



Intelligent Container Stacking System

Seaport Container Terminal

FAHEEM ABBAS

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Contact Information:

Author(s):

Faheem Abbas

E-mail: Faab14@student.bth.se

University advisor:

Dr. Lawrence E. Henesey

Assistant Professor

Department of Computer Science and Engineering

Faculty of Computing
Blekinge Institute of Technology
SE-371 79 Karlskrona, Sweden

Internet : www.bth.se
Phone : +46 455 38 50 00
Fax : +46 455 38 50 57

ABSTRACT

Context: The workload at seaport container terminal is increasing gradually. We need to improve the performance of terminal to fulfill the demand. The key section of the container terminal is container stacking yard which is an integral part of the seaside and the landside. So its performance has the effects on both sides. The main problem in this area is unproductive moves of containers. However, we need a well-planned stacking area in order to increase the performance of terminal and maximum utilization of existing resources.

Objectives: In this work, we have analyzed the existing container stacking system at Helsingborg seaport container terminal, Sweden, investigated the already provided solutions of the problem and find the best optimization technique to get the best possible solution. After this, suggest the solution, test the proposed solution and analyzed the simulation based results with respect to the desired solution.

Methods: To identify the problem, methods and proposed solutions of the given problem in the domain of container stacking yard management, a literature review has been conducted by using some e-resources/databases. A GA with best parametric values is used to get the best optimize solution. A discrete event simulation model for container stacking in the yard has been build and integrated with genetic algorithm. A proposed mathematical model to show the dependency of cost minimization on the number of containers' moves.

Results: The GA has been achieved the high fitness value versus generations for 150 containers to storage at best location in a block with 3 tier levels and to minimize the unproductive moves in the yard. A comparison between Genetic Algorithm and Tabu Search has been made to verify that the GA has performed better than other algorithm or not. A simulation model with GA has been used to get the simulation based results and to show the container handling by using resources like AGVs, yard crane and delivery trucks and container stacking and retrieval system in the yard. The container stacking cost is directly proportional to the number of moves has been shown by the mathematical model.

Conclusions: We have identified the key factor (unproductive moves) that is the base of other key factors (time & cost) and has an effect on the performance of the stacking yard and overall the whole seaport terminal. We have focused on this drawback of stacking system and proposed a solution that makes this system more efficient. Through this, we can save time and cost both. A Genetic Algorithm is a best approach to solve the unproductive moves problem in container stacking system.

Keywords: Unproductive moves, Automated guided vehicle (AGV), Genetic Algorithm (GA), Container stacking system (CSS).

Acknowledgement

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CHAPTER 1

INTRODUCTION

According to Sgouris P. Sgouridis (2002), during the past few decades, general cargo-handling technology changed dramatically with the introduction of containers [2]. A container is a rectangular metallic box with a huge capacity of storage. It has a standardized load unit, which is suitable for transportation and reduces the amount of product packaging and the possibility of damage. There are two standard sizes of container, 20 feet and 40 feet in length. Ceyhun Guven et al. (2014) stated that a 20-feet container occupies 1 TEU and a 40-feet container occupies 2 TEUs in the storage area [8]. The containers are used to transfer goods from one country to other countries in all over the world. They are loaded and unloaded, stacked and transported using different modes of transport over long distances efficiently. This is a cheap and most suitable way of trade than other means. The ships are used for this purpose.

Phatchara Sriphrabu et al. (2013) stated that the marine shipping industry is the main infrastructure for international trading and enhances potentiality as well as the efficiency of economic development [1]. A seaport container terminal plays a main role in the worldwide goods distribution. It is a gateway for a trade where ships come and containers are loaded and unloaded. According to Chuqian Zhang et al. (2003), a container terminal is an intermodal interface that usually connects container vessels on the sea with trucks on land and also serves as a temporary storage space for containers that are between two journeys on carriers [3]. We need to improve the container terminal more efficient and less costly due to an increase of its demand. We have two ways to improve the performance of the terminal. One is to enhance the seaport container terminal but it is not feasible in most of the case because there is no more free land available. The other option is to make an automated seaport container terminal. Through this, we can achieve the goal of the best performance of the terminal.

