

Literature review: Several studies have been conducted to identify some of the factors affecting the shipping cost. Micco and Perez identified factors that affected the shipping cost by using >300,000 annual data on shipments at some ports in the world. The results showed that by increasing the distance of 100% can have an impact onincreasing shipping cost by 20%. Furthermore, Micro and Peres also explained that the quality of port infrastructure had positive influence on the efficiency of shipping cost. It reinforced the previous research that stated the country, which has managed to improve the ranking quality of its port infrastructure from percentile 75-25, would be able to reduce shipping costs from 30-50%.

On the other hand, Chronic and Psaraftis have tested whether there was any link between ship size and shipping cost. They referred to the concept of economies of size which was measured by comparing the earnings units and unit costs for several different ship sizes. Based on their results, the empirical data did not support the hypothesis that the unit cost for operating a vessel would decrease by increasing the ship size simultaneously. In addition, the indicators of total shipping cost per TEU.mile also declined in line with the increasing in ship size. Beside the ship size, another variable was tested by Chronic and Psaraftis was vessel speed. The results showed that the greater ship speed, the lower unit cost per TEU.mile. In this case, the results of Gkonis and Psaraftis aligned with Cullinane and Khanna which indicated that the faster boats can be more economical for better utilization (Cullinane and Mahim, 2000). Moreover, Chronic and Psaraftis further clarified the effect of port time on the shipping cost. The results showed that the shipping cost can be optimized if some activities and infrastructures in ports should be optimized or developed with the aim to shortening the port time. Furthermore, Gkonis and Psaraftis explained that port time depends on the cargo volume, availability and utilization rate of loading and unloading equipment, inefficient port duration due to congestion and port service time.

According to Micco and Chronic, port efficiency is closely related to shipping cost. The higher port efficiency, the lower shipping cost. Therefore, some specialized studies have been conducted to identify the factors that affect port efficiency. Tongzon identified several factors that affect port efficiency by using factor analysis and linear regression. The results showed that port efficiency was affected by a delay or congestion, the utilization rate of loading and unloading equipment, the ship size, the cargo volume and the mixed-cargo (Tongzon and Ganesalingam, 1994).

The Theory of Constraint (TOC) is a management philosophy that has been used to improve system performance. Application TOC were initially widely applied in manufacturing industries. In manufacturing, the application TOC has reaped many successes. Having been applied successfully in manufacturing, the concept of TOC started to be adopted, modified and applied in the services sector. Siha (1999) focused on translating some of the vocabulary contained in the TOC to be used in the service industry. According Siha, inventory vocabulary commonly found in manufacturing can be translated in the service as a service that has not been utilized.

MATERIALS AND METHODS

The methodology used in this study is revealed in order to answer the question of how the business strategy necessary to achieve company goals. Every company, whether engaged in services and non-services, in conducting business activities require a strategy that would put the company in the best position, able to compete and continue to grow by optimizing all potential resources owned. Therefore, in this study, the Theory of Constraint (TOC) is selected as a tool to formulate strategies to achieve the company's objectives in the field of marine transportation system particularly. TOC is chosen because: provide a global performance measures at the level of strategic, tactical and operational; look at the system as a whole process and interrelated components and provide a framework to formulate measures of short-term tactical and long-term strategy.

This study focused on applying the concept of TOC in the marine transportation system. The purpose of TOC's application is to formulate a good strategy at the level of strategic, operational and tactical in order to improve the performance of marine transportation system. TOC selected as the main guideline and framework to enhance the performance of marine transportation system by the following considerations:

The marine transportation system consists of several components that are interconnected. The marine transportation system has at least one constraint that limits the system to improve its performance, especially with regard to the achievement of the objectives of the system.

Most efforts to improve the performance of the system is performed during sea transport is more focused on local optimum. Therefore, TOC offers new ideas related to system performance where the purpose of the improvement is to find a global optimum solution.

TOC provides performance measurement on the operational level that is consistent with the purpose of the overall system. Measures such as Throughput, Inventory, or Operational Expense can be adopted and modified the marine transportation system. Efforts to tackle constraints on sea transport system can be directed to increase throughput, decrease inventory or lowering operational expense which in turn could support the achievement of the overall system.

