Mechanics Transport Communications
ISSN 1312-3823 (print)
ISSN 2367-6620 (online)
volume 20, issue 2, 2022
Academic journal http://www.mtc-aj.com **article № 2211**

VEHICLE TO VEHICLE COMMUNICATION AT AUTOMATED CONTAINER TERMINAL

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***Key words**: Automated Container Terminal, Internet of Things, Vehicle-to-Vehicle and Vehicle-to-Infrastructure Communications, Simulation, Efficiency.*

***Abstract**: The aim of any Container Terminal is to increase efficiency to be able to handle the increase in demand and the increase in container vessel size. Considering the limited space and resources of any container terminal and the high cost of increasing the capacity, automation can be an efficient solution. Automated Container Terminal became a worldwide trend to be applied to many big container terminals. In addition, many researches are focusing on this topic to use automation and other technologies to increase efficiency in container terminals. This research paper will use Internet of Things (IoT) technology to increase transportation efficiency at an Automated Container Terminal. In addition, the research paper proposes an algorithm to increase efficiency in the automated container terminal and achieve the research objective. Finally, a simulation results will be shown to prove the effects of using the proposed algorithm in decreasing total discharging time and reducing terminal handling charges.*

I. INTRODUCTION

According to UNCTAD (2011), container business is the fastest growing type of freight transport with an average increase of 8.2 percent per year on cargo quantities between 1990 and 2010. In addition, according to Luo and Wu (2015), more than 60 percent of total general cargo shipping is done using containers. Containers are steel boxes that consist of three length standards, which are 20 feet, 40 feet and 45 feet. These boxes designed to increase material handling efficiency and reduce cargo damages. As a result of that fast demand growth of container shipping, sizes of container ships are increasing rapidly as well. Carlo, Vis and Roodbergen (2014) said that container ships capacity increased from few hundreds of TEUs (Twenty Feet Equivalent Units) since 1955 to more than 14 thousands TEUs today.

Moreover, to handle this rapid growth in container business and large container ships, many countries are expanding their container terminals. In addition, countries are investing not only in expanding terminals capacity, but as well in advance container terminal technologies to increase operations efficiency. According to Luo and Wu (2015), "With the development of material handling and information technology, a number of terminals, such as Europe Combined Terminal (ECT) in Rotterdam, the Container Terminal Altenwerder (CTA) in Hamburg, the Thames Port in the UK, the Pasir Panjang Terminal (PPT) in Singapore, the

Patrick Container Terminal in Brisbane and the Pusan Eastern Container Terminal, have started to employ automated container-handling equipment so as to satisfy the customers' growing demands and lower the labor costs". Furthermore, automated container terminal is the new trend of scientific research for many scientists and research centers. The new automated equipment's and the advance technology resources opened up many new research trends for resources scheduling and operations optimization.

Automated container terminal can be divided to three main operation equipment's as the following: 1- Quay Cranes (QCs), 2- Automated Guided Vehicles (AGVs) and 3- Automated Stacking Cranes (ASCs). Quay Cranes (QCs) are responsible for loading and discharging containers from and to vessels on the berth. These QCs are semi-automated cranes which are operated by operators at a remote control room. Crane operator will load and discharge containers according to stowage plan that the port will receive before vessel berthing to specify the sequence and location of each container in the ship. In addition, Automated Guided Vehicles (AGVs) are responsible to take containers from QCs and transport them to storage yard on discharging operation and from storage yard to QCs on loading operation. These AGVs are driverless vehicles which are moving based on pre-defined paths. They are equipped with sensors, controllers and other advance technologies to control autonomous movements. Finally, Automated Stacking Cranes (ASCs) are automated handling equipment's which are handling containers from AGVs when they arrive to storage yard. These ASCs job is to shift each container to a specific storage slot. Storage slots are represented by three variables x, y and z by allowing to stack containers above each other. In addition, ASCs are responsible to shift the container from the storage yard to the cargo receiver truck. To shift the container from the storage yard to the cargo receiver truck, the ASC is coordinating with the terminal gate to manage the traffic and insure smooth transportation at the gate. Currently, most of the container terminals are using a booking appointment system for the receiver trucks to manage the traffic at the terminal. However, this research paper is proposing to use Internet of Things (IoT) technology to allow smart communication between the QC and cargo receiver truck to increase the transportation efficiency at the Automated Container Terminal. The research paper is divided to the following sections: after this introduction, section 2 will have a Literature Review which consists of an overview for the related works which were done by other researchers in the literature. Then, section 3 shows the methodology which has the design framework and the proposed algorithm that will reduce vessel discharging time and reduce terminal handling charges. Section 4 will have the experiments and simulation results that have been taken from Arena simulation software. Finally, section 5 will conclude the work and give some recommendations.

II. LITERATURE REVIEW

A. Overview

The literature review are divided to 2 main parts as the following: the primary part will discuss differing types of container terminal operations from different researchers point of view. Additionally, it'll show several research papers on the way to increase AGVs dispatching efficiency and avoid vehicles collisions. The second part will concentrate on the utilization of Internet of Things in logistics sector and it'll show how Internet of Things can increase transportation efficiency.

