Container storage tariff policy analysis using combining game theory and system dynamics approach

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Abstract. This paper examines the storage tariff setting policy. The main purpose of this paper is to give consideration to optimal tariffs based on alternative strategies that reduce dwelling time. The main problem is the basic tariff for container storage in Container Yard is too cheap. This low-cost tariff of the storage container is used by customers so that containers are piled too long in Container Yard and cause dwelling time to be high. This has an impact on the congestion effect and the decline in utilities in the container terminal. This problem has complexity and suitability with System Dynamics. The linkage system between one cause and another cause will be modelled with System Dynamics so that the estimated output of container flows can be obtained. Furthermore, with the Non-Cooperative Game approach, a payoff matrix table will be obtained which contains the total profit obtained by the container terminal management and the total cost incurred by the customer. The main factors considered in the payoff matrix are the estimated container flows, the container storage tariff and the length of time accumulated in Container Yard. Finally, the optimal tariff from both sides was found (Nash Equilibrium), from the point of view of terminal container management and customer. This will help terminal management to make the right decision.

1. Introduction
The port has an important role to support an operational supply chain system. It can be considered as a part of supply chain systems and several entities involved such as terminal management, shipper, consignee, carrier, and forwarder. The port can also be seen as a gate of the flow of goods in and out. The problem that is almost experienced in every container terminal is limited storage space and stagnation. The limited storage space of the container has caused a bottleneck of the container that can be handled by the container terminal.

Martin et al [1] state that in general, terminal operators do not derive large profits from storage charges because their main activity is container transshipment between different modes of transportation, but they would like to satisfy certain targets by introducing storage pricing, as follows : (a) to prevent customers storing containers in container yards for a long periods, (b) to ensure the efficiency of terminal performance and greater profits from the storage area, (c) to provide additional services to customers which are currently in high demand, especially for users who do not have warehouse facilities. The storage duration of the container can be considered as one of the performance indicators on the container terminal. In case the longer dwelling time indicates the lower performance of the container terminal [2].
The policy to determine the tariff of container storage had been widely discussed by the researchers. Those are: Castilho and Daganzo [3] had to focus their main objective only to maximize the benefits obtained by terminal management. Then Kim and Kim [4] introduced a storage tariff policy with progressive rates, where progressive tariffs are used as a penalty rate imposed on customers. So customers are not using the container yard facility too long. In the last research, Qiu and Lam [5] used the game theory approach with the Stackelberg game model. The main objective is to maximize the benefits of terminal management while minimizing the expenditure of customer costs in container yards. The use of exact methods to determine container storage tariff has a weakness where the mathematical approach used usually has limitations in modelling the relationship of one variable to other variables. Even though in the real world, the determination of container storage tariff has many links between one variable to other variables.

The model that has many interrelationships between one variable and other variables can be solved using a simulation approach. The simulation approach has the advantage that the model used can be probabilistic; accommodate variables that have interdependence with other variables and systems that have complexity. In this paper, the researcher uses a system dynamics simulation approach to fill the payoff matrix from the non-cooperative game theory approach. The system dynamics approach is a field of study of the structure and behaviour of socio-technical systems to guide effective decision making, learning, and policy in a world full of dynamic complexity [6]. While the use of the game theory approach has the same characteristics where the game consists of two to several people or groups have a strategy that is made to maximize their own profits or minimize the opponent’s profits [7].

In this case, the researcher aims to develop a strategy where there is a balance between two players, the container terminal management and customers. So, container terminal management can have strategic considerations before making the right managerial decisions.

2. Literature study

2.1 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 an individual’s success in making choices depends on the choices of others [8]. The theory breaks naturally into two parts. There is a non-cooperative theory in 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 forms of behaviour. On the other hand, in the cooperative theory, the player is allowed to form binding agreements, and so there is a strong incentive to work together to receive the largest total payoff [9].

Based on the problem-solving strategy, game theory is also divided into pure and mix strategies. The example shows how each player can choose a strategy for rock, paper, and scissors. The value in the matrix is the payoff or consequences of each decision making. In this game, each of the two players can choose rock, paper, or scissors. If both players choose the same action, there is no winner and the utilities are zero. Otherwise, each of the actions wins over one of the other actions and loses to other remaining action. Whereas when viewed from the payoff matrix in the form of zero-sum games, the type of game that describes the amount of profit received by player 1 will amount to the loss felt by player 2 and vice versa [10].

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 in Figure 1. Non zero-sum games case, 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 choose 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 \[9\].

