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Proposal for Management and Control of Intermodal Containers Using Monte Carlo Simulation

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***Abstract*— when examining the increased attention in freight transportation, a necessity for sustainable and efficient transportation system appears. The presence of road and traffic complications as well as environmental concerns forces us to develop or adapt an alternative operational system that allows us to overcome these issues. Moreover, the escalation in fuel prices in addition to driver issues for road-only haulage forms an unprofitable and unreliable approach. In this on-going MBA project, container management issues are addressed. A number of delays and their casuals are discussed and analysed. Moreover a Monte Carlo simulation framework is proposed to be used to analyse the interaction of different loading and unloading resources and containers within intermodal container management.**

***Keywords* — Container Management Problem, Intermodal Freight Transportation, Monte Carlo Simulation, 3D Visualisation and Delay Analysis**

I. Introduction

According to [1] intermodal transportation is using a sequence of at least two transport modes in a single chain. Road networks are generally recognized as accessible to almost any location needed. This advantage is almost absent in any other transportation method such as rail, sea and air networks. In addition, road networks are acknowledged to be the most flexible method for transporting goods within a reachable destination. Meanwhile, rail networks are famous for the ability to transport goods for long distances at a low price. The combination of both freight and road networks provide a reliable sustainable cost-efficient approach which can be further more utilized through simulation to provide a systematic structure to be competently employed.

Intermodal transportation systems feature the advantage of being more efficient and reliable compared to unimodal systems. It is also considered to be much more complex due to the involvement of multiple systems within one chain. The inclusion of several decision makers to utilize numerous linked resources can produce a vast uncertainty. This demands a reliable consistent decision support system that can synchronize multiple dynamic resources efficiently.

In this project, container transportation and management is analysed by combining both rail and road modes. This transportation style for handling containers is approached to utilise the several strengths provided by these modes.

II. Problem Description

This project`s aim is to create a reliable efficient decision support system through Monte Carlo simulation. The “As-Is” scenario consists of a freight train arriving from destination ‘A’ to destination ‘B’ loaded with a number of containers. An overhead crane begins unloading the containers upon the arrival; one container at a time. This operation remains until the first group of containers is unloaded on the cargo zone.

This instance demonstrates the first issue that needs to be addressed. Upon the arrival of the train, 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 require to be wisely tackled to reduce the overall time wastage and increase the resources` utilization percentage.

After unloading the first group of containers, a number of lorries arrive randomly to transfer these containers. In this project, an additional truck crane is used to relocate the containers from the ground onto the lorries. The arrival time of lorries in this section presents the 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.

After finalizing the previous 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 truck crane and proceeding to the following section to load from the goods on the ground. 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.

his is an on-going process until the train is fully discharged from containers arrived from destination ‘A’. In addition, lorries will likewise arrive fully loaded with new containers to

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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. Fig.1. below shows the container management problem diagram.

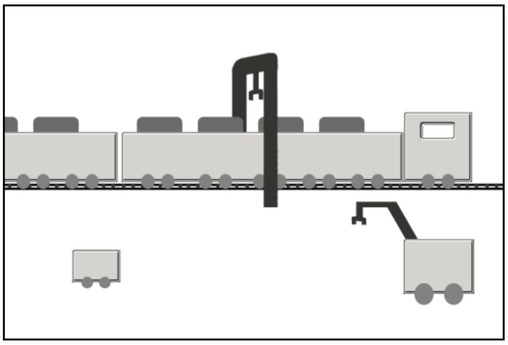

Fig. 1. Container Management problem diagram

The problem diagram in Fig.1 demonstrates a train loaded with containers. Two types of cranes (overhead and a huge forklift) appear to load and unload containers, finally a lorry which presents the second modal of transportation. The combination of all linked modules in fig.1 presents the main elements in this project.

III. PREVIOUS WORK IN CONTAINER MANAGEMENT

A number of works in the area of intermodal modeling is reviewed in order to understand and address issues related to intermodal modeling, container management and other related delay analysis: [3] examined the performance of intermodal networks within regions with widespread waterway networks through discrete event simulation methodology.