In general, the characteristics of the marine transportation system approach is close to a system that is contained in the logistics area. Therefore, in this study, the improvement plan of the Process of Ongoing Improvement (POOGI) will be adopted and implemented to improve the performance of marine transportation system. POOGI will be combined with several methods such as literature, case studies and simulations to determine the main characteristics of the marine transportation system.

Due to the limited methods of ICT implementation in the marine transportation system, this study also aimed to find, adopt, modify or build a new method that can be used to translate the stages that are common in the TOC in the marine transportation system. To determine the applicability of the TOC-based methods will be developed, in this study the method will be applied to draft improvement plan in one of the companies that provide marine transportation services. By applying this method into the case study is expected to answer the applicability of TOC in the marine transportation services and the efficacy of the TOC-based methods to improve the productivity and efficiency of marine transportation system. The solutions will be proposed to improve theperformance of marine transportation system that will be formulated on three levels, namely the strategic plan, tactical plan and operational plan as presented in Table 1. Based on the above solution framework, the analysiswill be constructed into three scenarios as follows:

Table 1: Solution framework

Levels	Performance measurement	Tools
Strategic	Net profit	TOC as a tool to bridge the gap between strategic and operational level
	NPV	
	IRR	
	Cost-benefit ratio	
	Throughput	
Operational	Operational expense	
	Productivity ratio	
	Inventory	

- Scenario-1 : when the capacity constraint will be
- Scenario-2 : when the capacity constraint will be
- Scenario-3 : when the capacity constraint will be

Each scenario will be compared between the real data and the simulated calculation results. Afterwards, investment efficiency ratio is computed to select the scenario that has optimum solution in order to improve the performance of marine transportation system. It will be determined by dividing the difference between the amount of money invested to improve system performance and the cost reduction in marine transportation system.

RESULTS AND DISCUSSION

In this research, the transportation system used as a case study is the energy transportation organized by state-owned company engaged in the business of oil and gas as well as other related business activities including the transportation, namely PT.X. The volume of cargo carried by PT.X in the period of 2008-2013 was 71.3 million kilo Litre (kL)/year in average. The largest volume carried was in 2013 which reached approximately 91.92 million KL. Furthermore, the cargo volume was dominated by product oil, especially white oil (Fig. 1).

Generally, the type of cargo transported by PT.X is divided into two major groups, namely oil product and crude oil. The cargo volume in general has an increasing trend, associated with the transport portion. However, the proportion of oil product volume has been declining

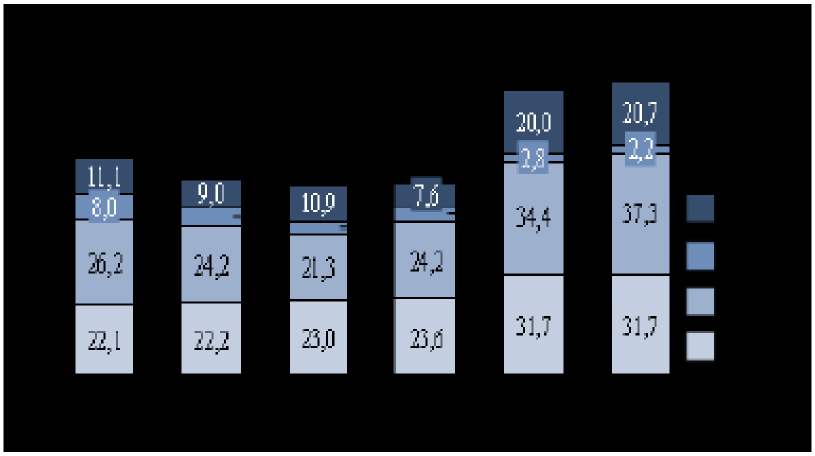

Fig. 1: Volume of Cargo

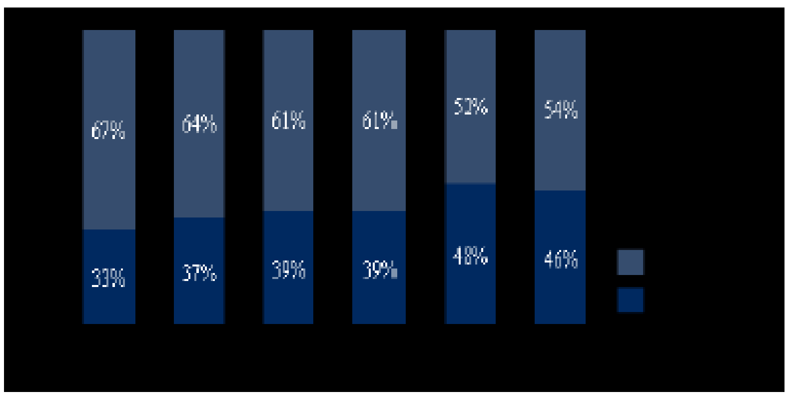

Fig. 2: Composition of cargo

from 67% in 2008 to 54% in 2013. On the other hand, the proportion of crude oil volume has been growing from 33% in 2008 to 46% in 2013 (Fig. 2).

