Petri Nets Approach in Optimizing Container Loading and Offloading Process in Inter Terminal Transfer Operation: A Research Framework

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Abstract—**This paper presents a research framework on loading and unloading process for inter terminal transfer (ITT) operation. Container movement in the transport industry depends on the service provided in the terminal. The complexity of the activities in the process could possibly contribute to potential delays occurred. In this paper, Petri Nets (PN) is introduced as new approach in modeling the container loading and unloading process in hierarchical structure. Several factors which is container, loading and environment will be considered in the model.**

Keywords—**container, loading and offloading, Petri Nets, inter terminal transfer**

I.   Introduction

Nowadays, the performance of intermodal transport supply system is measured based on level of efficiency in freight transportation. In this complex system, there are a lot of services and infrastructure connected with each other. In container terminal, it is important to provide an efficient operations in delivering goods to each model (ships, train and trucks) involved in the system. It shows that container terminals play as an essential role in the interchange between intermodal networks [1]. Many services are provided, seven days a week in container terminals. These include container loading or unloading to or from vessel or feeder ships for import and export purposes, internal container movement from stacking area to dedicated areas and distributed in the terminal area [2].

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The demand in the container transportation results in several issues including terminal congestion risk and delay in delivering. At this stage, time factor had been highlighted by [3] as a main requirement in this modern freight distribution. Identifying and determining the factors have been studied by many researchers around the world. However, some factors are believed associated with each other in contributing to potential delays occurred. Thus, by having a proper framework, a flexible and adaptable modelling technique can be implemented to achieve the best performance in designing and controlling the system.

In this paper, it aims to give an overview of the methodological framework in optimizing the loading and unloading process of container by using PN approach. In the first section, the literature on factors contributes to potential delays in container loading and unloading is highlighted. In the last section, the proposed research design as an alternative research approach. The complex system that consists of several events will be performed using Petri Nets. Several factors relate to container, loading and environment are integrated in a form of hierarchical structure in the model.

II.   Literature Review

A.   *Potential Delays Factors in Container Loading and Offloading Process*

In general, inter terminal transfer (ITT) operation involves movement through container from one terminal to another terminal. The whole process of this operation takes about 13 hours, which covers loading process, travel time and unloading process. By referring to the Standard Operating Procedure (SOP) of the operation, specific activities involved are explained in this part in order to provide a clear understanding of the operation. For each part and activities involve in loading and unloading process, potential delays may occur due to some factors. These problems may occur in each activity or part of the loading and unloading process in ITT operation. Moreover, it is very crucial to determine the frequency of the potential delay occurs during the process. More delays will create more time taken for each activities in the process. The delay indirectly affects the operation schedule of freight movement.

In the past few years, container terminal operation has been substantially studied by looking into several optimization problems. A model and algorithms provided by [4] for scheduling container handling equipment in an integrated way

in an automated container terminal but it considered only loading operations. Several approaches have been proposed in tactical, strategic and operational way to model the operation. In order to settle the problem, no standard modeling or simulation tool have been made by scientific literature, based on models of mathematical or research on empirical studies [5], formalism of PN [6-8] and simulation tools for non-deterministic event [9, 10].

In particular, container can only be loaded with small items as long as not exceed the weight limit. In such cases, weight limits may appear to be more restrictive than space constraints set by the dimensions of the containers. Weight limits can be model as linear space constraints, where the sum of the weights of the loaded items must be smaller than or equal to the weight limit applied to the container. Issues in weight constraints had been arise by several researchers where they are aim to integrate the problem. For example, [11] handled container problem in which the loading capacity of the container is limited in volume and weight. Weight distribution constraints require that weight of cargo must separate as event as possible across the container floor. The risk that the cargo shifts while the container is moved can be reduced in balanced loads [12, 13]. Unbalanced loads may result in unacceptable, uneven distributions of axle weights when the container is transported.

It is important to provide a good stacking plan for the containers of the train, where load planning is concerned. This planning is aimed to show steps needed in container distribution for final loaded train. When deals with loading plan, several constraints to be considered are limitation of load, weight and height [14]. The combined length of containers that can be placed onto a platform cannot exceed the length of platform. Containers are usually 20 and 40 feet long while platforms come in lengths of 40, 60 or 80 feet. When we are dealing with weight limitation, it will consider number of bogie or wheels. Each bogie or set of wheels have its own limitation in term of weight [15]. In practice, the limitation causes a problem for only a small number of very heavy containers which can only be placed efficiently in a small number of places. Besides that, the total height of any wagon should be restricted to ensure that the train fits under any structures such as bridges when it comes across. A wagon that has lowered platforms can be considered as well wagons since two containers are easy to be stacked.