![Figure 1. Non zero-sum games case](image)

2.2 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 dynamics to suppress the use of this methodology in fields other than business [11]. In system dynamics, the system is conceptualized as physical state variables and information (stock) that can accumulate, run out and 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

System dynamics can also be used in reviewing a policy regarding price. In a previous study of pricing in electricity transmission services [12], the simulation results showed that price determination has a positive effect in managing transmission congestion, transmission expansion and selecting cargo locations. Price points are very sensitive to operational conditions and network characteristics. It can also encourage electricity providers and users to avoid the cost of expensive transmission congestion and dramatic electricity price fluctuations.

In addition, in a recent study of the determination of Real-Time Charge (RCP) price on Electric Vehicle (EV) [13], the models made were quite extensive including EV power consumption, a generator sets, cost pricing, user response, evaluation of benefits of all stakeholders' interest and net life cycle of the electric charging station. This paper proves that increasing RCP will increase profits on charging service operators. This can happen if and only if the number of EV is large enough. While the increase in the number of EV is quite large, it only occurs if the government holds a gradual subsidy to users of EV. Besides being able to increase profits from charging EV service operators, it can also increase savings on non-renewable energy and reduce emissions.

3. System under discussion

Dwelling time is the length of the average container time in the container yard of a container terminal [14]. The consignee's pattern of container collection in the delivery process is also erratic, causing variability in container stacking time in the Container Yard.

Martin [1] proposes a mathematical model for the optimal tariff scheme on Container Yard assuming container arrivals by sea are stochastic (the number of containers unloaded per ship type is a random variable) and several vessels for two different purposes namely maximizing terminal operator profits and minimizing the cost of the whole system. The rate for storing containers based on flat-rate time can be seen in Figure 4 as follows:
Figure 2. Container storage tariff scheme at container terminal [1]

where:
\[ \alpha \]: zero or non-zero flat rate
\[ b \]: storage rates that are proportional to time
\[ t_0 \]: flat rate duration (in days)
\[ t \]: the length of time the container is in the terminal area
\[ c(t) \]: total customer expenditure at time t
\[ t_p \]: threshold time

Figure 2. Container storage tariff scheme at container terminal [1] assumes that customers minimize their own storage costs, assumptions taken from Kim and Kim [4] and the customer does not reschedule the time taken to take the container according to storage costs. Based on the price structure, the threshold time will divide into two categories:

1) Customer who has a delivery time (shorter than the time limit)
2) Customer with delivery times greater than the time limit

For the last category that must be minimized because it would be better to use their own warehouse facilities because the storage costs would be lower and not cause congestion effect in the container terminal.

4. Container storage system causal loop model and payoff matrix

4.1 Container storage system causal loop model

Dwelling time and container terminal utilities are influenced by many factors including economic and social factors. The causal loop model can be seen in Figure 3. Causal Loop Diagram of Container Yard, which is divided into 3 sub-factors. The main factors include activities at container terminals that influence each other. The second factor is what activities will directly affect the total revenue of container terminal 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 terminal 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 terminals. If the national
container flow is in peak season, then there will certainly be congestion in the container terminal area. Congestion will have an impact on container terminal utilities and waiting times on ships that will dock.

![Causal Loop Diagram of Container Yard](image)

Figure 3. Causal Loop Diagram of Container Yard

In this paper, the strategy for determining stacking rates will provide additional benefits to the temporary container storage activities for container terminal management. In addition, the number of ship arrivals and incoming container flows will also add to the benefits of container terminal management. On the other hand, customers will consider the difference between the container stacking rates at container terminal facilities and the cost of storing containers in their own warehouses.

![Input-output diagram relation to payoff matrix](image)

Figure 4. Input-output diagram relation to payoff matrix

In Figure 4, input-output diagram relation to payoff matrix, 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.
5. Future Work
Validation of the causal loop model is currently underway with a case study of the Banjarmasin container terminal. The purpose of the validation of the causal loop model is to ensure all factors and valid and reasonable factor relationships. The model of the causal loop will be updated and modified based on recommendations and feedback received from the results of validation. 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, dwelling time and container terminal utilities.

The advantage of this model is the model can capture the effect of increasing tariff on equipment utilities, container terminal revenue and the flow of goods in the container terminal. In previous studies only considered the effect of increasing rates on dwelling time. While the lack of this model is the model has not considered inflation and the value of profits from the flow of goods in the container terminal.

6. Conclusion
Validation of the causal loop model is currently underway with a case study of the Banjarmasin container terminal. The model of the causal loop will be updated and modified based on recommendations and feedback received from the results of the validation. In this case, the results of the validated model will be used to simulate the scenarios that are in the two-person non-zero sum game. 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, dwelling time and container terminal utilities. So, container terminal management can have strategic considerations before making final managerial decisions.

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