[2] 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. [4] assessed the potential demand for US coastal container ports. They identified some major issues in port planning, development and decision-making. A simulation model was developed for multi-modal container transportation to evaluate the impact of use fees on port demands and the properties of sustainability. [5] 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. [6] 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. [7] 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 used which provide uniqueness to this project. Subsequent to identifying bottlenecks in the system and analysing them, 3D visualisation was produced using Autodesk Maya to support the examination phase in the project. Additionally, Monte Carlo simulation will be applied in this project to provide efficient outcomes for utilisation, synchronisation and time-wastage issues.

IV. AIM & OBJECTIVES

The complexity of intermodal transportation chains generates a degree of uncertainty and ambiguity to decision makers that are responsible for managing and controlling the system. Additionally, integrating multiple transportation modes within one system that defines intermodal transportation stands as a solid obstacle for efficiently synchronizing resources to amplify their utilisation.

The main aim of this project is to propose an innovative Monte Carlo Model that processes various dynamic variables and attributes in ability to form a reliable efficient potential solution of intermodal transportation systems. Moreover, this system strategically support decision makers and provides a firm backing to operating frameworks and IT infrastructures.

A number of objectives are set to deliver the aim above:

- To review the current practices in the area of container management and other intermodal odelling.
- To identify the logic of container management operations in order to understand the current mechanism of such operations for further improvements.
- To develop a 3D animation that describes the problem being investigated for better understanding.
- To preview the general "As-Is" scenario and all prime operations within the system.
- To analyse the container management current delay and its causes.

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- To develop a Monte Carlo simulation framework as a first phase of container management optimisation model.

V. Proposed Conceptual Model for the Container Management Model

Due to the complexity of intermodal transportations, a proposed conceptual model adopted in this project was introduced to breakdown the operations within the system. The model connects the inputs of this scenario such as train and crane numbers and arrival times. These dynamic inputs presented in the diagram provide the main interactions which affect the system, see fig.2.

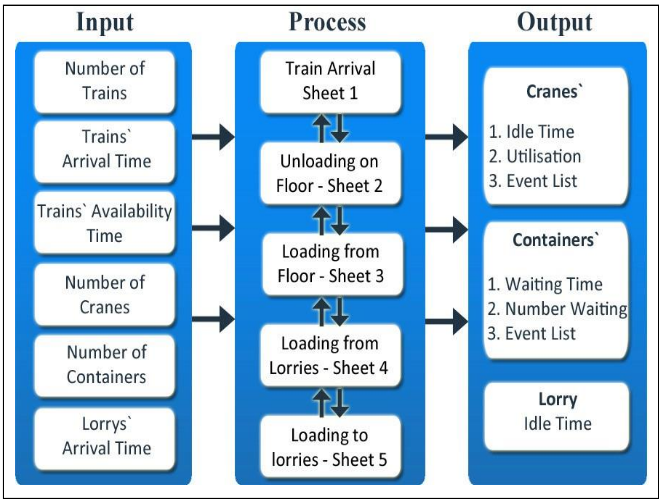

Fig. 2. Container Management Diagram

In fig.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.

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VI. Simulation Model Development

In ability to furthermore identify the logic of container management, certain models were developed such as a flowchart and a fish bone diagram. These types of models help investigate in delay causes which present the main key issues in the transportation system.

A. Logic Identification

Fig.3 presents the flowchart which was designed as a method for simplifying the logic of the system. This chart serves a step-by-step visual presentation of detailed processes within the system. Each major component was stated in the diagram to identify the inputs and outputs affecting it inability to recognise the elements that needs to be tackled. Additionally, this chart serves as a supportive technique to firmly understand the logic of the system and to create a planned strategy to enhance key performance indicators within the system.