A seaport container terminal has three main areas. One is quayside where the ships come and dock, a quay crane load and unload the container from ship and load on AGVs or lifting vehicles on another side, other is landside where a railway system for transferring the containers and truck stand where trucks wait for the turn to load container for delivery and the third one is yard where containers are stacked and retrieved. Yang J. H. and Kim, K. H. (2006) said that the increasing demand of global transportation necessitates the concern of productivity of container yards [30]. The operational efficiency of seaport container terminal is influenced by the performance of its sub-systems. So it is necessary to investigate all sub-systems but mainly focus on the most important part of the system which is the container yard. If that part is working well, then it means we achieve maximum efficiency in the form of time and cost reduction of a container terminal because container handling in the yard is very expensive and especially in the case of re-handling or unproductive moves in stacking system. There are many operational rules to achieve the operational efficiency at the terminal.

As container terminal plays the main role in trade, same like this, a container yard plays a vital role at the terminal that affects the overall performance of seaport container terminal. According to Miguel A. Salido et al. (2009), a container stack is a type of temporary store where containers await further transport by truck, train or vessel [35]. The container yard is a storage area where containers stacked and retrieved for further delivery. Gamal Abd El-Nasser A. Said and El-Sayed M. El-Horbaty (2015) stated that the container yard serves as a buffer for loading, unloading, and transshipping containers [4]. Ceyhun Guven et al. (2014) stated that the yard is a temporary storage area where containers remain until transported to

their next location by truck, train or vessel [8]. According to Phatchara Sriphrabu et al. (2013), container stacking is a major problem at a container terminal because the container location assignment affects the operating time of the container terminal [1]. Chuanyu Chen et al. said that the decisions on the storage locations of containers directly affect the allocation and scheduling of yard cranes, the dispatching of the prime movers and indirectly affect the efficiency of Quay cranes [10]. We need to focus on this part of seaport container terminal and to make it more efficient and intelligent to save time and money both. According to Riadh Moussi et al. (2011), to increase the efficiency of a container terminal, containers are optimally stacked in the storage areas in the form of stacks [5].

The major problem in container stacking system is container's reshuffling/unproductive moves which occur due to not properly arranged stacking system. According to Ceyhun Guven et al. (2014), an unproductive move of a container required to access another container stored underneath and has a negative effect on the operational efficiency of the container terminal in terms of cranes and operators' workloads [8]. Wei Jiang et al. (2011) stated that the additional movement which assigns the position of a blocking container is called a reshuffle or unproductive move [11]. Amir Hossein Gharehgozli et al. (2014) said that the containers' reshuffles at a container terminal is time-consuming and increases a ship's berthing time [9]. This is the main reason of other problems which occur like delay in operational time at the terminal, cost increases and late container's delivery etc. Phatchara Sriphrabu et al. (2013) stated that a relocation is most important to storage and pickup operation in block stacking because it affects the handling cost [1]. According to Niraj Ramesh Dayama et al. (2014), the total cost incurred in container handling operations is the sum of the (vertical) stack rearrangement costs and the (horizontal) crane movement cost [7].

Yang J. H. and Kim, K. H. (2006) said that the block stacking is an efficient way for usage of storage space in the container yard [30]. A block size is a storage space unit in the container yard at seaport terminal. Phatchara Sriphrabu et al. (2013) said that the block size affects yard crane operation and productivity [1]. According to Gamal Abd El-Nasser A. Said and El-Sayed M. El-Horbaty (2015), the container yard is divided into blocks: each container block is served by one or more yard cranes (YC) [4]. A block is the product of a bay, row, and tier (express as Tone Equivalent Unit/TEU). Tao Chen (1999) said that higher container stacking in the yard will inevitably influence most of the operations carried out in the terminal [44]. Miguel A. Salido et al. (2009) stated that the main efficiency problem for an individual stack is to ensure easy access to containers at the expected time of transfer [35]. According to Jose M. Vidal and Nathan Huynh (2010), Import containers are typically stored in the available designated blocks [6].

CHAPTER 2

BACKGROUND

2.1 Sea Port Container Terminal

There exist many complex systems in today's world and we need to understand and identify the drawbacks / weakness in existing systems, try to remove drawbacks those can be seen as "bottlenecks" and ultimately improve the performance from a system's thinking perspective. Various solutions and ideas exist in managing complexity.

Similarly, a sea port terminal is a complex system that includes multiple in-out operations of trade and works as the essential intermodal interfaces in the global transportation network also. Ceyhun Guven et al. (2014) said that a container terminal is an interim storage area, where vessels dock on berths, unload inbound containers and load outbound container. Often sea ports are servicing vessels for handling cargo which is increasing day by day [8].

