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Management of Container Terminal Operations Using Monte Carlo Simulation

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Abstract

The escalating demand on container transportation necessitates an efficient container management system to manage daily operations. Perpetual advances in this sector enables us to enhance the overall performance measures such as resource utilisation, time-wastage including waiting and idle times is crucial incapability to manage a vast number of containers effectively. Moreover, such improvements can eventually overcome ground barriers in construction site operations such as resource allocation and synchronisation by providing the transported construction materials. In this on-going project, container management issues are addressed. Additionally, a Monte Carlo simulation model is developed to analyse different resource interactions within the system inability to identify feasible schedules for resources in container terminals.

Keywords: 3D visualisation; container management problem; discrete event methodology; construction products; Monte Carlo simulation; resource allocation and scheduling

1. Introduction

Nowadays, managing containers is becoming more complex due to the massive escalation of transported goods domestically and internationally in both volume and value. According to Coyle et al. (1996), the efficiency of businesses significantly relies on the efficiency of the company`s logistic activities associated with the general organization and their operations regarding the stream of goods. Accordingly, managing container terminals require a sophisticated dynamic system, which has the ability to process the vast number of resources that handles transported containers. Such system necessitates an efficient decision making structure which enables us to intelligently organise resources in terms of location and synchronisation.

The purpose of this project is to boost transporting construction materials in order to deliver them in an efficient procedure, synchronising resources and scheduling them within an intermodal setting is considered as a vital key main frame. Moreover, tackling additional key performance indicators issues such as delays and utilisation problems are well-undertaken inability to enhance the overall performance of the system.

2. Problem Description

The key aim of this project is to provide a feasible allocation and synchronisation of the overhead crane, which presents the main resource responsible for loading and unloading containers onto and from the train. Intermodal transportation is adopted in this project as an infrastructure for the main scenario. The scenario consists of a freight train arriving from destination ‘A’ to destination ‘B’ loaded with a number of containers. The train is divided into three main zones which enable the system to strategically concentrate on each zone individually in order to perform more efficiently. The system checks the inter-arrival time of the first group of lorries incoming randomly to load the cargo and transfer them to a desired destination. If lorries’ arrival times are more than a predefined threshold value, the overhead crane begins unloading the containers, one container at a time on the cargo area. An additional truck crane can be used as well to relocate the containers from the ground onto the lorries. On the other side, if lorries arrive before the beginning of the unloading process, containers will be unloaded onto lorries directly. This operation remains until the first group of containers is unloaded fully.

This instance demonstrates the main issue that needs to be addressed. The location of the overhead crane portrays a major dynamic variable that requires careful examination due to the amount of delay that can be created. Repositioning the crane is also an additional barrier that requires wise tackling inability to reduce the overall time wastage and increase the resources` utilisation percentage. Synchronising the overhead crane with the arrival time of lorries also presents a key factor in which the waiting time of the entities; which are the containers, rely on. This postponement in the inter-arrival time must be reduced to its minimum to lessen the time wastage within the system. Subsequent to the unloading process, a following stage takes place consisting of an additional number of lorries loaded with containers from the current location arrive. The containers brought by the lorries are loaded onto the freight train using the crane and proceeding to the following section of unloading the freight train from incoming containers. Figure 1 below presents a 3D conceptual model that visualises the processes occurring in the system. It also demonstrates how the system processes individual containers based on their colour (type). Lorries incoming to load these containers have similar colours which indicates the targeted containers. Similar attributes and variables must be taken under consideration to enhance the operational functionality such as crane utilization, location, delay, repositioning and truck inter-arrival times.

This is an on-going process until the train is fully discharged from containers arrived from destination ‘A’. Furthermore, lorries will likewise arrive fully loaded with new containers to supply the freight train with cargo ready to be transferred for a new destination. Finally the train is loaded with new containers completely prepared to launch for a similarly succeeding journey.

