SYSTEM DYNAMIC MODELING FOR CARGO DELIVERY REVENUE IMPROVEMENT IN CGD DRY-PORT

Asep Ridwan
Department of Industrial Engineering, Sultan Ageng Tirtayasa University,
Cilegon 42435 Indonesia, E-mail: asep.ridwan@untirta.ac.id

Muhammad Iman Santoso
Department of Electrical Engineering, Sultan Ageng Tirtayasa University,
Cilegon 42435 Indonesia, E-mail: iman.santoso@untirta.ac.id

Ratna Ekawati
Department of Industrial Engineering, Sultan Ageng Tirtayasa University,
Cilegon 42435 Indonesia, E-mail: ratna.ti@untirta.ac.id

Reno Prasetyo
Department of Industrial Engineering, Sultan Ageng Tirtayasa University,
Cilegon 42435 Indonesia, E-mail: prastyren@gmail.com

ABSTRACT

CGD Dry Port is a dry port that uses rail transportation mode as facilities of container transporter for the distribution of goods between regions. Control of Over Dimension Over Loaded (ODOL) has an impact on increasing demand for delivery the goods at the CGD Dry Port mainly demand delivery of goods. CGD Dry Port hasn't been able to handle the demand delivery of cargo in full. This research aims to determine the factors that can affect the delivery volume and design improvement to improve the delivery volume using system dynamics simulation. The study commences by problem identification, model conceptual design, stock-flow diagram development, implement base case simulation, validate model, and improvement scenario plan. It is found that the delivery volume of KS products influences the Non-KS delivery volume. The total capacity of delivery is affected by the capacity of carriages container and delivery patterns. The GD 54 type carriage container has improved by our simulation. It was originally 48 tons, then becomes to 49 tons. Thus, we enhance the pattern of delivery into 20 times in a month, which has initially been 15 times. Based on the results of the improvement scenario, the average delivery volume of amount reaches 7476,48 tons/month in which the existing conditions amount only 3227 tons/month. Hence, the estimated income goes up until IDR 388.230.336/month in compare to the current revenue of IDR 164.917.505/month.

Keywords: Dry Port, ODOL, Simulation, System Dynamics

1. INTRODUCTION

CGD Dry Port is a dry port owned by PT KB that uses the railway for container transporter to distribute the goods between regions. The operation of this dry port is supported by the government that prioritizes logistics by relying on the cooperation between PT KB and PT KA. This dry-port also keeps sea-port services, e.g., container loading-unloading, fields rent, etc. Besides that, CGD controls the container that Over Dimension and Over Loaded (ODOL).ODOL raise the demand for goods delivery, mainly from the products which do not arrive from Krakatau

Steel Co. (KS) or called Non-KS goods. However, CGD Dry Port hasn't been able to maximize it. CGD Dry Port has not been able to handle the demand delivery of Non-KS cargo in full. CGD Dry Port prioritizes the most significant demand for delivery volume first, then remains the space for Non-KS costumers. Such an approach generates a risk of delivery shortage for Non-KS cargo. CGD need to change the system to solve this dilemma. Nevertheless, directly shifting the system will require time and high costs, so we make a simulation model.

The system is defined as an assembly of components that interact with each other or relate to each other (Simon, 1991; Basu, 2006), Cândido, 2007). The relationships between components may be uni-directional and/or causal. Mutual influences or causality increase the complexity of system behavior. The model is a description or analogy used for helping to visualize something that cannot be directly observed. In some cases, we may be able to keep certain aspects of it. Based on structure, a model may be iconic, analogous, or symbolic (Daellenbach, 1994) while a simulation is an attempt to copy features, appearance, and characteristics of the real system (Heizer & Render, 2011). According to Daellenbach (1994), system dinamics is a state of a system that change over time. Each future decision may face different situation from the system that has been affect by changes in environmental inputs. Sterman (2000) states system dynamics is method for enhancing learning in complex systems.