B. Container Terminal Operations

Many researchers in the literature studied different operational aspects in the container terminal. Each one of these authors looked at those operation problems from different angle to provide more efficient solution than existing ones. Huang, Yan and Wang (2015) proposed a mixed integer programing model to optimize scheduling of non-automated container terminal resources. The researchers focused on optimizing the scheduling of Quay Cranes, Internal Trucks and Yard Cranes. The objective of the model is to minimize vessel waiting time and reduce terminal energy consumption. In addition, they integrated a Genetic Algorithm in their model and tested the efficiency of the suggested model. Wu, Luo, Zhang and Dong (2013) suggested a linear mixed integer programing and non-linear mixed integer programing models to increase container yard efficiency. The linear method used for storage planning and resources allocation in the terminal. In the other hand, the non-linear model used to decrease computational period and eliminate some constrains. In addition, the researchers suggested a Genetic Algorithm for the linear model to show the performance effects of several variables in the model and prove its ability to handle large computational problems. Luo and Wu (2015) proposed a mixed integer programing model for AGVs (Automated Guided Vehicle's) dispatching and storage allocation optimization under objective of minimizing vessel berthing period in a fully automated container terminal. They used simulation software to show the optimal solution for small size computational problem. Moreover, the researchers proposed a Genetic Algorithm to solve larger problems because of its efficient computational time advantage. According to Xin et al. (2015), "The control of automated container terminals is complex since Quay Cranes (QCs), Automated Guided Vehicles (AGVs) and Automated Stacking Cranes (ASCs) interact intensively for transporting containers, while collision avoidance of equipment must be ensured". In addition, the authors proposed a mixed integer linear programing model with has an objective of minimizing terminal operations time. The proposed methodology considers safety of operations between all the container terminal equipment's. Finally, they provided a simulation results that prove the advantage of the proposed methodology.

C. Internet of Things

Rapid technology evolution is a great advantage of solving complex problems surrounding us, and one of these advance technologies is Internet of Things. Internet of Things (IoT) is the technology of smart and connected systems, which can makes our life much easier and efficient. According to Sun (2012), "Internet of Things is defined as: The radio frequency identification (RFID), infrared sensors, global positioning systems, laser scanners and other information sensing device, according to the agreed protocol, to any article connected to the Internet up to information exchange and communication, in order to achieve intelligent identify, locate, track, monitor and manage a network". According to Lee and Lee (2015), there are five types of technologies, which act as Internet of Things components. These technologies are the RFID, which acts as an electronic identification for the device, wireless sensor network to sense the physical environment, middleware, which is backend software, cloud service, which acts as a central online-shared data center, and application software as a frontend user software. In addition, there are three categories of Internet of Things applications, which are monitoring and controlling, collaboration and information sharing, and business analysis and big data.

There are a lot of authors in literature wrote about Internet of Things technology in supply chain and logistics industry, and suggested smart solutions and designs to increase efficiency. Gnimpieba, Nait-Sidi-Moh, Durand and Fortin (2015) proposed a collaborated platform architecture that consists of Internet of Things, Cloud Computing, GPS/ GPRS and RFID technologies that is able to monitor and control containers in logistics business. In addition, this platform will allow all supply chain parties to track cargos and share information to increase operation performance. Haass, Dittme, Veigt and Lutjen (2014) proposed a smart container solution, which can save food from being wasted. This solution controls container temperature and guide the truck driver to deliver the food cargo using the fastest route.

In addition, many researches were conducted on using Internet of Things and smart technologies in container terminals. According to Siror, Huanye and Dong (2011) “Ports globally face considerable challenges ranging from efficiency in operations to security threats. These call for research on innovative solutions with minimal reliance on manual interventions and controls”. As a result, they proposed an RFID based smart solution for Mombasa container terminal. This smart solution considers the operations of containers, which are entering, exiting or still in the terminal. It gives the status of containers, tracks them, allows authorized and stops unauthorized containers. Finally, the authors tested the benefits of the proposed solution using simulation software to show operations of the port. Furthermore, Tsai and Huang (2012) studied the Cost and Benefits Analysis of applying RFID e-seal system in Kaohsiung Container Terminal, Taiwan. This system was proposed from Taiwan government to add safety and increase efficiency in the container terminal. The researchers concluded that the benefits, which the container terminal will get, are much more than the cost of the suggested system.