There are three types of containers in stacking area, inbound, outbound and transshipment containers at the seaport terminal. The inbound container is a container that unloads from ship and store in the yard. Nathan Huynh and Jose M. Vidal (2010) stated that the inbound/import containers are discharged from a vessel. They are stacked in the allocated space without any segregation [6]. The outbound container is a container that waits for loading on the ship. Transshipment container is a container that unload from one ship and temporary store until to load on another ship. The stacking area is divided according to types of containers.

2.2 Container stacking yard

The container stacking yard is an important strategic area that affects the overall performance of the terminal. Stacking yard is one of the seaport's core facilities for container storage in order to prevent delay in berthing time. The incoming containers into the storage yard are separated into several blocks that consist of several bays, rows, and tiers. The maximum stacking height (tiers) depends on the yard crane's height. In most of the cases, the average tiers are 03. Most of the container terminals make blocks according to containers' attributes. This storage involves a criterion for container stacking to minimize the reshuffling and extra movement of the yard cranes. Therefore, Chuanyu Chen et al. stated that the proper planning and well-designed storage yard can largely improve the port performance by efficient space utilization [10].

2.3 RTG Crane

A rubber-tired gantry crane (RTG) or yard crane is a mobile gantry crane which is used for intermodal operations (pick up, transfer and store) to their stacking positions in the block of the stacking yard. According to Nathan Huynh and Jose M. Vidal (2010), Most U.S seaport terminals use rubber-tired gantry (RTG) cranes often referred to as yard cranes to load and unload containers in the yard blocks [6]. RTG crane has some types. One is ARTG (automated RTG). That is operated by an automatic system. Another one is Manual RTG which is operated by manually. The third one is a reach stacker that is introduced by Konecranes. The Konecranes Company launched the world's first hybrid reach stacker recently [41].



Figure 2.1: RTG in container yard

The most of the container terminals have used RTG/yard crane in the yard area. Some seaport container terminals like Helsingborg seaport container terminal are using Reach Stacker instead of RTG in the stacking yard to reduce the cost. Konecranes reach stackers are equipped with powerful, low-emission engines while reducing fuel consumption. It can handle 10-45 tons heavy containers [41].



Figure 2.2: Reach stacker in yard at Helsingborg port

2.4 Sea Port of Helsingborg

The Swedish Maritime Administration has established the significance of the port of Helsingborg as being a national interest of Sweden. Helsingborg port is as a logistics hub. It is a Sweden's second largest container port. It is located in a booming part of the Nordic region. More than 350,000 TEU pass through the Helsingborg port every year. This port has 13 reach stackers, nine are used for loading and unloading trucks, and others are mobile cranes and one 16 ton fork lift truck to handle containers filled with rolls of steel plate [44].

This port is a second largest port of Sweden and easy to approachable for us to visit and investigate the actual problems that occurred and what's the reasons of these problems and how can we solve them. We have visited this port on 28-04-2015 and asked questions related to our problem, took an understanding of the stacking system and its flaws and improvable areas. Through this, we can perform this work in the better way and get the efficient results.