Several studies related to system dynamics simulation have been conducted by (Ridwan and Noche, 2018; Pejic Bach et al., 2019; and Randers, 2019). Ridwan and Noche (2018) built a model of the port performance metrics by integration six sigma and system dynamics. These metrics are used to eliminate "waste" in the handling process of cargo at ports. This waste involves of damaged and lost cargo, transporter and equipment breakdown, and transporter and equipment delay time. Pejic Bach et al. (2019) determined the main characteristics of system dynamics in sustainable urban development. The review states the practice of system dynamics modelling in the sustainability of urban development has significantly improved. Randers (2019) proposed a review that differentiates between modelling and implementation methodology of system dynamics. He expressed three suggestions for the implementation methodology of system dynamics, are: 1) differentiate between four target for social change: business, public, individuals and civil society organizations); 2) differentiate between two aspiration level for social change: in behavior and in preferred policy and; and 3) differentiate among the most common causes why implementation collapses.

Some researchers investigated system dynamics simulation in ports like (Jurčević et al., 2010; Ridwan et al., 2017; Moshrefi, R. and Ansari, 2017; and Božić et al. 2017). Jurčević (2010) proposed a system dynamics approach for freight rate forming in shipping. Unfortunately, such an argument just only in concept and theory, it was not implemented yet. Ridwan et al. (2017) proposed the minimization of vessel waiting time using system dynamics approach. Moshrefi, R. and Ansari (2017) investigated a flight simulator to improve the sea port capacity by system dynamic simulation. Božić et al.(2017) studied more applicable system dynamics to model a management of maritime shipping organization. However, they only considered loading, unloading, occupancy of capacity, and timing. There is no economic analysis, like costing and revenue calculation. In the other side, our study aims to determine the factors that can affect the delivery volume. We also designed a proposal to increase the delivery volume using system dynamics simulation and establish average estimate revenue from the best improvement.

2. METHOD

This research uses system dynamics simulation to increase the revenue of cargo shipping. The conceptual model with a causal loop diagram was obtained from the development of

Ekawati's model (2017). Interviews and brainstorming were conducted with experts at CGD Port to develop this conceptual model. The actual data was obtained through direct observation for the model validation at the CGD Dry Port. The scenario design is based on discussions with experts at CGD Port so that the improvement scenario is more realistic.The following of Figure 1 is a flowchart in this research:

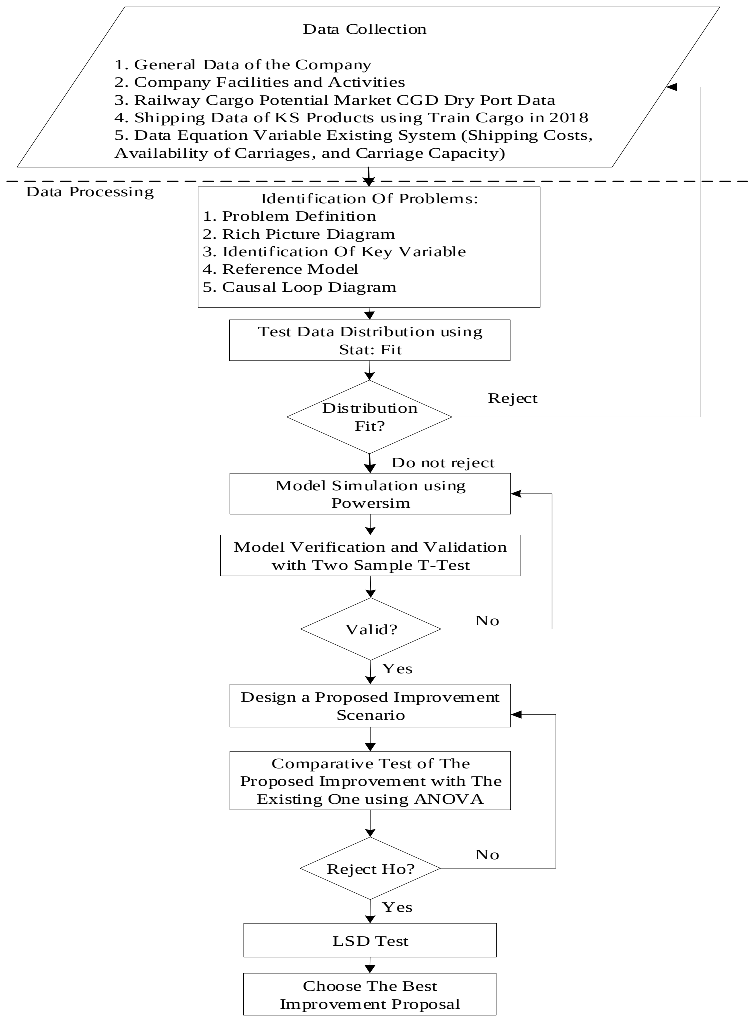

Figure 1. Research Flowchart

Based on Figure 1, this research starts with a conceptual and supported by a model. Then finally, the model is simulated by Powersim software. Afterward, we verify and validate the model. It is followed by an improvement proposal, and later we make a comparison test with the existing-condition using ANOVA. Furthermore, Fisher Least Significant Difference (LSD) Test is employed to determine the differences between each proposal and the existing-condition. Moreover, we compare the current estimated income with the best improvement proposal to evaluate the result of the selected improvement proposal.

3. RESULT

It is found that the main problem exists because of CGD Dry Port priority. They cannot handle the demand delivery of cargo in full because CGD Dry Port prioritize the most significant demand first, which is from PT KS. If this condition continues, it can produce a risk of delivery shortage for this cargo. To overcome the problem requires a dramatic change in the system, which must be time-consuming and high costs. That is why we need modeling and simulation.

3.1 Causal Loop Diagram

First of all, we build causal loop diagrams. It is developed from numerous dynamic model references obtained for the delivery of cargo in the CGD Dry Port. This diagram fits the real conditions by observation. Besides that, the causal loop diagrams also perfected by interviews with employees there.

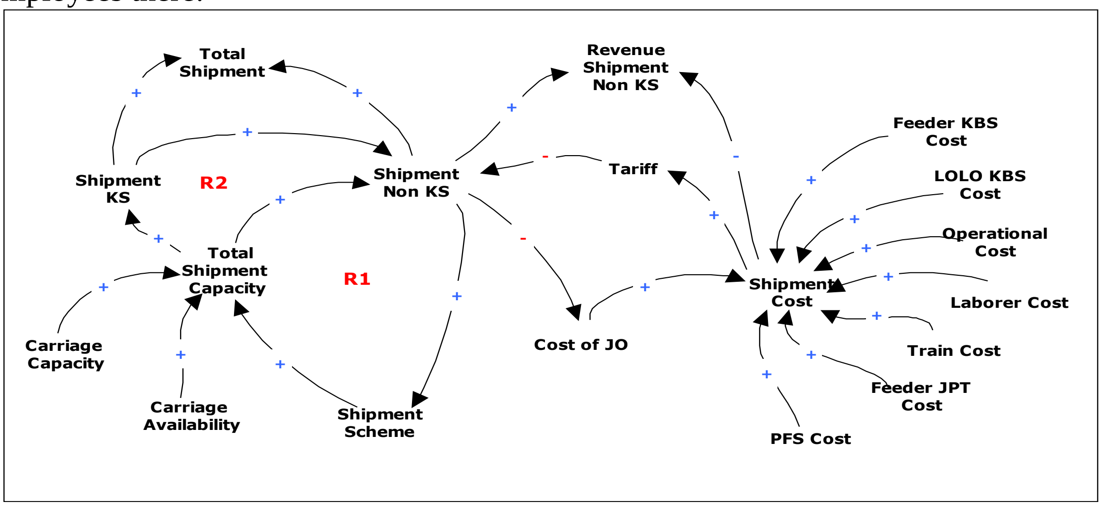

Figure 2. Causal Loop Diagram of the Revenue of Non-KS delivery

3.2 Stock Flow Diagram

The stock flow diagram of the delivery revenue are shown in Figure 3.