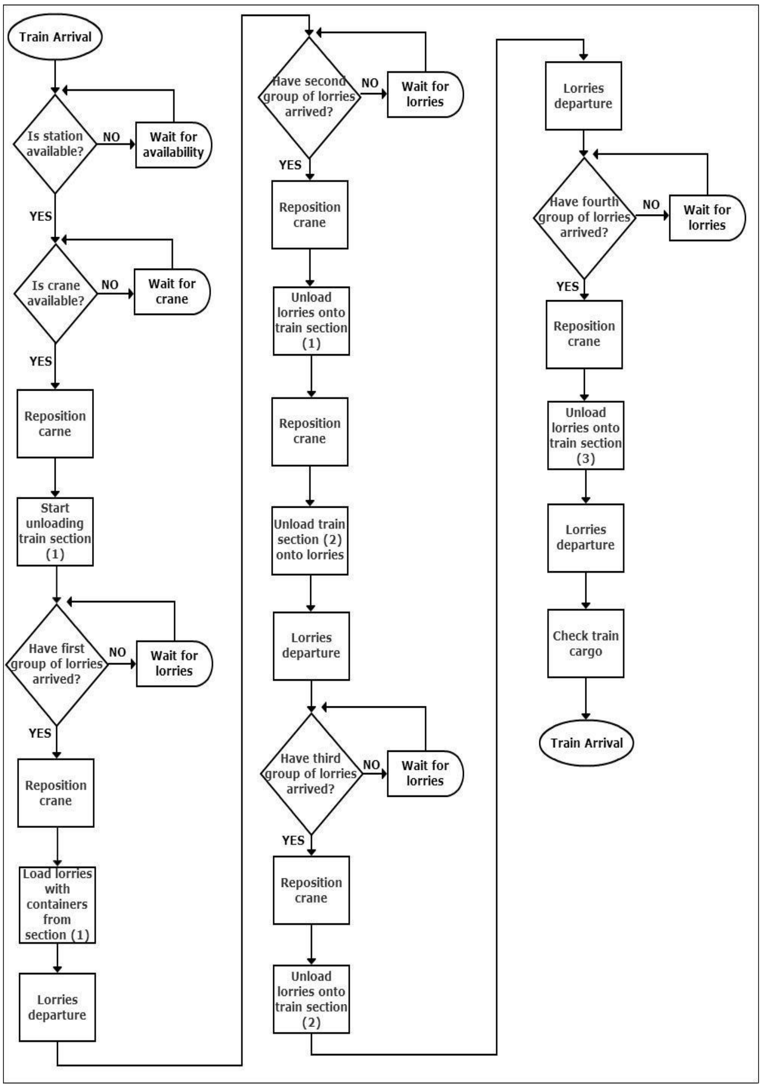

Fig.3. The container management logical operations

The above flowchart starts with the arrival of the train. Following is a check for the availability of the station. This check occurs with every train arrival in the system to assure the readiness of the station to comprehend the incoming train. Correspondingly, a check for the availability of the crane

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occurs. If the crane appeared to be busy, the system will keep waiting for its availability due to the fact that there are no operations to be done other than unloading containers using this crane. Following each single check is a crane repositioning operation. This particular operation takes place with the start of every loading/unloading process.

Next is the unloading phase which initiates with the readiness of the crane. This process will carry on until the lorries arrive to the terminal and reach the cargo area inability to load the containers from the ground and depart.

Subsequently is a continuous similar phase with the exception of the lorries being loaded with outgoing containers to be placed onto the train. This is an on-going process until the train is loaded with new containers inability to depart to a new location.

B. DELAY ANALYSIS

As the key elements that affect the performance of the system were identified, delays presented one of the major factors that need to be tackled inability to introduce an efficient system to be applied. 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. Fig.4 shows analysis of delay relates to container management using fish bone technique.