There are many researchers studied the effects of Internet of Things on transportation sectors and how to increase traffic efficiency. Ashokkumar, Sam, Arshadprabhu and Britto (2015) proposed a smart transportation platform based on cloud and Internet of Things technologies. This platform will allow drivers to share traffic information, which can lead to more efficient and safer transportation. In addition, the researchers contributed on building a computer program, which connect Internet of Things system, which can be installed on cars, with cloud, based system in one platform. HomChaudhuri, Pisu and Ozguner (2015) suggested a methodology for connected cars localization and distributed fault diagnosis using Vehicle-to-Vehicle communications. The authors used a Dedicated Observer Design schema for the isolation and fault observation process. Furthermore, they showed some results, which prove the efficiency of their suggested solution. Talebpour, Mahmassani and Hamdar (2015) proposed a collaborated game theory model for vehicles lane changing in a connected cars platform. This model will help drivers for safe lane changing to avoid traffic conjunctions and collisions. In addition, the authors succeeded to show good results of predicting lane-changing events and prove that the proposed model performs better than a basic gap-acceptance model. Osman and Ishak (2015) proposed a Connectivity Robustness model, which helps to test status of Vehicle-to-Vehicle Communication. This model considered real life physical factors that can affect connectivity of connected cars environment. In addition, researchers used regression analysis to study those physical factors. Finally, the results of the study showed the effectiveness of the proposed model on finding the level of significant of the studied physical factors. Guler, Menendez and Meier (2014) claimed that information such as, instantaneous velocity and location for all cars in an intersection will help to control the traffic much more efficiently. The researchers proposed an algorithm that collects these data and controls the flow of connected cars in the intersection to achieve less waiting time. Finally, they tested the proposed algorithm and achieved a 60 percent decrease in waiting time for small size traffic problem.

As a result, according to the above literature review and as shown below in figure1, it is clear that there is a research gap in using Internet of Things for AGVs traffic optimization in the automated container terminal. As proven in the above literature review, applying Internet of Things in transportation sector increased traffic efficiency and reduced possibilities of collisions. However, this thesis will show that using Internet of Things and Vehicle-to-Vehicle Communication technologies in AGVs can increase traffic efficiency in the automated container terminal to achieve the objective of reducing vessel-discharging time.

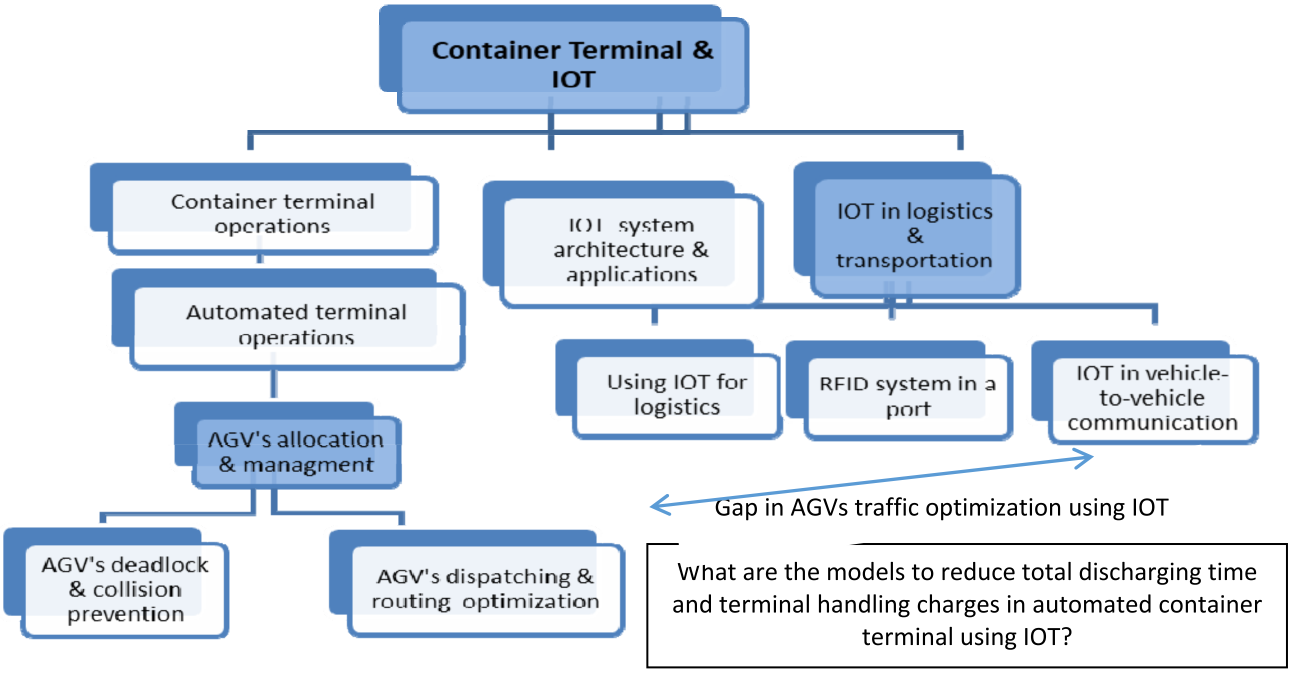

Figure 1: Literature review map

III. METHODOLOGY

This research paper will be focusing on the lower level of the AGVs operations only. The lower level will consider the movements of AGVs, obstacles detections and collision avoidance between AGVs and other static obstacles.

❖ *AGVs movements:*

As shown below in figure 2, AGVmove function will begin by calculating the number of zones needed to be crossed during transportation from current location to point of origin and from point of origin to point of destination of the AGV. Then, the function will call obstacle_detection function to check if there is an obstacle in front of the AGV it will call collision_avoidance function otherwise it will move one zone foreword and it will repeat this process to move until it reach to the point of destination.