In 2013, PT.X operated 186 ship which included three owned ships and 133 chartered ships. Type of ship operated by PT.X might vary from the type and capacity such as small tanker, Very Large Crude Carrier (VLCC), Very Large Gas Carrier (VLGC), etc.

Define the system's goal of TOC: Basically, the goal of the system of marine transportation services can be seen from several perspectives. From the aspect of quality, marine freight service system is expected to meet the transport demand in a timely manner, in the right amount and in the right quality. This can be interpreted as an attempt to keep the services provided to meet basic standards set forth such as delivery on time, right quantity, quality products and so forth.

From another aspect, the marine transport services is expected to maximize the performance based on existing resources, i.e., to optimize transport productivity. Because the quality of service is something that beyond of the scope, so this study will be focused on achieving the goals that can be measured directly. The basic assumption is built to optimize the marine transport performance based on limited resources by improving the service quality. Based on that, the goal of the existing marine transportation system in this research is to maximize the marine transportation productivity.

Define the performance measurement of TOC: At this stage will be conducted the determination of some performance measures of marine transportation systems. As described, TOC provides a measurement of global performance at the operational and strategic level. Thus, the layers of TOC's performance measures are in harmony with each other, so achieving the goal at the lowest level can support the achievement of strategic performance. Based on that in this study will be determined performance measurement for the operational and strategic level as follow:

Table 2: Plotting dominant factors that influence the marine transport productivity

Factors	Effect size related	Sources
Congestion	-0.72	Jetty capacity
Pumping	-0.23	Cargo pump capacity
Load factor	0.08	Port draft

- Operational performance: throughput, inventory, operating expenses and productivity
- Strategic performance: net profit, net present value and return on investment

Identify the constraints of system: In order to identify the constraints that exist in the marine transportation system, we implement the concept of TOC, thus, we could also determine the impact of anysuch constraint on the efficiency of the system. By usingsimulation method combined with statistical tests based on linear regression, we create a model of ship's arrival, a model of ship turnaround time and Cost-Utilization Diagram. As a result, we obtain the dominant factors in marine transportation that influence the marine transport productivity are congestion, pumping and load factor (Table 2). Effect size depicts how big the correlation between each factor and productivity. The lower this value, the lower its productivity. For instance, increasing one unit of congestion will decline the productivity by 0.72 unit.

After formulating the dominant factors that affect the marine transport productivity, thus by applying cost-utilization diagram, we identify the related sources for each factor. The results are jetty capacity, cargo pump capacity and port draft. These three related sources are identified as constraints.

Elevate the constraint of TOC: In order to determine the impact of each constraint to the performance of marine transportation system, we analyse the change of each constraint by dividing into three scenarios. Therefore, we could obtain the best scenario for the optimum expansion of each constraint.

Expansion of jetty constraint: Without considering the transport demand growth, the most optimal expansion scenario of jetty constraint is adding the number of jetty to be three units. Hence, the operating expenses for such scenarios is 64 billion rupiah. Meanwhile, the productivity ratio for this scenario is 0.0159 and inventory for the scenario is 1,583,540 kL/day.

On the other hand, by considering the transport demand growth, the result of the operational impact on the expansion of jetty activities on marine transportation system show on Table 3. When the jetty capacity increases of 150% which has five units of jetty will provide the lowest value operating expense and the highest value of productivity ratio greatest. Nevertheless, this scenario development has the highest total inventory. However, in terms of inventory, the lowest value is obtained when the expansion activities of jetty constraint is carried out by 50% of the initial capacity which are three units.

The comparison between performance measures and jetty constraint expansion scenarios in terms of the strategic aspect can be seen in Table 4. It shows that the highest value can be achieved by scenario 3 (increasing 150% of capacity constraint) in terms of NPV cash flow. However, in terms of IRR and benefit-cost ratio, the best scenario is expansion the jetty capacity by 50%.