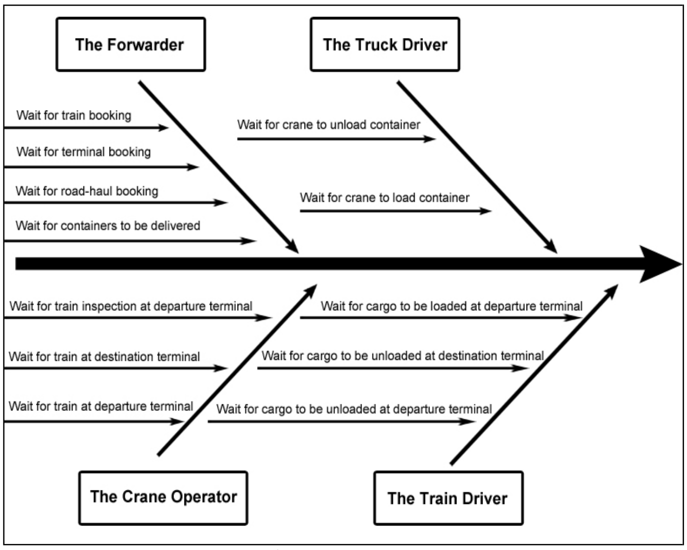

Fig.4. Fish-bone diagram for container management delay analysis

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

The truck and train driver present the second and third delay sources in figure 4. These two sources can be considered as the main flexible components were the delay can be minimised inability to reduce the time wastage in the system.

The fourth delay source is the crane operator; this source is about waiting for the train arrival at both destinations. Synchronising the terminals is the main key for decreasing the delay in this source.

VI. CASE STUDY

Synchronizing and utilizing the resources within intermodal container management is considered as the key main frame in this project. Additionally, minimizing the overall time wastage and introducing potential solutions are strongly undertaken in this system.

Tangible outcomes will be presented by the completion of this project to provide beneficial solutions to the field of container management and intermodal transportations. Monte Carlo simulation is used as a core technique and discrete event methodology is presented as the backbone for this project. Furthermore, business operations will be evaluated based on dynamic variables to subsequently deliver a comprehensive decision support system.

This project is for one of the logistics companies in the United Kingdom. Therefore, one main scenario is tackled in this project which is based on a specific number of containers, trains and lorries: A single freight train transports 30 containers from destination A to destination B. These containers will be unloaded on the cargo area by two types of cranes (overhead crane and truck crane). Each 10 containers will be treated as a set inability to breakdown the unloading process. After unloading the first 10 containers on the ground, 10 lorries will arrive randomly to load them and depart. The second two groups of containers will be treated exactly the same. Additionally, the second, third and fourth groups of lorries will be loaded with containers to supply the goods required for the train to deliver from destination B. After exchanging the 30 containers from both destinations, the freight train will depart.

A. Data Collection

Onsite visits were scheduled and attended by the researcher to personally investigate and identify the main problems in the system. Furthermore, real-life observations simplify business processes and operations that help generate a firm understanding of the overall setting, see table 1.

ISSN: 2961-662X

Table 1. Loading Train with Containers

Train Loading				
		Operator`s Experience		
Item No.	Item Name	Longest	Mode	Shortest
B2E1	Deciasion: Box Route	E	E	E
B1.1	Delay: Box to Ground	0.5	0.25	0.25
B2.1	Wait Incoming Train	5	4	2
B2.3	Long Delay: Box to Store	168	120	1
B2.4A	Recover Box to Ground	0.5	0.25	0.25
B2.5	Box Loaded to Train	0.05	0.25	0.25
B2.6	Wait Train Loaded	1.5	2	5
B2.7	Pre-Departure Checks	1	0.75	0.5
B2E2A	Final Manifest + Tops	1	0.75	0.5
B2.8	Wait Scheduled Departure	2	1	0
B2E3	Train Departure	E	E	E

Additionally, tools such as stop watches were used to accurately measure time durations for processes to be complete, this type of data gathering is crucial to supply the research with vital operating information. A sample of time duration amounts is presented in table 1. This table views different time durations for some of the operations for the train loading process, these durations provide essential inputs for the As-Is scenario.