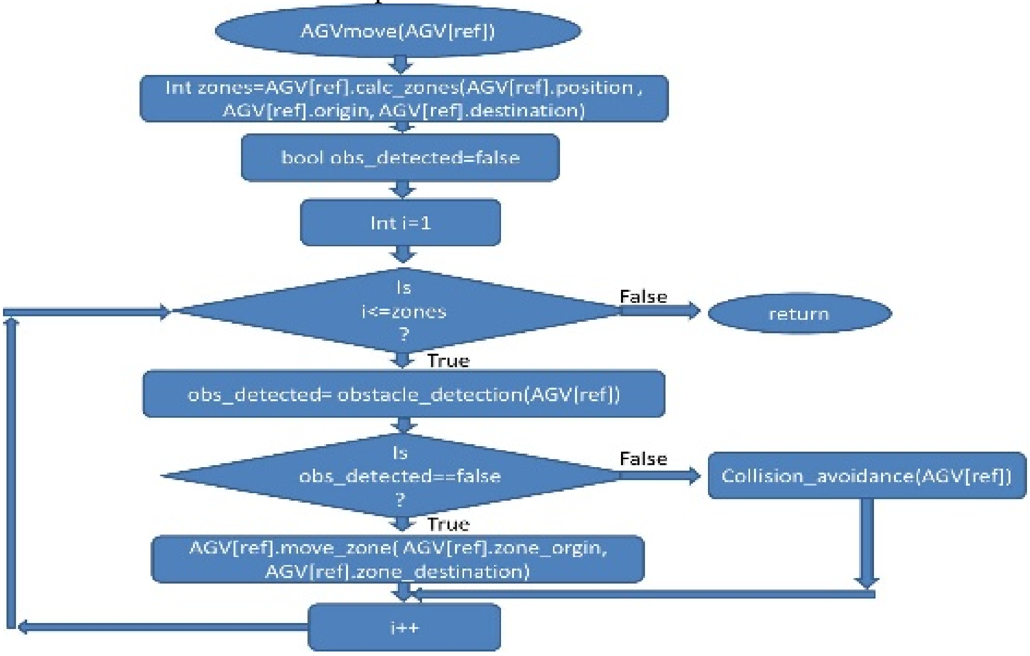

Figure 2: AGVmove function, which is responsible for AGVs movements

❖ *Obstacles detection:*

In the automated container terminal, there are two types of obstacles 1- Static Obstacles and 2- Dynamic Obstacles. Static Obstacles are the non-moving obstacles such as cranes and the other infrastructure in the container terminal as shown in figure 3. On the other hand, Dynamic Obstacles are the other AGVs, which are moving and interacting with each other using common paths and intersections. To manage these interactions Vehicle-to-Infrastructure and Vehicle-to-Vehicle Communications will be used to assure smooth and safe transportation in the automated container terminal.

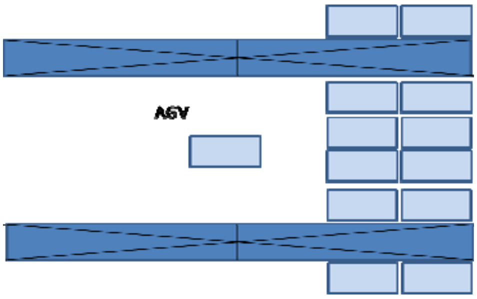

Fig 3(a): Outer view of the 2 static obstacles

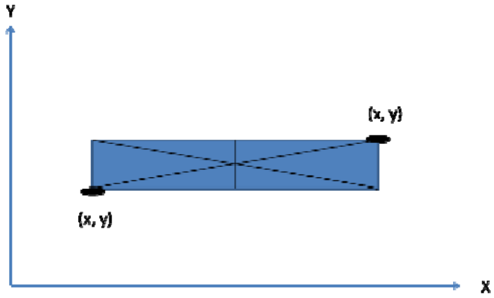

Fig 3(b): Focused view on dimensions of static obstacles

As shown below in figure 4, Vehicle-to-Infrastructure communication will help to detect static obstacles by allowing the AGV to know the exact location of all the static obstacles in the automated container terminal. This can be done by uploading a detailed map with all exact dimensions and locations of static obstacles to a central cloud system that a local AGV system can read. In addition, the infrastructure will broadcast a message to all surrounding AGVs to alert them from a possible collision with it.

Vehicle-to-Vehicle Communication will be used to detect dynamic obstacles while an AGV is moving. There will be a local system in every AGV and this system will contain an one-meter accuracy GPS and a radar sensor to act as a two layers safety sensor.