Figure 1 Problem description

3. Literature Review

A number of works in the area of intermodal modelling is reviewed in order to understand and address issues related to intermodal modelling, container management and other related delay analysis:

Ottjes et al. (2006) introduced a generic simulation model structure for the design and evaluation of multi terminal systems. The model is constructed by combining three basic functions: transport, transfer and stacking. Rizzoli et al. (2002) developed a simulation model to visualise the flow of Intermodal Terminal Units (ITUs). MODSIM III was used as a development tool to implement discrete event simulation as a key methodology in this project. Several elements were assessed using the simulator such as terminal equipment, ITU residence time and terminal throughput using the simulator. Flodén (2007) developed a Heuristic Intermodal Transport model (HIT-model) to assess multi-modal transportation in Sweden. Some of the model`s characteristics is that it is not limited to any specific size or geographical area. Moreover, input and output data can be simply modified, managed and evaluated without necessitating any advanced computer abilities. The model can be used to measure the value of potential intermodal transport systems and to test the impact of changes on the system. Berger et al. (2011) tackled the problem of delays in railway networks. They argued the need for simulation inability to evaluate waiting policies for Online Railway Delay Management (ORDM). A simulation platform was developed to assess and compare various heuristics for ORDM with stochastic delays. Their strategy was to combine both theoretical and practical models to offer better accessibility for users reflecting an enhanced performance. Kondratowicz (1990) provided an object oriented simulation model "TRANSNODE" that offered a tool that can be applied in several scenarios without requiring any user simulation knowledge. The model was initiated to support users with strategic and tactical decisions to evaluate the design and policies of transportation terminals. Additionally, unacceptable outputs from such terminals were analysed such as queues and waiting times as an attempt to resolve them.

On the other hand, this project is characterised to be distinctive in terms of the approach container management issues are tackled, various methods and techniques are mentioned in section 2, which provide uniqueness to this project. Subsequent to identifying bottlenecks in the system and analysing them, 3D visualisations to support the problem understanding phase in the project. Additionally, Monte Carlo simulation will be applied in this project to provide optimal crane allocation and synchronisation.

4. Container Management Simulation Modelling

In ability to identify and breakdown the logic of this container management scenario, several diagrams were developed as logical identifying models. These forms of models help investigate in the main barriers that need to be addressed such as delay causes; which present a key issue in transportation systems.

4.1. Model development architecture

The system operates initially through inputting specific variables by a user. Values inserted for such variables consider the number of trains, containers, lorries and other related fields inability to explicitly customise the system based on the necessitated scenario. Afterwards, the system processes the inputs and starts developing a sequence mainly based on the initial position of the crane and the number of trains arriving. Meanwhile, for every sequence generated a separate excel spread sheet is created which contains the key performance indicators in the system. This spread sheet provides the user with a friendly interface that contains all the desirable average values for attributes such as resources` utilisation, ideal time, waiting time and number waiting. The system keeps operating and populating sequences through a Monte Carlo technique while saving each sequence and its outcomes. Eventually, the system will provide the user with all possible results with the best sequence for the overhead crane as an optimal schedule linked with the random arrivals of lorries incoming to load/unload containers from and onto the train.

One of the major barriers appeared while developing the code for the sequence function is synchronising the last positioning value of the sequence for the current train with the initial positioning value for the following train incoming. This issue was resolved through developing an additional function that tests if the above-mentioned positioning values are identical, or not. If both values are equal, the function passes the sequence to the system to generate the outputs. If not, the function keeps swapping digits within the same sequence until the desired goal is achieved which is an identical value. This functionality is characterised of not only synchronising sequences but also it increases randomness to the newly formed sequence.

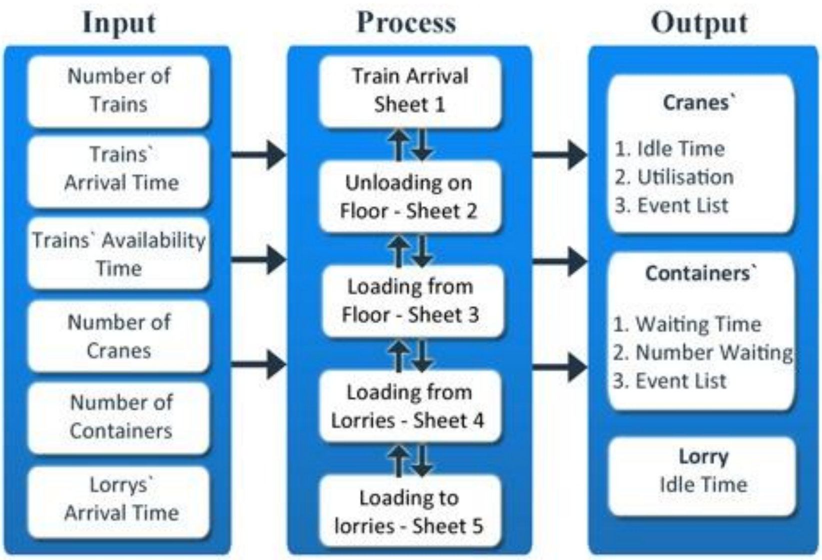

Figure 2 Container management diagram

In Figure 2, the process block is affected by the inputs inserted by the user which provide the backbone in which the system operates. Additionally, the sheets which present the main elements in the process block are linked together to obtain accurate results from the system. An example of such linkage is using outputs from sheet 1 such as train`s waiting time as inputs in sheet 2 to calculate containers` overall waiting time. As Figure 2 shows, all sheets are connected together with one or more links. Outputs gained from the process block are used to resolve bottlenecks in the system which provides potential solutions to be applied in construction material transportation.