Expansion of port draft constraint: As shown in Table 5, if we do not consider the growth in marine transport demand, the most optimal expansion scenario of jetty and port draft constraint from operating expense and productivity ratio point of view is adding 1 unit of jetty and dredging the port draft by 6 m. In terms of inventory, the most optimal solution is without jetty expansion, however, it should be expansion on port draft by 6 m.

The concept of benefit from the port draft expansion on the strategic layer is defined as the difference between a reduction of the ship cargo that does not utilize and the additional investment costs and operating costs of dredging activity (Table 6).

It can be concluded, if PT.X does not have elevation constraint on the jetty and port draft, so PT.X will not earn net benefit. However, if the PT.X has a little effort of elevation constraint on the jetty, so the highest net profit is obtained when the jetty was developed into five units. In this condition, PT. X will acquire net benefit of IDR 2.6 billion. Lastly, if the PT.X has elevation constraint on the jetty and port draft, so the optimum net profit would be obtained when PT.X has developed a jetty into 3 units and has performed dredging into 6 m of port draft.

Expansion of cargo pumping capacity constraint: We repeat the benefit operational evaluation for the onshore cargo pump expansion activities. Indicators used to measure the impact of operations are throughput, operating expense, productivity ratio and inventory. For jetty and port draft expansion activities, total throughput for a period of time has not changed despite the increased capacity of the onshore cargo pump. It is because the throughput is determined by the transport of energy

Table 3: The result of operational impact on increasing jetty capacity with considering demand growth

Scenarios	Description	Performance measures	Total	Unit
Existing	Initial capacity constraint	Throughput	75,020,206,956	L
		Operating expense	188,957,684,600	IDR
		Productivity ratio	0.0148	L/(IDR)
		Inventory	2,526,529	kL.day
Scenario 1	Increasing capacity constraint by 50%	Throughput	75,020,206,956	L
		Operating expense	173,802,799,729	IDR
		Productivity ratio	0.0162	L/(IDR)
		Inventory	1,417,160	kL.day
Scenario 2	Increasing capacity constraint by 50%	Throughput	75,020,206,956	Liter
		Operating expense	161,904,605,734	IDR
		Productivity ratio	0.0174	L/(IDR)
Scenario 3	Increasing capacity constraint by 50%	Inventory	1,782,064	kL.day
		Throughput	75,020,206,956	L
		Operating expense	153,079,257,149	IDR
		Productivity ratio	0.0183	L/(IDR)
		Inventory	2,245,545	kL.day

Table 4: Strategic performance measures of jetty expansion

Performance measures	Scenario 1 (increasing 50% of capacity constraint)	Scenario 2 (increasing 100% of capacity constraint)	Scenario 3 (increasing 150% of capacity constraint)
NPV cash flow (IDR)	95,932,582,963	157,952,308,056	190,395,349,278
IRR	41%	29%	21%
Benefit/Cost ratio	5.9	5.4	4.9

Table 5: The result of operational impact on increasing jetty capacity and port draft

Performance measures	Jetty draft	Without port draft expe	Port draft (5 m)	Port draft (5.5 m)	Port draft (6 m)
Throughput (L)	Without jetty expansion	1,026,602,448			
	Adding 1 unit jetty				
	Adding 2 unit jetty				
	Adding 3 unit jetty				
Operating expense (IDR)	Without jetty expansion	69,492,361,345	65,747,987,388	65,116,280,384	64,562,353,283
	Adding 1 unit jetty	64,378,970,945	60,994,284,478	60,722,264,964	60,528,025,353
	Adding 2 unit jetty	65,873,219,692	62,799,940,516	62,839,328,292	62,956,495,971
	Adding 3 unit jetty	68,673,219,692	65,911,347,806	66,262,142,872	66,690,717,841
Productivity ratio (L/(IDR))	Without jetty expansion	0.0148	0.0156	0.0158	0.0159
	Adding 1 unit jetty	0.0159	0.0168	0.0169	0.017
	Adding 2 unit jetty	0.0156	0.0163	0.0163	0.0163
	Adding 3 unit jetty	0.0149	0.0156	0.0155	0.0154
Inventory (kL.Hari)	Without jetty expansion	1,291,600	1,182,777	1,152,384	1,123,950
	Adding 1 unit jetty	1,583,540	1,474,717	1,444,323	1,415,890
	Adding 2 unit jetty	2,266,158	2,157,335	2,126,941	2,098,508
	Adding 3 unit jetty	2,992,184	2,883,361	2,852,968	2,824,534