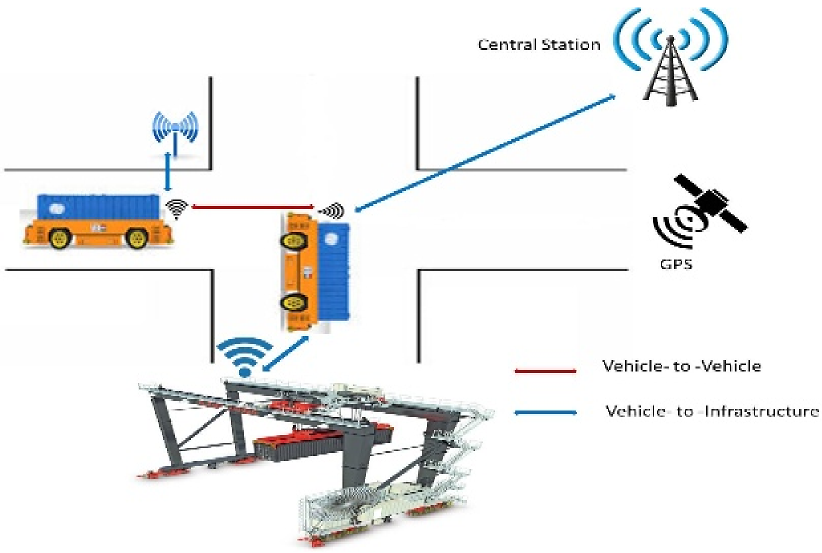

Figure 4: Vehicle-to-Vehicle & Vehicle- to- Infrastructure Communications

Every AGV local system will share its real time location with other surrounding local systems and the central cloud system to allow other AGVs to read this important information. In addition, the radar sensor, which surrounds the AGV, will act as the second layer of safety to detect any obstacle surrounding it. So, these two layers of safety will assure correct detection of obstacles by analyzing the two readings and giving a better decision.

Furthermore, Obstacle_detection function will read and analyze the readings from the GPS and the radar sensor. Based on these readings the function will decide if there is an obstacle in the way of the AGV or no as shown below in figure 5. The function will return a true to AGVmove function if any of the two sensors detect an obstacle and false if no obstacle detected.

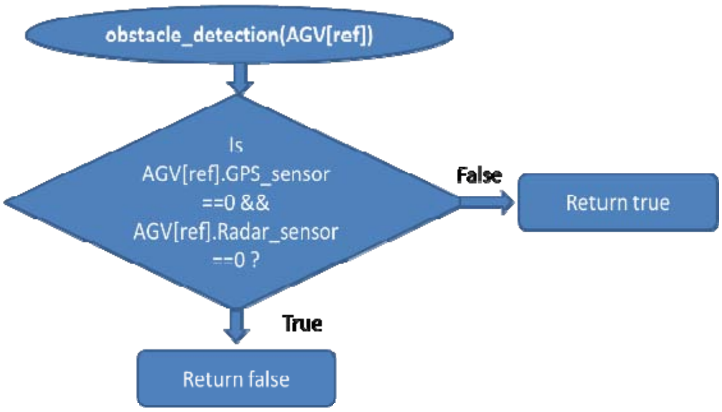

Figure 5: Obstacle_detection function, which is responsible for detecting any obstacles in the way of AGVs

❖ *Collision avoidance:*

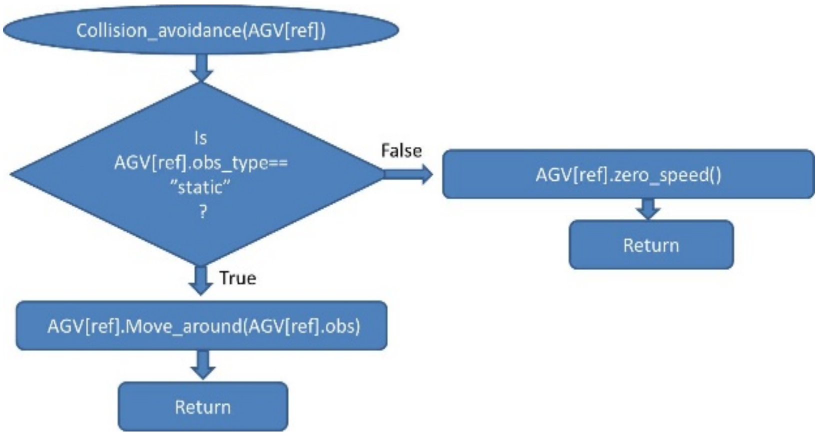

Figure 6: Collision_avoidance function, which is responsible to control AGVs movements to avoid collisions

IV. EXPERMINTS

A. Reference system

To apply some experiments and prove the efficiency of the suggested methodology we can use below typical container terminal map in figure14 that shows the environment of the operations (Xin et al., 2015). This container terminal map or reference system assumes 5 QCs for discharging containers from the ship, 5 AGVs to transport containers from the QCs to the ASCs and 5 ASCs for 5 stacking areas so each ASC will be responsible for one stacking area.

