An Analysis of Dynamics Effects on Increasing Temporary Container Storage Tariff: A Case Study Banjarmasin Container Port

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Abstract—**To reduce dwelling time, special steps are needed regarding the handling speed of containers, stacking rates in container yards and management of important container documents. In 2016, the Banjarmasin Container Port (BCP) operator expanded the Container Yard area because it was considered as a step to overcome the overload in the CY area. This is proven to reduce density the following year. But along with the increasing flow of containers coming out and entering through the BCP, there could be an increase in the density of container flows. This study aims to re-evaluate and give consideration to the effect of container stacking rates on utilities and the smooth flow of goods at container Ports where new container stacking rates are beneficial for both parties (BCP operators and customers). The approach used in this study are game theory and system dynamics. System dynamics have characteristics with problems in container ports that are interrelated between one entity and another entity that has its own complexity. Game theory will give consideration to strategies that will benefit both parties if new rates are set. Based on the results, the optimal tariff is 50% (IDR 21,630) and the response decreases dwelling time for 6 days. The new tariff setting has an impact on increasing loading speed 22.09 B/C/H and unloading speed of 23.95 B/C/H. In addition, it also reduced revenue from temporary storage activities by 35.51%. While from the customer side with a 6 days response can save savings costs by 30.5%. This will help port management to make the right decision.**

Index Terms—**system dynamics, non-cooperative game, storage pricing, utility**

I. Introduction

The port functions as a gate for the flow of goods in or out to a place, which has a role as one of the important nodes in the supply chain of goods. Ports in their operations involve many entities that are systemically related to one another. These entities include port management, shipper, consignee (recipient of goods), carrier (ship owner) and forwarder (freight forwarding businessman). Port Management Authority is an important entity other than those mentioned above and determines the operational performance of each related entity.

Several researchers have examined the topic of determining stacking rates in Container Yards and analysing demand for the length of time of stacking containers. De Castilho and Daganzo show how efficient pricing schemes for various situations aim to avoid misuse of temporary storage areas [1]. Meanwhile, Kim and Kim propose storage prices for imported containers. Fees are based on free-time limits and variable storage costs (depending on the length of time in Container Yards) [2]. Whereas Qiu and Lam [3] have completed the research of Sauri [4] by considering from both sides, with the aim of maximizing the benefits of port managers and minimizing costs incurred by service users. But with the case study the application of free-time tariffs at the beginning of a certain period.

In a recent study, Amin developed a model that considers container port capacity, tariffs, ship delays and loading and unloading rates at container ports [5]. But it has not taken into account the expenditure of costs from service users.

Based on the above problems, it is necessary to further analyse the increase in temporary container storage rates for utilities, port management benefits and consumer spending.

II. Literature Study

A. Game Theory

Game theory is a branch of applied mathematics that is used in the social sciences, most notably in economics, as well as in biology (particularly evolutionary biology and ecology), engineering, political science, international relations, computer science, social psychology, philosophy and management. Game theory attempts to mathematically capture behaviour in strategic situations, or games, in which individual's success in making choices depends on the choices of others [6]. The theory breaks naturally into two parts. There is non-cooperative

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theory which the players, if they may communicate, may not form binding agreements. An example of this situation is the interaction between companies in an industry in the environment where antimonopoly laws make it illegal for companies to reach agreement on prices or production quotas or other form of behaviour. On the other hand, in the cooperative theory the player are allowed to form binding agreements, and so there is strong incentive to work together to receive the largest total payoff [7].

Non-zero sum games are types of games that are not totally counted because some result shave a net result that is greater or less than zero. The most famous example is the case of prisoner dilemma shows on Figure 1, where prisoners have the choice to confess or evade when asked by the police. In this game, player 1 can see that no matter which column player II chooses, he will be better off if he chooses row 2. For if player I chooses row 2 rather than row 1, he wins 4 rather than 3 if player II chooses column 1, and he wins 1 rather than 0 if she chooses column 2. In other words, player I's second strategy of choosing the second row strictly dominates the strategy of choosing the first. On the other hand, the game is symmetric. Player II's second column strictly dominates her first. However, if both players use their dominant strategies, each player receives 1, whereas if both players use their dominated strategies, each player receives 3 [7].