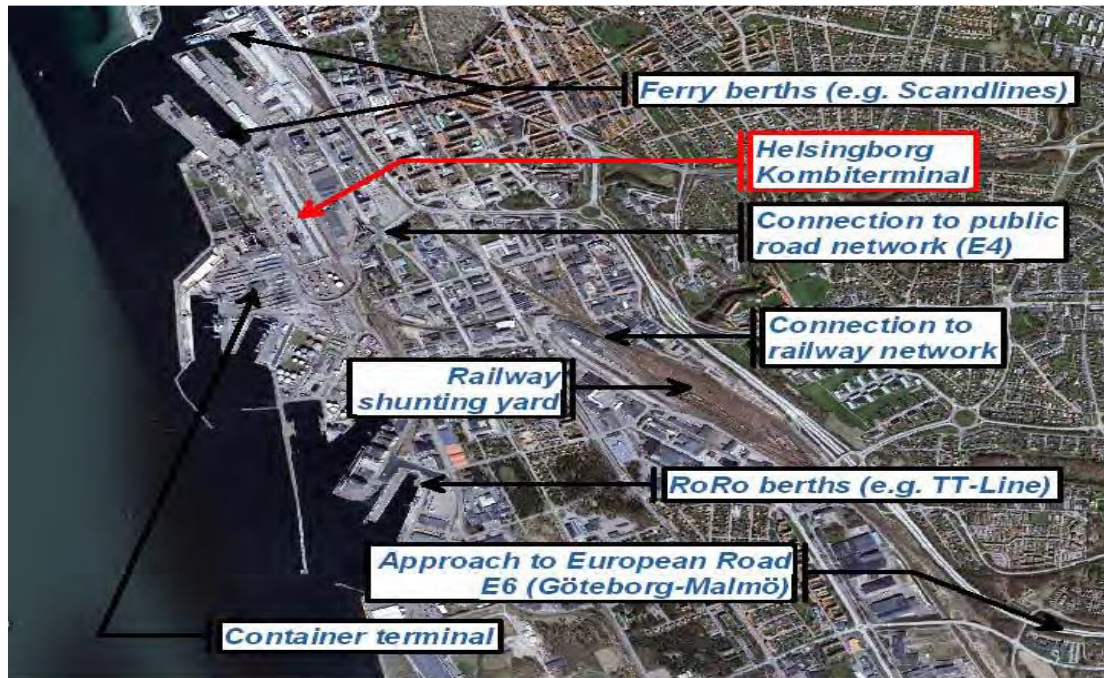


Figure.2.3: Intermodal seaport terminal of Helsingborg

This figure 2.3 is taken from [43] to understand the layout of Helsingborg port.

2.4.1 Helsingborg seaport terminal

The information about Helsingborg seaport terminal was collected from [42].

Terminal Area / Equipment	
Land area	1479000 m ²
Water area	673600 m ²
Warehouse floor area	28544 m ²
Refrigerated store floor area	8900 m ²
Receiving station for waste oil	2000 m ²
Quay length	4100 m
Dry dock	1
Maximum water depth	13.5 m
Gantry container crane	4
Mobile container /Grab crane	4
Reach stacker to load/unload	9

Table 2.1: Helsingborg port terminal's information



Figure 2.4: Aerial view of Helsingborg seaport container terminal

2.4.2 40' feet single container handling cost

In 2014 and 2015, a single 20-45' feet full/empty container handling cost at Helsingborg port was 1165 SEK. Now the Helsingborg port reduced the charges for the year 2016 which is mention below.

Loading/unloading (To/from onboard from/to vehicle or railway via rest place)	710 SEK/Unit
--	--------------

Additional charges for heavy lift

The customers will be needed to pay the following additional charges per unit.

< 10 tons	1225 SEK
10-25 tons	1940 SEK
26-35 tons	2450 SEK
36-45 tons	3875 SEK
46-60 tons	6120 SEK

Table 2.2: heavy lifting charges

Additional charges for stuffing / stripping

The minimum charges to handle a single container for stuffing or stripping is mention here.

Minimum Charges per container	2650 SEK
-------------------------------	----------

Additional charges for storage

A 40 feet container (Import and export) can remain free of charge for 05 working days from the date of arrival at the port. After this, the additional charges per day will be charged according to the below mentioned rates.

Export container	136 SEK/Unit
Import container	420 SEK/Unit

Empty 40 feet container charges

The following charges for empty 40 feet container will be charged from arrival day at the port.

Empty container	60 SEK/Unit
-----------------	-------------

Indoor storage charges

The indoor storage charges for a full 20' and 40' feet container from the day of arrival will be charged at following rates.

20' feet Full container	214 SEK/Unit
40' feet Full container	428 SEK/Unit

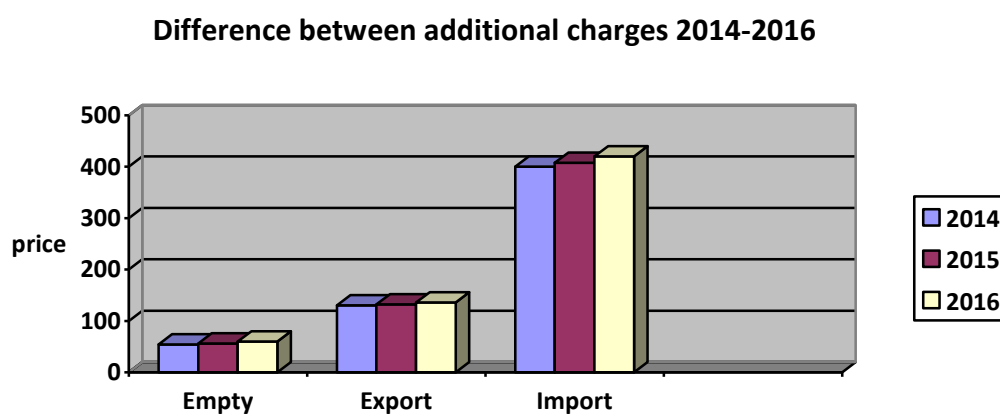


Figure 2.5: Comparison of additional charges (2014-2016)

The figure 2.5 has shown that the import/inbound container additional charges are higher than empty and export/outbound containers at Helsingborg port.