Table 6: Strategic performance measures of jetty and port draft expansion

Scenario	Performance measument	Without port draft expension	Port draft (5 m)	Port draft (5.5 m)	Port draft (6 m)
Initial jetty capacity	Net profit (IDR)	-	3,744,373,957	4,376,080,960	4,930,008,062
	Cost benefit ratio	-	7.52	4.81	3.86
Increasing capacity constraint by 50%	Net profit (IDR)	5,113,390,400	8,498,076,867	8,770,096,380	8,964,335,992
	Cost benefit ratio	4.20	4.35	3.53	3.04
Increasing capacity constraint by 100%	Net profit (IDR)	4,219,141,652	7,292,420,829	7,253,033,053	7,135,865,374
	Cost benefit ratio	2.32	2.64	2.27	2.03
Increasing capacity constraint by 150%	Net profit (IDR)	2,619,141,652	5,381,013,539	5,030,218,473	4,601,643,504
	Cost benefit ratio	1.55	1.85	1.64	1.49

demand contained in the port of destination. The remaining indicators are computed with regard to expansion on jetty capacity, port draft and onshore pump simultaneously (Table 7).

Similar with jetty and port draft expansion, the concept of benefit from the onshore cargo pumping expansion at strategic layer is defined as the difference between a cargo hold reduction that does not utilize and the additional investment costs and operating expenses from investment activities of the pump. The summary of net profit and cost benefit ratio for jetty, port draft and onshore pump expansion can be seen in Table 8.

The optimum net benefit would be obtained if PT.X develops 3 units of jetty, performs dredging so that the port has 6 m draft and invests onshore pump that has a flow rate of 550 kL/h. In this scenario, the net benefit to be gained by PT.X is IDR 13.2 billion/year.

Table 7: The result of operational impact on increasing jetty capacity, port draft and onshore pump

		1 jetty (onshore pump expension)			
Scenario	Performace measurement	Without	450 kL/h draft	500 kL/h draft	550 kL/h draft
Without port draft Expension	Operating expenses (Min. IDR)	64,378.97	61,958.09	60,874.24	60,095.74
	Productive ratio	0.01595	0.01657	0.01686	0.01708
	Inventory (kL/day)	1,583,540	1,502,732	1,473,221	1,451,404
Port draft (5 m)	Operating expenses (Min. IDR)	60,994.28	58,573.41	57,489.56	56,711.05
	Productive ratio	0.02	0.02	0.02	0.02
	Inventory (kL/day)	1,474,717	1,393,909	1,364,398	1,342,582
Port draft (5.5 m)	Operating expenses (Min. IDR)	60,722.26	58,301.39	57,217.54	56,439.03
	Productive ratio	0.02	0.02	0.02	0.02
	Inventory (kL/day)	1,444,323	1,363,516	1,334,005	1,312,188
Port draft (6 m)	Operating expenses (Min. IDR)	60,528.03	58,107.15	57,023.30	56,244.79
	Productive ratio	0.02	0.02	0.02	0.02
	Inventory (kL/day)	1,415,890	1,335,082	1,305,571	1,283,754
		2 jetty (onshore pump expension)			
Scenario	Performace measurement	Without	450 kL/h draft	500 kL/h draft	550 kL/h draft
Without port draft Expension	Operating expenses (Min. IDR)	65,873.22	63,714.40	62,659.67	61,910.28
	Productive ratio	0.01558	0.01611	0.01638	0.01658
	Inventory (kL/day)	2,266,158	2,185,350	2,155,839	2,134,022
Port draft (5 m)	Operating expenses (Min. IDR)	62,799.94	60,641.12	59,586.39	58,837.00
	Productive ratio	0.2	0.2	0.2	0.2
	Inventory (kL/day)	2,157,335	2,076,527	2,047,016	2,025,200
Port draft (5.5 m)	Operating expenses (Min. IDR)	62,839.33	60,680.51	59,625.78	58,876.39
	Productive ratio	0.20	0.20	0.20	0.20
	Inventory (kL/day)	2,126,941	2,046,134	2,016,623	1,994,806
Port draft (6 m)	Operating expenses (Min. IDR)	62,956.50	60,797.68	59,742.94	58,993.55
	Productive ratio	0.02	0.02	0.02	0.02
	Inventory (kL/day)	2,098,508	2,017,700	1988,189	1,966,372
		3 jetty (onshore pump expension)			
Scenario	Performace measurement	Without	450 kL/h draft	500 kL/h draft	550 kL/h draft
Without port draft Expension	Operating expenses (Min. IDR)	68,673.22	66,776.46	65,750.84	65,0.30.57
	Productive ratio	0.01495	0.01537	0.01561	0.01579
	Inventory (kL/day)	2,992,184	2,911,377	2,881,866	2,860,049
Port draft (5 m)	Operating expenses (Min. IDR)	65,911.35	64,014.59	62,988.97	62,268.70
	Productive ratio	0.20	0.20	0.20	0.20
	Inventory (kL/day)	2,883,361	2,802,554	2,773,043	2751,226
Port draft (5.5 m)	Operating expenses (Min. IDR)	66,262.14	64,365.38	63,339.77	62,619.50
	Productive ratio	0.20	0.20	0.20	0.20
	Inventory (kL/day)	2,852,968	2,772,160	2,742,650	2,720,833
Port draft (6 m)	Operating expenses (Min. IDR)	66,690.72	64,793.96	63,768.34	63,048.07
	Productive ratio	0.02	0.02	0.02	0.02
	Inventory (kL/day)	2,824,534	2,743,727	2,714,216	2,692,399