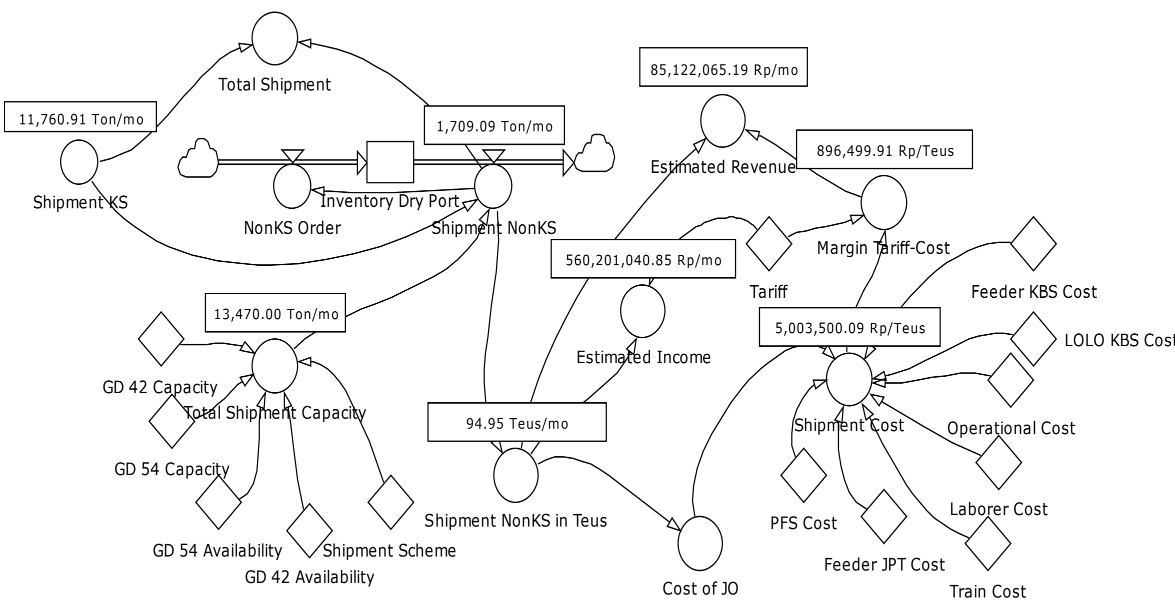

Figure 3. Stock Flow Diagram (modification from Ekawati, 2017)

The constant that used in the simulation is given in the Table 1.

Table 1. Constant Existing System Data

No	Variable	Value
1	GD 42 Capacity	38 ton
2	GD 54 Capacity	48 ton
3	GD 42 Availability	11 GD
4	GD 54 Availability	10 GD
5	Shipment Scheme	15 Shipment/Month
6	Tariff	IDR 5.900.000/TEUs
7	PFS Cost	IDR 144.000/TEUs
8	Feeder JPT Cost	IDR 1.500.000/TEUs
9	Train Cost	IDR 2.250.000/TEUs
10	Laborer Cost	IDR 100.000/TEUs
11	Operational Cost	IDR 10.000/TEUs
12	LOLO KBS Cost	IDR 450.000/TEUs
13	Feeder KBS Cost	IDR 50.000/TEUs

The results of the current condition simulation of cargo shipments listed in the Table 2.

Table 2. Current Condition Simulation Results

Month	KS Shipment Existing Simulation (ton/month)	Non-KS Shipment Existing Simulation (ton/month)
Jan	10846	2624
Feb	12807	663
Mar	10916	2554
Apr	10171	3299
Mei	10008	3462
Jun	9905	3565
Jul	7605	5865
Aug	9195	4275
Sep	12454	1016
Oct	7852	5618
Nov	9393	4077
Dec	11761	1709
Average	10243	3227

3.3 Verification and Validation

The comparison results of the cargo shipments listed in the Table 3.