4.2. Delay analysis

As the key elements that affect the performance of the system were acknowledged in previous stages, delays presented one of the major factors. The fish bone diagram is famous for identifying possible causes of a certain issue. Therefore, a diagram was designed for this project to visualize the potential ground roots for delay causes in the system to reduce time wastage for resources. Figure 3 shows analysis of delay relates to container management using fish bone technique.

The diagram breaks down delays into four main sources. The forwarder is the first source, which presents the delay causes of pre-arrival entities and resources. The dispatching operator mainly controls this source. In addition, the forwarder source is characterised to be hard to tackle as it is mainly affected by external factors.

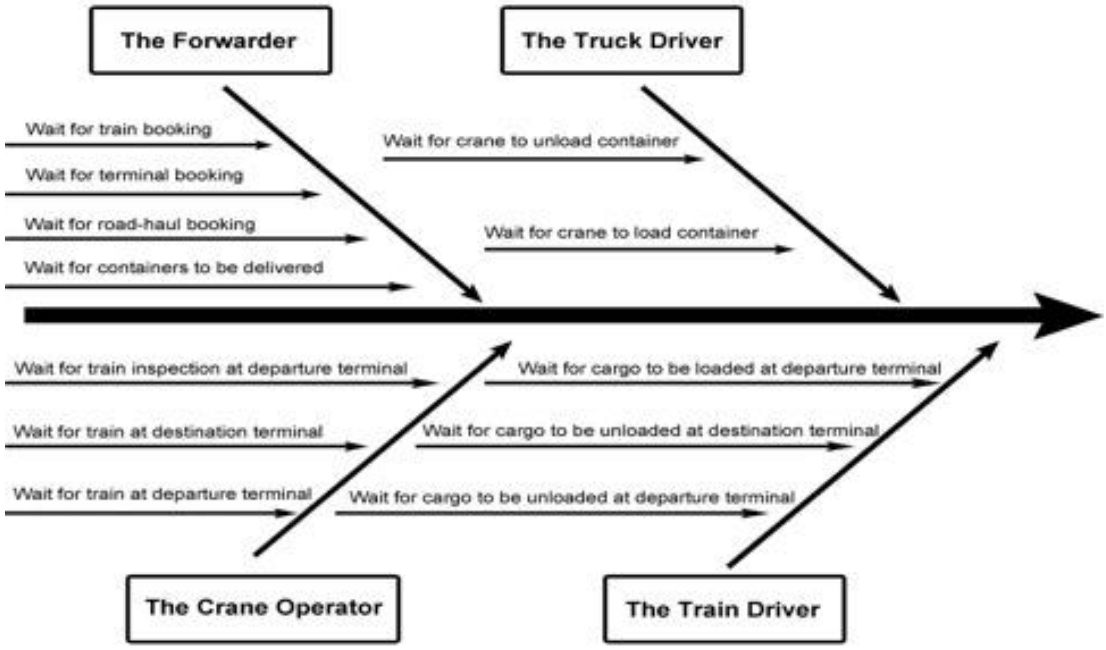

Figure 3 Fish-bone diagram for container management delay analysis

The truck and train driver present the second and third delay sources in Figure 3. These two sources can be considered; as the main flexible components were the delay could be minimised inability to reduce the time wastage in the system. The fourth delay source is the crane operator; this source considers waiting for the train arrival at both destinations. Synchronising the terminals is the main key for decreasing the delay in this source.

5. Case Study

This project is for one of the logistics companies in the United Kingdom researched inability to improve construction materials` transportation. Therefore, key issues were addressed in order to develop the overall construction operations. Evolving the transportation approach will eventually lead to an improved construction process through utilising resources efficiently and reducing the total wastage time in transporting construction materials and products.

6. Future Work

- Run the developed simulation model
- Collect all relevant data such as train and lorry arrival times.
- Validate the developed simulation model using a case study.
- Develop a heuristics rule to investigate promising crane schedules.

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