$$\begin{array}{l c} & \begin{array}{cc} \text{cooperate} & \text{defect} \end{array} \\ \begin{array}{l} \text{cooperate} \\ \text{defect} \end{array} & \begin{pmatrix} (3,3) & (0,4) \\ (4,0) & (1,1) \end{pmatrix} \end{array}$$

Figure 1. Non zero-sum game case

B. System Dynamics

The system dynamic concept was developed by Forrester in the 1950s in the form of Industrial Dynamics books. The term Industrial Dynamics then changes to a system dynamic to suppress the use of this methodology in fields other than business [8]. In system dynamics, the system is conceptualized as physical state variables and information (stock) that can accumulate, run out and or increase by variable rates (flow), all of which interact through closed loops of cause and effect (feedback loops).

The use of a system dynamics approach is more precisely modelled on the problem as follows:

1. Has dynamic properties (changes with time)
2. The structure of the model contains at least one feedback structure

III. Container Storage System Causal Loop Model and Stock Flow Diagram

Dwelling time and container port utilities are influenced by many factors including economic and social factors. The causal loop model can be seen in Fig. 2, which is divided into 3 sub-factors. The main factors include activities at container ports that influence each other. The second factor is what activities will directly affect the total revenue of container port management. The last factor is any activity that will affect the total expenditure of the customer in the storage of temporary containers.

In the causal loop model, the length of accumulation in temporary facilities will be the main key of container port utilities. The length of accumulation in temporary facilities will be the decision of the customer where the higher the cost of warehouses outside compared to the rate of accumulation in temporary facilities, the longer the accumulation time will be. The length of container stacking will directly affect the capacity of containers that can be accommodated at container ports. If the national container flow is in peak season, then there will certainly be congestion in the container port area. Congestion will have an impact on container port utilities and waiting times on ships that will dock.

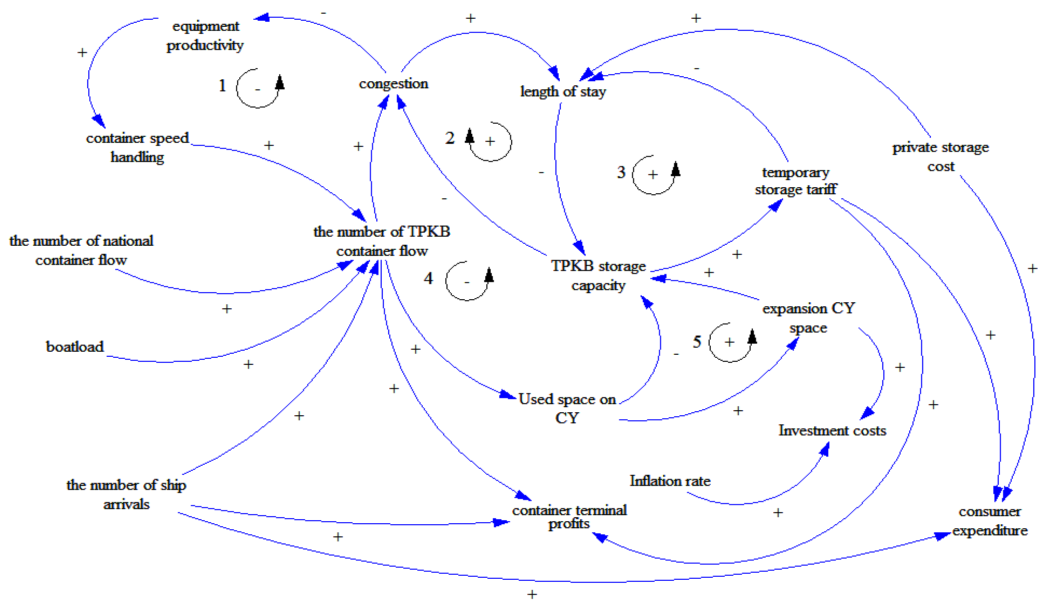


Figure 2. Causal loop diagram of container yard

Causal loop diagram in Fig. 2, then proceed with making stock flow diagram which is divided into two main parts, container handling activities which can be seen in Fig. 3 and container financial activities that can be seen Fig. 4.