Table 3. CGD Dry Port Actual Shipping Data

Month	KS Shipment Actual (ton/month)	Non-KS Shipment Actual (ton/month)
Jan	12621	481,41
Feb	10305	480,14
Mar	13927	263,12
Apr	13241	437,91
Mei	13091	312,72
Jun	4831	61,44
Jul	10623	402,93
Aug	12284	10152,45

Sep	10083	1461,33
Oct	11737	1814,52
Nov	11621	1486,68
Dec	7055	934,56
Average	10952	1524

There are two variables for the validation test of the existing system. Such analyses, including the KS product shipping validation test and the Non-KS product shipping validation test.

The validation test results using two sample t-tests on each variable:

1. KS Shipment Validation Test

The significance value obtained is greater than the α value of 0.05 because the confidence value used is 95% (0.215> 0.05). Thus, the variance of the two systems is assumed similar.

H_0: μ1 = μ2, i.e. there is no significant difference between the average output of the real system and the average output of the simulation.

H_1: μ1 ≠ μ2, i.e. there is a significant difference between the average output of the real system and the average output of the existing simulation.

The confidence level used is 95%, then the alpha value is 0.025 with v or df of 22 which is obtained from the formula n1 + n2-22 which is 12 + 12-2. So the value for t (0.025; 22) is 2.0739. With this it can be seen that the value of -t (α / 2; v) ≤ t arithmetic ≤ t (α / 2; v) that is (-2,0739 ≤ 0,786 ≤ 2,0739) for the reception area. So the conclusion drawn is accept H_0 which means that it means there is no significant average difference between the shipment of the real system KS with the existing simulation results.

2. Non-KS Shipment Validation Test

The significance value obtained is greater than the value of α that is equal to 0.05 because the value of trust used is 95% (0.758> 0.05). Thus, the variance of the two systems is assumed to be the same.

H_0: μ1 = μ2, i.e. there is no significant difference between the average output of the real system and the average output of the simulation.

H_1: μ1 ≠ μ2, i.e. there is a significant difference between the average output of the real system and the average output of the existing simulation.

The confidence level used is 95%, then the alpha value is 0.025 with v or df of 22 which is obtained from the formula n1 + n2-22 which is 12 + 12-2. So the value for t (0.025; 22) is 2.0739. With this it can be seen that the value of -t (α / 2; v) ≤ t arithmetic ≤ t (α / 2; v) that is (-2,0739 ≤ -1,833 ≤ 2,0739) for the reception area. So the conclusion drawn is accept H_0 which means that it means that there is no significant average difference between real system Non-KS shipments and existing simulation results.

3.4 Design of Proposed Improvements

The next stage is the design of the proposed improvements that have been declared valid based on the results of the two sample t-tests.

1. Proposed Improvement Scenario-1

   Change the transport capacity of the GD 54 carriage type, which was originally 48 tons into 49 tons. The changes adopted by the fact of the GD 54 max capacity, which is determined by PT KA is 54 tons. The GD 54 wagon is managed to load containers among four tons (empty) and lashing equipment (less than one ton).

2. Proposed Improvement Scenario-2
   The second proposal increase Non-KS cargo shipments to improve the CGD Dry Port shipping pattern. It is originally 15 times a month, then rose to 20 times a month. This improvement is still manageable because, in the past, CGD even delivered 30 times a month (without achieving maximum revenue).
3. Proposed Improvement Scenario-3
   The proposed improvement scenario-3 is a combination of proposed improvement scenario-1 and 2.

3.5 ANOVA Test (Analysis of Variance)

ANOVA (Analysis of Variance) tests are conducted to see whether there are differences between the results of existing system, proposed improvement scenarios 1, proposed improvement scenarios 2, and proposed improvement scenarios 3.

Table 4. ANOVA Test Results with SPSS Software

ANOVA

Data

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	168946593,1	3	56315531,03	19,603	,000
Within Groups	126403468,8	44	2872806,109		
Total	295350061,9	47			

From ANOVA, we identify that the Fcount is 19,603. This value is greater than Ftable which is 2,816. It means that H_0 is rejected. There is a significant mean difference between the results of the existing system and the three proposed improvement scenarios.