Implement the investment efficiency ratio for selecting optimum solutions: As the results of the simulation, several improvement scenarios of the marine transportation system in PT.X are able to improve the performance of the system, both on the operational and strategic level. If the budget is unlimited, the stakeholders of marine transportation system in PT.X can implement all of improvement scenarios, so that the performance of the system can simultaneously be improved. Nevertheless, in fact, the investment activity always has a limited of funds. Therefore, in this study, we compute the investment efficiency ratio in order to show the ratio between the results obtained from investing activities with efforts or costs incurred on investments.

Because the limitation of investment activity that often comes up in the practical area is the availability of funds, so the investment efficiency ratio in this research will be used to determine the ratio between the reduction

Table 8: Strategic performance measures of jetty, port draft and onshore pump expansion

Scenario	Performance measurement	1 jetty (onshore pump expansion) Without	450 kL/h draft	500 kL/h draft	550 kL/h draft
Without port draft expension	Net profit (Min.IDR)	5,113.39	7,534.27	8,618.12	9,396.63
	Cost benifit ratio	3.2	3.49	3.84	4.04
Port draft (5 m)	Net profit (Min.IDR)	8,498.08	10,918.96	12,002.81	12,781.31
	Cost benifit ratio	3.35	3.53	3.78	3.93
Port draft (5.5 m)	Net profit (Min.IDR)	8,770.10	11,190.97	12,274.83	13,053.33
	Cost benifit ratio	2.53	2.82	3.03	3.16
Port draft (6 m)	Net profit (Min.IDR)	8,964.34	11,385.21	12,469.07	13,247.57
	Cost benifit ratio	2.04	2.35	2.53	2.65
Scenario	Performance measurement	2 jetty (onshore pump expansion) Without	450 kL/h draft	500 kL/h draft	550 kL/h draft
Without port draft expension	Net profit (Min.IDR)	4,219.14	6,377.96	7,432.69	8,182.08
	Cost benifit ratio	1.32	1.75	1.97	2.11
Port draft (5 m)	Net profit (Min.IDR)	7,292.42	9,451.24	10,505.97	11,255.336
	Cost benifit ratio	1.64	1.91	2.08	2.19
Port draft (5.5 m)	Net profit (Min.IDR)	7,253.03	9,411.85	10,466.59	11,215.97
	Cost benifit ratio	1.27	1.55	1.7	1.79
Port draft (6 m)	Net profit (Min.IDR)	7,135.87	9,294.68	10,349.42	11,098.81
	Cost benifit ratio	1.03	1.3	1.42	1.51
Scenario	Performance measurement	3 jetty (onshore pump expansion) Without	450 kL/h draft	500 kL/h draft	550 kL/h draft
Without port draft expension	Net profit (Min.IDR)	2,619.14	4,515.90	5,541.52	6,261.70
	Cost benifit ratio	0.55	0.95	1.12	1.23
Port draft (5 m)	Net profit (Min.IDR)	5,381.01	7,277.77	8.303.39	9,023.66
	Cost benifit ratio	0.85	1.12	1.25	1.34
Port draft (5.5 m)	Net profit (Min.IDR)	5,030.22	6,926.98	7,952.59	8,672.87
	Cost benifit ratio	0.64	0.89	1	1.08
Port draft (6 m)	Net profit (Min.IDR)	4,601.64	6,498.40	7,524.02	8.244.29
	Cost benifit ratio	0.49	0.72	0.82	0.89