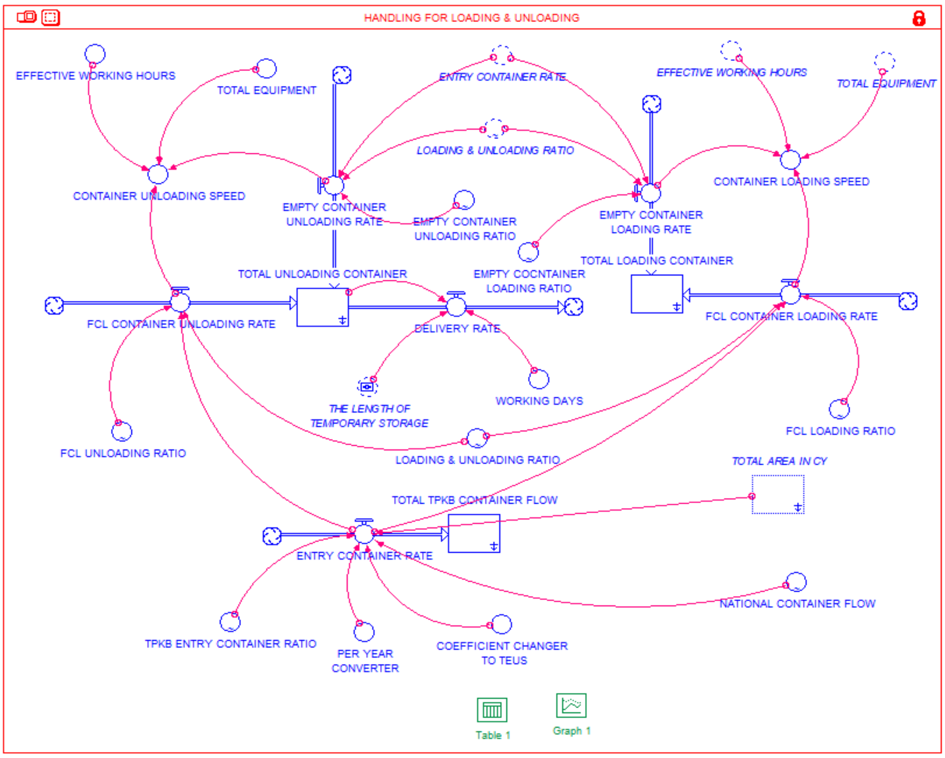


Figure 3. Stock flow diagram of handling container activity

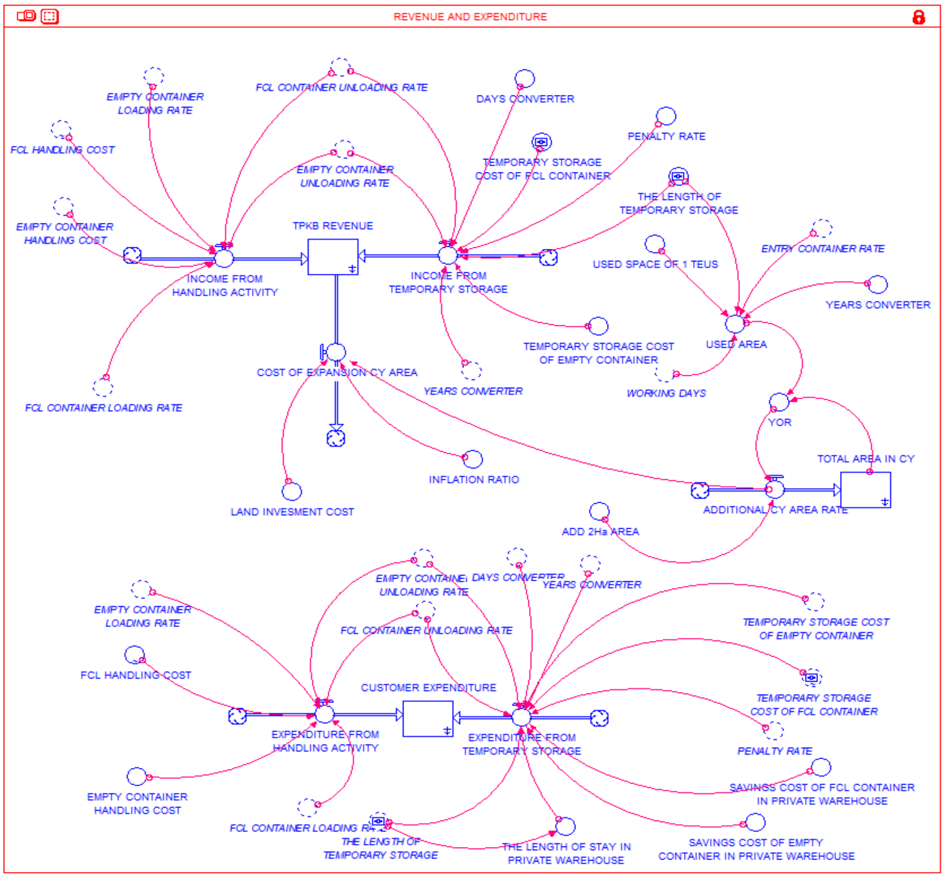


Figure 4. Stock flow diagram of financial container activity

In Fig. 3 and Fig. 4, policy analysis regarding storage tariff with a system dynamic approach. With the simulation of the container tariff strategy model the strategy is expected to result in a decrease dwelling time, increased utility and increased profits.

IV. Validation of Stock Flow Diagram

On Model validation is the stage of testing the model, whether the model is able to represent or describe the real system. Validation of the model is done by testing the simulation results with a real system or also called the Mean Comparison. A model is considered valid if it has an error value less than 5%. (see Table I-Table II)

TABLE I. Mean Comparison for the Number of BCP Container Flow

Year	The number of BCP container flow (TEUS)		
	Real	Simulation	*Error*
2013	421,548	421,362	0.044%