CHAPTER 3

PROBLEM DESCRIPTION

It is the most common at many container terminals that the retrieval containers are not properly stacked in the yard and we cannot avoid the containers' reshuffles. Amir Hossein Gharehgozli et al. (2014) stated that a reshuffle is the removal of a container stacked on top of the desired container [9].

This thesis's work addresses the land-side container handling operation in the yard to address the issue of unproductive moves or reshuffling during stacking of inbound containers and to determine the most effective and best possible solution to maximize the efficiency of stacking system. There are two types of container handling operation, one is stacking and another is retrieval. If the containers are stacked on best possible location then the retrieval time of container, waiting time, and cost of the delivery truck will also be reduced. According to Ceyhun Guven et al. (2014), a reshuffling move of the container is an unproductive move during stacking or retrieving operations and hence adding to the overall transportation cost. An efficient container handling (storage and retrieval) at the terminals is highly significant for reducing transportation costs and keeping shipping schedules [8]. According to Jose M. Vidal and Nathan Huynh (2010), the reshuffling container is time-consuming and increases a ship's berthing time [6]. Yang J. H. and K. H. Kim (2006) stated that the allocation and reshuffle of containers are both time consuming and expensive, which is one of the most critical issues that decrease the productivity of container operations [30].

To help mitigate the complex decision making, one way of improving the performance of existing resources is an intelligent container stacking. According to Ndeye Fatma Ndiaye et al. (2014), efficient management of the storage space is essential to ensure the productivity of a port [12]. The container stacking is based on various rules, policies and priorities to have the unaffected shipping schedules. Wei Jiang, Yun Dong and Lixin Tang (2011) stated that the efficient stacking strategy can minimize the number of containers' reshuffles [11]. Since each move of the yard crane implies cost which needs to be minimized. Therefore, an adaptive algorithm that can provide a near/best possible solution to this problem. According to a preliminary investigation, container stacking using delivery date has not been investigated previously. The delivery date is the key metric in assigning priorities to containers for transportation.

The policy for stacking inbound containers is based on delivery date. Through this, costly repositioning and unnecessary container handling in the yard can be minimized, while containers with dwell time are stacked in a separate location in the yard. The objective of this improvement is to find the exact or minimum reshuffle location for incoming containers in the yard, yard space utilization within a shorter time and hence improving the accuracy to minimize the cost.

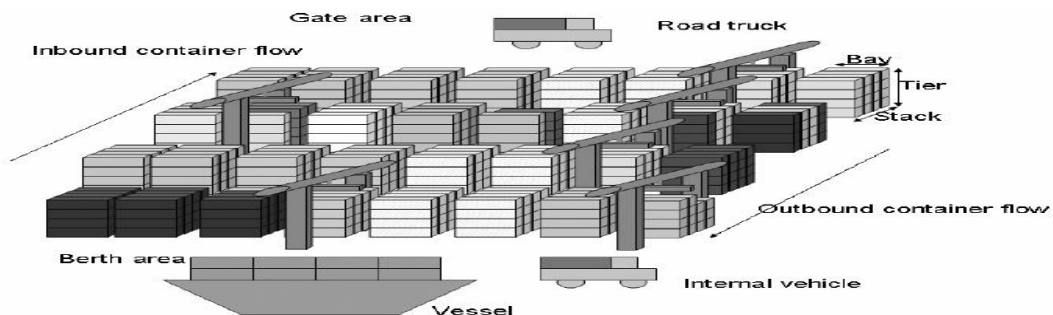


Figure 3.1: Container handling system at seaport terminal

The figure 3.1 is showing the idea about inbound and outbound container flow, stack, bay, and tier. All these are common terms which we have used in this work.

3.1 Scope of work

The focus of this work is on container stacking in the yard area of the Helsingborg port. The main focus is on the following points of container stacking system.

1. Find the exact or less reshuffle location to store the incoming container in the yard.
2. Avoid the costly extra movement of the cranes in the yard
3. Avoid late delivery of the container to the destination through truck

This thesis is on handling a block of 150 containers having the following properties.

- Equal size
- Heavy-weight
- Non-refrigerated

According to the delivery date of the containers, a Genetic Algorithm is used to find the best possible storage location for incoming containers in the yard. For this purpose, a fitness value will be taken into account.