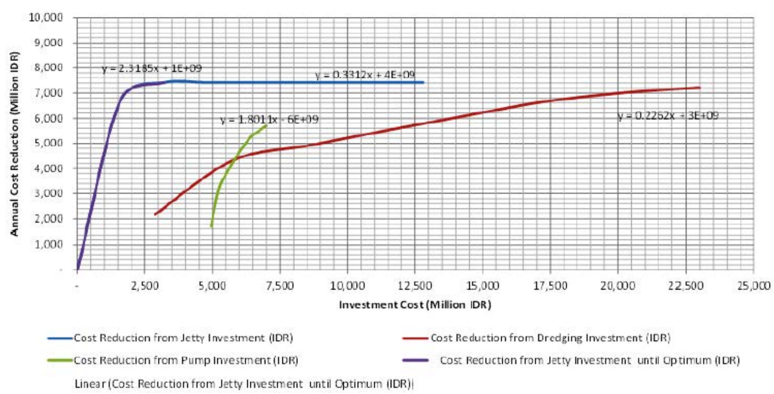

Fig. 3: Investment efficiency ratio of contrait

in operating costs from investment activities of the marine transportation system constraint and the amount of money invested to increase its constraint capacity. The relationship between the annual operational costs reduction of marine transportation system in PT.X with the amount of money invested to increase the capacity constraint that is done by simulating ceteris paribus can be in Fig. 3.

Based on the Fig. 3, if the investment is only made until the optimum point of the operating costs reduction, the highest efficiency comes from the jetty investment. Effect size of jetty investment in this scenario is 2.3 which means that for every unit of money invested into the jetty, then the impact of decreasing in operating expenses amounted to 2.3 units of money. Once the optimum point of the operating costs reduction is obtained, the investment of jetty no longer gives an impact reduction into operational costs. Each unit of money invested in onshore pump capacity will have impact on the operational costs of marine transportation system in PT. X by 1.8 units. For the dredging activities, each unit of money invested will affect on the operating costs of marine transportation system in PT.X by 0.2 units.

CONCLUSION

Based on the TOC concept, the efforts to improve the system performance will be optimal and appropriate, if it is done by a major constraint on the system. To deal with the constraints that have been identified, TOC framework provides several stages: exploit, subordinate, and elevate constraint. This study has been performed several simulations of investment to three constraints (jetty, port draft and cargo pump) with a large number of scenarios to determine the investment required and the impact of each scenario of the investment to increase the system performance.

To select the most optimal scenario, this study has constructed the indicators namely investment efficiency ratio which is the ratio between the cost reduction successfully obtained from investing activities compared to the cost of investment made to increase the capacity constraint. If the investment will be made only against a constraint, based on the results of the simulation scenarios, an investment jetty with slope at 2.318 will give the highest ratio. It means that every unit of rupiah spent to increase the capacity of the jetty will result in a decreasing of operating costs by 2.318. It will run until the optimum point where increasing the jetty capacity is no longer affect the reduction in operating costs or conditions where the jetty capacity has exceeded demand carriage. In addition, for onshore cargo pump, the ratio is obtained by investing activities amounted to 1.8 which means thatevery unit of rupiah spent to increase the onshore cargo pump capacity will result in a decreasing of operating expenses of 1.8. Lastly, the ratio for investing activities such as dredging amounted 0.22 which means every unit of money invested will have impact on the system's operational costs amounted to 0.22 units.

By using the investment efficiency ratio, it can be concluded that the greatest impact derived from investment activities that was obtained from elevation constraint of jetty. Afterwards, the second largest ratios derived from the improvement of the onshore cargo pump capacity constraint. The lowest investment efficiency ratio in this case is obtained for port draft constraint.

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