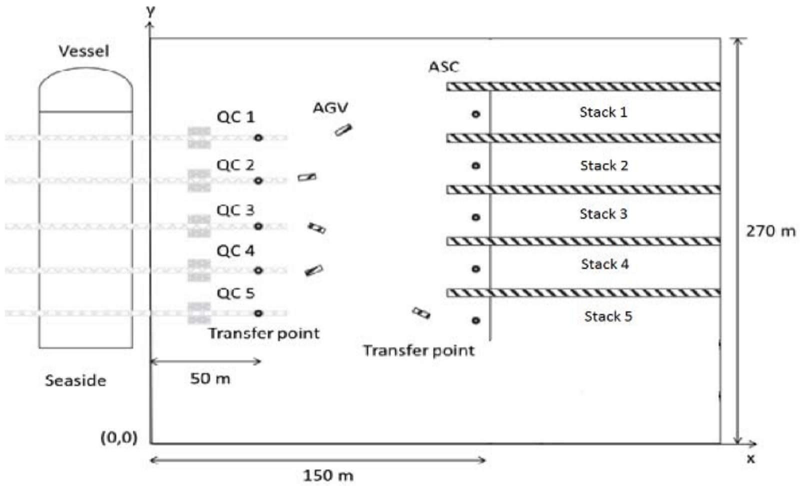

Figure 7: A reference system for an automated container terminal (Xin et al., 2015)

As shown in figure 7, the AGV will take the container from the origin transfer point, which is the QC discharge point to the destination point, which is the ASC loading point. The coordinates for these transfer points of the automated container terminal are shown below in the table.

Table 1 Transfer points coordinates of the automated container terminal

QCs	Coordinates	ASCs	Coordinates
QC 1	**(50, 170)**	**ASC 1**	**(145, 222.5)**
QC 2	**(50, 150)**	**ASC 2**	**(145, 187.5)**
QC 3	**(50, 130)**	**ASC 3**	**(145, 152.5)**
QC 4	**(50, 110)**	**ASC 4**	**(145, 117.5)**
QC 5	**(50, 90)**	**ASC 5**	**(145, 82.5)**

In addition, there are some assumptions for the experiments should be taken as following:

- Assume the vessel stowage width is equal to 8 TEUs.
- Assume that the maximum distance between the QC interchange point and a container in the vessel is 100 meters.
- The container terminal yard area is 150 m x 270 m.
- Each stacking location has volume of (36 TEU length x 10 TEU width x 6 TEU height).
- The maximum speed (velocity) for QCs is 4 m/s, AGVs is 6 m/s and ASCs is 4 m/s.
- The maximum acceleration for QCs is 0.4 m/s^2, AGVs is 1 $m/s^2$and ASCs is 0.4 m/s^2.
- Each QC or AGV or ASC will handle 1 TEU only at the same time.
- The initial position for all AGVs and ASCs are loading positions, and for all QCs are discharging positions.
- The QC handling time of each container depends on its position in the ship.
- Random generation of the container storage slot in the stacking area.
- Different storage slots for each stacking area.
- Ignore the container exchange time between the QC, AGV and ASC.
- Arena simulation software was used in these experiments.

The experiments, which will be conducted to show the efficiency of the proposed algorithm, will focus about the following performance indicators:

- **Total Discharging Time (Research Objective):** the completion time for handling all containers, which leave the ship.
- QC average operation time per container: the average time that the container will spend in the QC stage which is starting from waiting in the QC queue until it got discharged to the AGV.
- AGV average operation time per container: the average time that an AGV will spend starting from the requesting time ending to delivering the corresponding container to the final destination.
- ASC average operation time per container: the average time that the container will spend in the ASC stage which is starting from waiting in the ASC queue until it reaches to the final location in the stacking area.
- Average Waiting Time: the average time that a container will wait in queues during all stages of operation.

B. Results

First, comparison experiments have been conducted between the proposed algorithm in this paper and a benchmark experiment in the literature (Xin et al., 2015).

To do comparison experiments I started with the same constrains and number of resources that the benchmark used. As a result, an experiment of the proposed algorithm using 5 QCs, 10 AGVs and 8 ASCs was conducted and as shown below in figure 8 a better result was proven in the total discharging time.

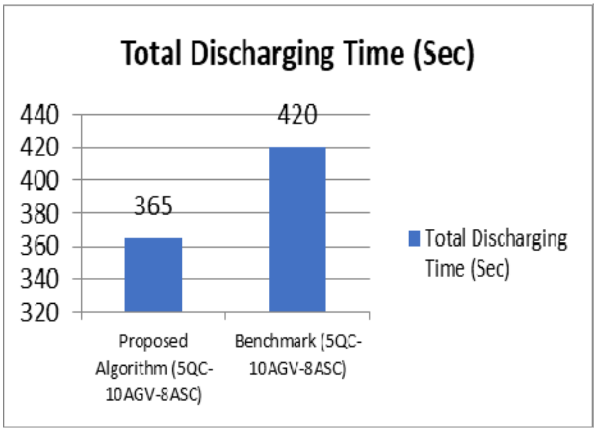

Figure 8: Comparison between total discharging time of the proposed algorithm and benchmark for the case of (5QC-10AGV-8ASC)