2014	413,737	413,802	0.016%
2015	388,419	388,535	0.030%
2016	407,688	407,635	0.013%
2017	421,808	421,619	0.045%
2018	408,095	407,967	0.031%
		Mean =	0.030%

TABLE II. Mean Comparison for Revenue from Handling Activity

Year	Revenue from handling activity (IDR)		
	Real	Simulation	*Error*
2013	203,164,360,000	203,290,600,000	0.06%
2014	197,154,760,000	197,742,160,000	0.30%
2015	182,443,480,000	182,330,640,000	0.06%
2016	193,775,960,000	194,391,680,000	0.32%
2017	223,578,287,000	238,877,470,000	6.84%
2018	225,912,808,000	233,274,746,000	3.26%
		Mean =	1.81%

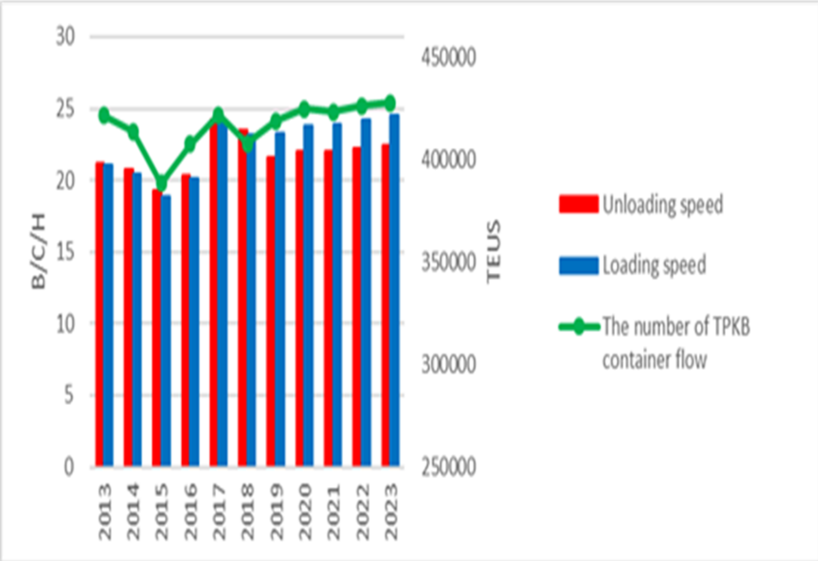
V. Result of Simulation

The results of running with the strategy of raising rates by port management and the response of reducing the length of container stay by the customer are summarized into the payoff matrix. After running on the software, the output is in the form of Nash Equilibria with several options: Pure Strategies, Global Newton Tracing and Dominance. (Table III).