3.6 LSD Test

This test is conducted by calculating average results to find out the best alternative proposal.

$$\text{LSD} = t_{(\text{df error}\,;\,\alpha/2)}\sqrt{\frac{2 \times \text{MSE}}{12}}$$

$$= t_{(44\,;\,0.025)}\sqrt{\frac{2 \times 2872806{,}66}{12}}$$

$$= 2.0154 \times 691{,}954$$

$$= 982{,}332$$

Table 5 shows comparison for each condition after treatment using the LSD method:

Table 5. Condition Comparison Value

Sistem	Existing System ($\bar{x}_1$= 3227,39)	Scenario 1 ($\bar{x}_2$= 4114,99)	Scenario 2 ($\bar{x}_3$= 7258,10)	Scenario 3 ($\bar{x}_4$= 7476,48)

Existing System ($\bar{x}_1$= 3227,39)		$\lvert\bar{x}_1 - \bar{x}_2\rvert = 887,59$ 887,59 < 982,332 Not Significant	$\lvert\bar{x}_1 - \bar{x}_3\rvert = 4030,70$ 4030,70 > 982,332 Significant	$\lvert\bar{x}_1 - \bar{x}_4\rvert = 4249,08$ 4249,08 > 982,332 Not Significant
Scenario 1 ($\bar{x}_2$= 4114,99)			$\lvert\bar{x}_2 - \bar{x}_3\rvert = 3143,11$ 3143,11 > 982,332 Significant	$\lvert\bar{x}_2 - \bar{x}_4\rvert = 3361,49$ 3361,49 > 982,332 Significant
Scenario 2 ($\bar{x}_3$= 7258,10)				$\lvert\bar{x}_3 - \bar{x}_4\rvert = 218,38$ 218,38 < 982,332 Not Significant
Scenario 3 ($\bar{x}_4$= 7476,48)				

Table 6. Sequence of the Best Proposed Scenarios

No.	Condition	Output Average (ton/month)
1	Scenario 3	7476,48
2	Scenario 2	7258,10
3	Scenario 1	4114,99
4	Existing System	3227,39

It is seen from the table, the proposed improvement scenario-3 has the highest average output of 7476.48 tons/month. Therefore, the proposed improvement of scenario 3 is chosen as the best-proposed scenario..

3.7 Comparison of Estimated Revenue between Existing and the Best Proposal

The revenue comparison is a comparison to find out the difference income between the existing system and our best scenario. This estimated revenue is generated by our simulations using Powersim software.

Table 7. Comparison of Estimated Revenue

Month	Non-KS Shipment (ton/month)		Estimated Revenue (IDR/month)	
	Existing Simulation	Best Proposed Simulation	Existing Simulation	Best Proposed Simulation
Jan	2623,54	7624,20	IDR 133.181.686	IDR 395.994.086
Feb	663,29	6600,26	IDR 30.159.520	IDR 342.180.194
Mar	2554,41	6573,62	IDR 129.548.207	IDR 340.780.349
Apr	3299,25	6471,58	IDR 168.693.696	IDR 335.417.382
Mei	3462,33	9966,38	IDR 177.264.500	IDR 519.088.645
Jun	3565,40	9418,98	IDR 182.681.826	IDR 490.319.987
Jul	5865,20	9063,64	IDR 303.548.582	IDR 471.644.541
Aug	4275,06	6965,27	IDR 219.978.210	IDR 361.363.846
Sep	1016,09	7886,24	IDR 48.701.217	IDR 409.765.505
Oct	5617,67	4690,00	IDR 290.539.759	IDR 241.785.556
Nov	4077,41	5160,22	IDR 209.590.787	IDR 266.498.458
Dec	1709,09	9297,31	IDR 85.122.065	IDR 483.925.486
Total	38728,73	89717,71	IDR 1.979.010.056	IDR 4.658.764.035
Average	3227,39	7476,48	IDR 164.917.505	IDR 388.230.336

Hence, the estimated average CGD Dry Port revenue in the existing condition is IDR 164,917,505 / month. In the other side, the estimated average CGD Dry Port revenue when applying the best proposal is IDR 388,230,336 / month.