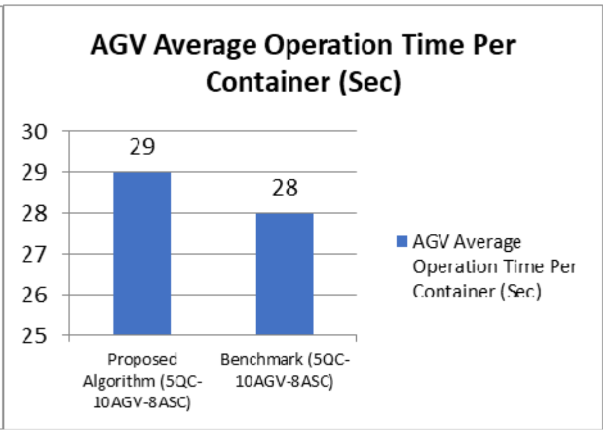

Figure 9: Result comparison between AGV average operation time of the proposed algorithm and benchmark

The total discharging time of the proposed algorithm was recorded as 365 seconds, which is less than the benchmark that scored 420 seconds. This result is showing 55 seconds or 13 per cent difference between the proposed algorithm and the benchmark, which proves that the proposed algorithm is more efficient.

However, the benchmark scored a better result on AGV average operation time compared with the proposed algorithm. In the case of 5 QCs, 10 AGVs and 8 ASCs, the proposed algorithm scored 29 seconds and the benchmark scored 28 seconds for the AGV average operation time as shown above in figure 9.

This little increase in the AGV average operation time of the proposed algorithm is because of the extra collision avoidance logic that has been applied to the proposed algorithm.

This collision avoidance logic is to assure smooth transportation without any accident between the AGVs which are using common paths and intersections while moving. As a result, this little difference in time will allow the operation to process more containers in parallel while assuring collision free operation and this will result on an overall faster total discharging time.

Then, a comparison experiment was conducted between the proposed algorithm and the optimum possible solution as an ideal case scenario. The optimum solution is the ideal one when there is an assumption of zero waiting time for each container and zero transportation waiting time.

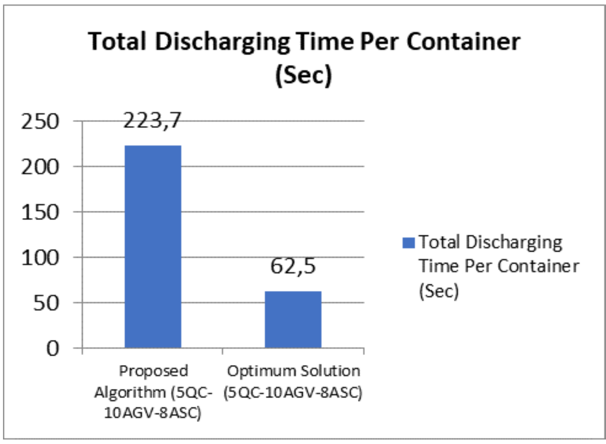

Figure 10: Comparison between total discharging time per container for the proposed algorithm and optimum solution

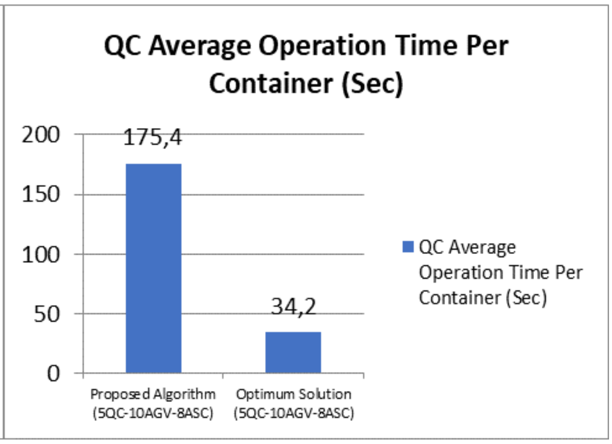

Figure 11: Comparison between QC average operation time per container for the proposed algorithm and optimum solution

As shown above in figure 10, the total discharging time per container for the optimum solution is 62.5 seconds compared with 223.7 seconds for the proposed algorithm. There is around 161 seconds difference between the proposed algorithm and the optimum solution, and this difference is the container waiting time. As a result, to achieve this optimum result, no shared resources should be considered in the automated container terminal, which makes it a very expensive solution, and it leads to a very low utilization of resources.

In addition, a detailed experiment was conducted to compare between the proposed algorithm and the optimum solution for every stage separately. As shown above in figure 11, the proposed algorithm scored 175.4 seconds in the QC stage (stage 1) compared with 34.2 seconds for the optimum solution. Therefore, there is around 141 seconds difference between the two solutions and this difference is the container waiting time in the QCs stage.

Moreover, AGV average operation time per one container for the optimum solution is 15.5 seconds and the proposed algorithm is 29 as shown below in figure 12. For this optimum solution, the average operation time of an AGV is considered for one way traveling which means that this result is under the assumption of having an AGV ready on the loading point for each container.

Finally, stage 3 result was showing that the proposed algorithm scored 19.3 seconds ASC average operation time per container compared with 12.8 seconds for the optimum solution, as shown in figure 13. Therefore, there is a 6.5 seconds container waiting time in the ASC stage.