Generally, environmental factors can be considered as any external factors such as climate and weather where it may affect condition of container. While goods are being transported, they are frequently subject to climatic stresses. It may occur during storage and packaging. Climatic stresses are caused by conditions of changing climatic during inland transport (road or rail) and water transport. Moreover, the condition of extreme climate may happen in different condition, which is from tropical to temperate climatic zones. It is useful to protect the cargo inside from external climatic agents such as rain and light for closed containers. In certain condition, condensation may occur even the containers are protected against these agents. Besides that, moisture in the container influences relative humidity in the container. The enclosed air in the container, the cargo itself, and packaging of cargo and stowage material are examples of moisture sources. Therefore, the cargo should be handled with practical care [16].

B. *The application of Petri Nets*

A Petri Nets (PN) is one of the graphical and mathematical modelling tools invented by Carl Adam Petri in 1962. It is a set of places and transition which are capable tool for specification and analysis on concurrent, asynchronous, distributed, parallel, non-deterministic and stochastic. It also can be used as visual communication aids, that similar to flow charts, block diagrams and network. Through mathematical tools, it deals with state equations, algebraic equations and other mathematical models that lead to the function of the system. PN represents a well-established modelling tool. Their basic capability is in the graphical representation and formal analysis of all processes in a discrete event system [17]. PN are suitable for describing precedence relations, synchronization, mutual exclusion and many other forms of interaction between concurrent events . In other words, PN had been practicing in the area of software design, workflow management, data analysis, concurrent programming, etc.

Recently, PN have been used in simulating the handling of port operation and container terminal analysis in different types of terminal operations. When simulating discrete models of processes such as container loading and unloading, the queuing and delay time for the next activity or event can be identified since it deals with critical system [1]. The capability of Petri Nets covers the integration between activities make it suitable to be captured the container loading and unloading process.

III. **Proposed Research Design**

The proposed framework for developing the performance model is illustrates as in Figure 1. This framework provides steps for modelling approach for further discussion. The method used for this model started with identification of problem and activities involved in the terminal transfer operation. From this step, each activity that involve in the container loading and unloading process will be determined. At this stage, parameter also will be estimated which useful for model formulation. Parameters used in this study consider direct observation real data, real time data and the previous record of rail operator. The combination of primary data from site observation and secondary data consider three main parameters which are container, loading and environmental factors. These factors relate to the activities involved in the process.

The next stage in this proposed framework involves PN application for model formulation and model execution. In order to formulate this model, it requires parameter characterization that derived from the previous stage. At the same time, the model structure will be developed in hierarchical format to illustrate the complexity of the activities involved in the container loading and unloading process. Understanding of proposed model in the hierarchical format provides a clear overview. Activities involved and parameter

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estimated are translated into statics and dynamics properties called place and transition in PN model. In order to formulate and execute the model, PN requires PN tools as a support.

The last stage will consider model verification, calibration and validation. Sensitivity analysis will be used in determining the changes in the parameter of the model. By showing how the model behavior responds to changes in parameter, this analysis is a useful tool in model building as well as model evaluation. Process of validation requires performance assessment of the model. It involves real site data compared with other real data. This is to ensure that the model is proved via following the procedures in the method required and result acquired.
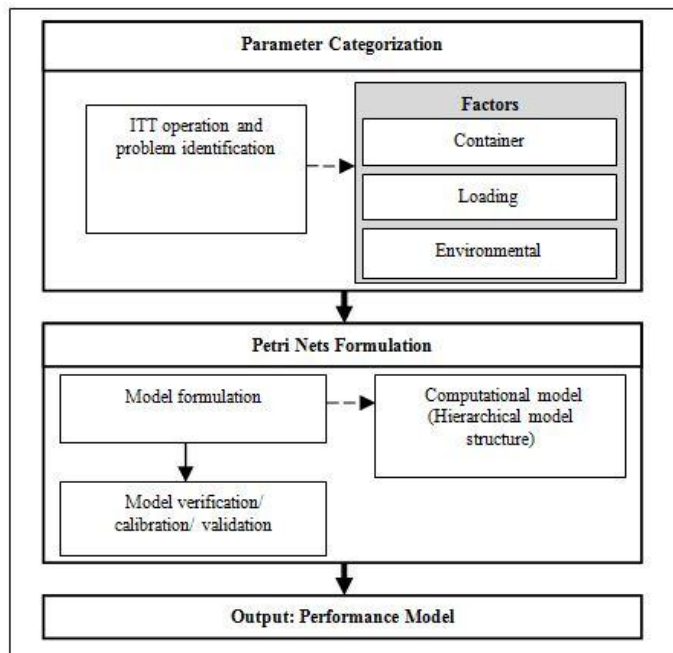

Figure 1.　Model development framework

IV.　**Discussion and Conclusion**

Process of container loading and unloading can be considered as a complex activity. The complexity of the activities is possibly can be observed by segmenting it into sub events. A proper model with hierarchical structure is proposed to make the process more reliable. This paper highlights the proposed framework for optimizing the container loading and between each level. This approach is very significant since it would integrate container, loading and environment factors simultaneously. The integration of these elements is able to be observed directly from the graphical format of PN model. The capability of PN in handling complexity event is highlighted. It is expected that appropriate performance model with potential delay detection will be the output from the study.

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