B. 3D Visualisation of Container Management Operations

The current scenario of the container management process is visualised to gain better understanding of the problem being investigated. The processes involved in such operations have already been discussed in section VI. See the figure below for a visualised aspect being used:

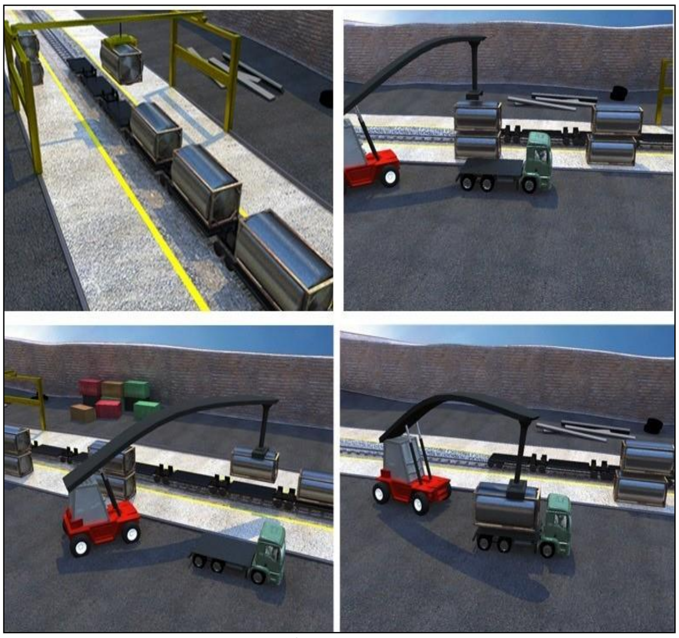

Fig.5. 3D visualisation of container management operations

Fig.5 presents the four core operations in the system. All operations are linked together inability to successfully unload incoming and load outgoing containers.
The image on the top left presents unloading incoming containers on the cargo area. Following is the image on the top right which presents the process of loading containers from the ground onto lorries. The image on the bottom left visualise the process of unloading containers directly on lorries from the freight train. Finally, the image on the bottom right views the process of loading outgoing containers from lorries onto the train directly.

VII. Future Phase of this Work

As mentioned earlier, this is an on-going project which will be furthermore extended. As an initial phase, additional Excel spread sheets will be populated to consider a dynamic number of containers, trains and lorries. Employing these spread sheets will enable us to generate several “What-If” scenarios that host multiple numbers of cranes and forklifts.

A mathematical model will be developed to identify optimal allocation of resources involved in the container management process. Visual Basic for Applications (VBA) will also be used as a programming language to develop a graphical user interface for data input.

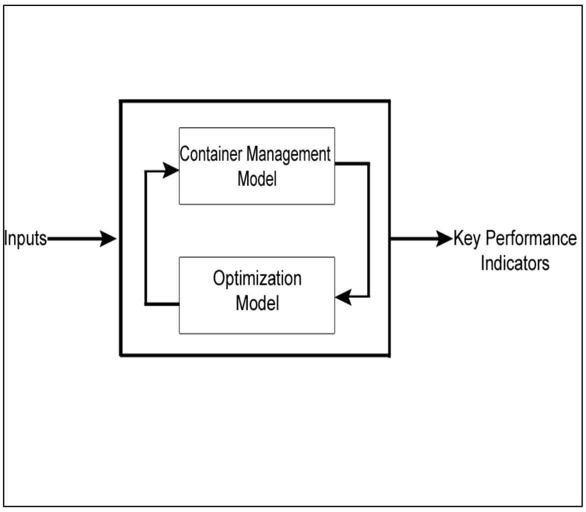

Fig.6. The proposed optimisation module

The method presented in fig.6 will help manage and control data in Microsoft Excel. Moreover, the ability to control the variables in the system such as the number of resources and entities will provide the capability to make the system easily applicable in diverse scenarios. Finally, Solver a Microsoft Excel add-in will be used for optimisation purposes as mentioned in fig.6.

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