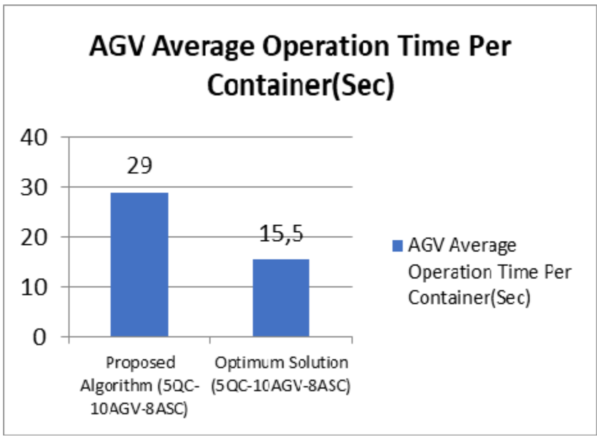

Figure 12: Comparison between proposed algorithm and optimum solution AGV average operation time per container

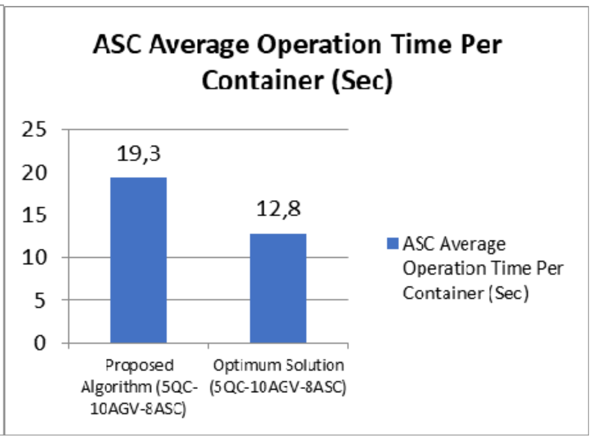

Figure 13: Comparison between proposed algorithm and optimum solution ASC average operation time per container

V. CONCLUSION

This paper studied the three stages of operations in the automated container terminal and proposed an algorithm to increase its efficiency. The objective of proposed algorithm and research paper is to decrease the total discharging time of a vessel. In addition, Internet of Things technology was used for Vehicle- to -Vehicle and Vehicle- to -Infrastructure communications to achieve smooth movements of trucks. Internet of Things technology helped to manage the increase in traffic and movements caused by the increase in discharging rate. As a result, the proposed algorithm increased the discharge rate and the Internet of Things technology was the smart tool for assuring smooth traffic in the automated container terminal.

To test the efficiency of the proposed algorithm, experiments were conducted using Arena Simulation Software which proved the decrease on total discharging time compared to the benchmark results in all the tested cases. Moreover, the proposed algorithm proved that can work with fewer resources than the benchmark and achieve better results as well. As a result, the efficiency of the proposed algorithm was tested using different experiments and it showed its ability to achieve the objective of this research paper.

Furthermore, future work will cover different scenarios of different containers sizes to be able to handle 40 feet containers and 2x20 feet containers at the same time. This ability of handling 2 TEUs at the same time will increase the efficiency of the automated container terminal even more than now. Finally, Internet of Things technology will be used to cover all the three stages of operations and the pre-berthing operation of all vessels. Using Internet of Things technology to cover all the vessels operations will increase the efficiency of the overall automated container terminal.

ACKNOWLEDGMENT

I would like to thank my dissertation supervisor, Prof. Ognyan Andreev – the Dean of Faculty of Management at Technical University of Sofia. The door for Prof. Ognyan Andreev was always open to help me and guide me to work on my thesis and contribute something great to the literature. I would also like to thank everyone gave me a valuable comment to improve my work. Without their comments and help, I would not do a great achievement like this. Finally, I would like to thank my family and friends for motivating and supporting me to accomplish my thesis.

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КОМУНИКАЦИЯ „ПРЕВОЗНО СРЕДСТВО – ПРЕВОЗНО СРЕДСТВО“ В АВТОМАТИЗИРАН КОНТЕЙНЕРЕН ТЕРМИНАЛ

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Ключови думи: *Автоматизиран контейнерен терминал, Интернет на нещата, Комуникации „превозно средство – превозно средство“ и „превозно средство – инфраструктура“, Симулации, Ефективност.*

Резюме: *Целта на всеки контейнерен терминал е да се повиши ефективността, за да може да се справи с увеличаването на търсенето и размера на контейнерните кораби. Като се има предвид ограниченото пространство и ресурси на всеки контейнерен терминал и високата цена за увеличаване на капацитета, автоматизацията може да бъде ефективна алтернатива. Автоматизираният контейнерен терминал се превърна в световна тенденция, която се прилага към много големи контейнерни терминали. В допълнение, много изследвания се фокусират върху тази тема, за да използват автоматизация и други технологии за повишаване на ефективността в контейнерните терминали. Настоящата публикация използва технологията на „Интернет на нещата“ (Internet of Things – IoT) за повишаване на транспортната ефективност на автоматизиран контейнерен терминал. В допълнение е предложен алгоритъм за повишаване на ефективността в автоматизирания контейнерен терминал и постигане на целта на изследването. Накрая са показани резултатите от симулация, целяща да бъде доказан ефектът от използването на предложения алгоритъм за намаляване на общото време за разтоварване и редуциране на таксите за обработка на терминала.*