4. CONCLUSION

The following conclusions can be drawn from the modeling and simulation results. Affecting factors of Non-KS cargo shipments in the CGD Dry Port are not limited to the volume of KS product. The total capacity of the shipments influenced by the carriage's transport capacity and the shipping patterns as well.The best simulation proposal for Non-KS cargo shipments improvement can be made by changing the capacity of the GD 54 carriage capacity from 48 tons to 49 tons. It should also be followed by the CGD Dry Port shipment pattern modification from 15 times a month to 20 times a month.The average Non-KS shipment volume produced from the best simulation proposal is 7476.48 tons/month where the current shipment is only 3227 tons/month. The estimated average revenue of the best simulation proposal is IDR 388,230,336 / month, better than the existing condition which is only IDR 164,917,505 / month.

REFERENCES

Basu, A., Bozga, M., Sifakis, J. (2006) Modeling Heterogeneous Real-time Components in BIP, *Fourth IEEE International Conference on Software Engineering and Formal Methods (SEFM'06)*, Pune, pp. 3-12.

Božić, R., Sandro, B., Žana, B. B. (2017) System Dynamics Simulation Modelling of Managing a Maritime Shipping Organization, *2nd International Conference on Computer, Network Security and Communication Engineering (CNSCE 2017)*, ISBN: 978-1-60595-439-4

Cândido, G., Barata, J., Mařík, V., Vyatkin, V., Colombo, A. W. (2007) A Multiagent Control System for Shop Floor Assembly, *Holonic and Multi-Agent Systems for Manufacturing*, Springer Berlin Heidelberg, pp. 293-302

Daellenbach, H.G., (1994). *System and Decision Making a Management Science Approach*. John Wiley and Sons Ltd., England.

Ekawati, R., Wahyuni, N., Ridwan, A., and Fitri A. (2017) Shifting Analysis of FSO Ardjuna Sakti Using System Dynamic Simulation. *1st International Conference on Multidisciplinary Studies*, Serang, Banten.

Heizer, J. and Render, B., (2011). *Operations Management*. Tenth Edition, Prentice Hall, New Jersey.

Jurčević, M., Mitrović, F., Nadrljanski, M. (2010) System Dynamics and Theory Of Chaos In Freight Rate Forming In Shipping, *Traffic & Transportation*, Vol. 22, 2010, No. 6, pp. 433-438

Midiawati, M. and Singgih, S. (2017). Comparative Analysis of TE 67 HS Coal Quality in Stockpiles and in Railway Carriage Using Statistics Tools. *Industrial Engineering Online Journal* 6 (4).

Moshrefi, R. and Ansari, B. (2017). A Flight Simulator for Sea Port Capacity Improvement: A Case Study of Rajaee Port of Iran. *Proceedings of the 35th International Conference of the System Dynamics Society and 60th Anniversary of System Dynamics Celebration*, Cambridge, Massachusetts.

Pejic Bach, M., Tustanovski, E., Ip, A., Yung, K. and Roblek, V. (2019) "System Dynamics Models for the Simulation of Sustainable Urban Development", *Kybernetes*.

Ridwan, A., Ferdinant, P. F., Kurniawan, B., and Aurelia (2017) Minimization of the Vessel Waiting Time Using System Dynamics Simulation. *Proceedings of National Seminar Institute of Supply Chain and Logistics Indonesia (ISLI)*, Makassar, pp.54-61.

Randers, J. (2019), The Great Challenge for System Dynamics on the Path Forward: Implementation and Real Impact, *System Dynamics Review*, Vol.35 No.1, pp.19-24.

Ridwan, A. and Noche, B. (2018). Model of the Port Performance Metrics in Ports by Integration Six Sigma and System Dynamics, *International Journal of Quality & Reliability Management*, Vol. 35 No. 1, pp. 82-108.

Simon H.A. (1991). The Architecture of Complexity. In: Facets of Systems Science. *International*

Federation for Systems Research International Series on Systems Science and Engineering, vol 7. Springer, Boston, MA.

Sterman, J., (2010). *Business Dynamics: System Thinking and Modeling for A Complex World*. The McGraw Hill Companies, Boston.