TABLE III. Nash Equilibrium for Port Management Profits and Customer Expenditure

Two Person Non-Zero Sum Games		Customer					
		8 days		7 days		6 days	
Port management	Tariff 10%	206,375,184,100	(190,091,106,580)	165,100,147,280	(179,011,325,632)	123,825,110,460	(167,931,544,684)
	Tariff 20%	165,299,511,280	(203,782,997,520)	132,239,609,024	(189,964,838,384)	99,179,706,768	(176,146,679,248)
	Tariff 30%	217,474,888,460	(203,782,997,520)	200,918,351,136	(189,964,838,384)	184,361,813,812	(184,361,813,812)
	Tariff 40%	192,683,293,160	(231,166,779,400)	154,146,634,528	(211,871,863,888)	115,609,975,896	(192,576,948,376)
	Tariff 50%	206,375,184,100	(244,858,670,340)	165,100,147,280	(222,825,376,640)	123,825,110,460	(200,792,082,940)

Note: Unit cost in IDR



Year	Unloading Speed (B/C/H)	Loading Speed (B/C/H)
2013	21.13	21.1
2014	20.77	20.44
2015	19.32	18.83
2016	20.31	20.17
2017	24.19	23.97
2018	23.43	23.15
Mean	21.52	21.27

Year	Unloading Speed (B/C/H)	Loading Speed (B/C/H)
2019	21.63	23.30
2020	22.03	23.82
2021	22.05	23.90
2022	22.27	24.23
2023	22.47	24.51
Mean	22.09	23.95

Figure 5. The comparison of container flow and container handling utility

In Fig. 5, it can be seen that in the period 2013-2018 fluctuations in the rate of loading and unloading of containers are in line with the BCP/TPKB container flow. At its lowest point in 2015 with a container flow of 388,419 TEUs affected the loading and unloading speed index. Based on output of the system dynamics simulation, where there is no indication of congestion, the number of containers that can enter the BCP also experiences an increasing trend every year. This also has an impact on the reduction in idle time and the increase in container loading and unloading indices at BCP.

VI. Conclusion

There are three influences from the new tariff setting strategy for container port operators: firstly, the decline in income from temporary storage activities by 35.51% from an average of 5 years IDR 38,400,520,260 to IDR 24,765,022,092. The second effect is with the response time of container storage time which drops to 6 days. This shows that there is no congestion in the 2019-2023 period in the output of system dynamics simulation. The third advantage is that without congestion, the number of containers entering also increases each year, thereby increasing the average loading index from 21.52 B/C/H to 22.09 B/C/H and increasing the average initial loading speed 22.09 B/C/H to 23.95 B/C/H. While the effect on the customer when the BCP operator raises the tariff by 50% from the basic tariff, the customer responds by reducing the length of container stay on container yard to 6 days, which saves expenses from temporary storage activities by 30.5%.

In the end, the researcher will help decision makers to understand the advantages and expenses of the game results related to the increase in basic rates for container storage and container port utilities. So, container port management can have strategic considerations before making final managerial decisions.

Conflict of Interest

The authors declare “there is no conflict of interest”.

Author Contributions

This paper is part of research project was funded by Indonesian Ministry of Research, Technology and Higher Education (Kemenristek-Dikti). The main idea of this research related "The Solution to The Congestion Effect that occurred at the Banjarmasin Container Terminal" was initiated by Budisantoso Wirjodirdjo as research leader. He defined the problem and developed the model using System Dynamics methodology. I. Nyoman Pujawan as one of research team proceeded to verify and validate the model developed, before the model developed was used to create and simulate the scenario to reduce the congestion in the Banjarmasin container terminal. Akhmad Ghiffary Budianto and Iffan Maflahah as member of researcher had supported collecting and sorting the required data from the Banjarmasin container terminal. This paper was written by Akhmad Ghiffary Budianto under supervision of Budisantoso Wirjodirdjo and all of research members had approved this paper.

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