As early discussed, stacking area is the main part of the container terminal that affects the overall performance of the terminal and increasing the cost of container handling also. Our opinion is that if we shall manage this part of the terminal in a good manner through finding the best possible location before stacking then the overall performance will be improved automatically. According to Tao Chen (1999), one major consequence would be a higher number of unproductive container movements taken in the terminal operations thus influencing overall operations efficiency [44]. This solution will assist to stacking area management to avoid costly repositioning of containers and save the time. Container without a delivery date is known as the dwell container. The latter is not considered in this thesis.

3.2 Aim and Objectives

The aim of this thesis is to improve the accuracy in stacking system by finding the exact or less reshuffled location for the incoming container in the yard. It will be helpful for stacking area management to reduce the cost of container handling in the yard. The overall cost of containers handling will also be reduced.

To achieve this aim, the following objectives will be considered.

- Analyze the existing “stacking system” at seaport container terminal, Helsingborg, Sweden
- Investigate the already provided solution(s) of reshuffling problem during stacking
- Find the best optimization technique for best or near possible solution
- Suggest the best possible solution(s) for this problem
- Test the suggested solution which is based on suggested algorithm (GA)
- Analyze the results with respect to the desired solution.
- Write the report on the basis of tested results

3.3 Contribution

The main contribution in this work is discrete-event simulation model for inbound container stacking in the yard and the Genetic Algorithm with high fitness value parameters that is used to determine the appropriate location for inbound container stacking to minimize the container's reshuffle. The results of GA have been compared to Tabu Search's results. This design is based on the delivery date of the container. The integration between the fitness value and handling cost has been shown by using GA. A proposed mathematical model to show the integration between the cost and the number of moves in the container yard.

The other contribution is a data classification method to classify the literature on container handling at the seaport container terminals. Most of the articles in this literature review are published in 2012 to 2015. The purpose to focus on recent work is to consider newly and updated research work in this field. We have classified the literature on the basis of following KPI's (Time, cost and container's reshuffle) for the minimization problem which will be beneficial for readers to find the literature on their relevant KPI easily.

CHAPTER 4

LITERATURE REVIEW

The literature about container reshuffling and stacking problems in the yard area at seaport container terminal has been reviewed. For this purpose, a literature review has been conducted. We have used some keywords and search strings related to the problem on the below mentioned online databases to find the articles. The classified data from these studies according to KPI's is mention at the end of this thesis.

Keywords

- 1) Seaport container terminal
- 2) Yard area
- 3) Container stacking
- 4) Inbound
- 5) Outbound
- 6) Containers reshuffles
- 7) Minimize reshuffling
- 8) Optimization techniques
- 9) Landside operations

String to Search

- a) 1 AND (2 OR 3 OR 4 OR 5 OR 6)
- b) 3 AND 1 OR 2
- c) 4 AND (2 OR 3 OR 6)
- d) 7 AND (1 AND 2 OR 3)
- e) 8 AND (1 OR 2 OR 3 OR 7)
- f) 9 AND 1

Online resources/Databases

- ❖ IEEE
- ❖ Science Direct
- ❖ Springer
- ❖ ACM Digital Library
- ❖ arXiv.org

The relevant articles are selected to explain the focused problems and their solutions which are mention here in the literature review.

Phatchara Sripkrabu et al. (2013) said that the container stacking problem in container terminal is an important part of port management. The simulated results based on genetic algorithm are more efficient than FIFS (First-in First-serve) solution for containers' location assignment with minimized total lifting time [1]. The given solution is a comparison of two simulation models and results that showed the best one model is using GA.

Amir Hossein Gharehgozli et al. (2014) proposed a decision-tree heuristic approach to minimize the expected number of reshuffles when containers should be stacked in a block. They used a heuristic algorithm that uses the results of a stochastic dynamic programming model built on work of Kim, Park and Ryu (2000). The proposed approach based model's results are same but much faster to solve the small-scale problem as compared to other DT

heuristic approach. For large scale problems, proposed approach performed better than common heuristic [9].

Chuanyu Chen et al. presented a comprehensive survey of the operations in container terminals and their simulation and optimization issues from a hierarchy point of view. They discussed the management of automated terminals by decomposing it into separate types of decision-making to solve the problems [10].

Wei Jiang et al. (2011) had done a simulation study on reshuffling problem in logistics operations of a container terminal yard. Their simulation model for container stacking, reshuffling and retrieving in one bay for static and dynamic environments are evaluated. Their model is highly extensible and well-suited for the stacking and retrieving operations in container terminals [11].

Ndeye Fatma Ndiaye et al. (2014) proposed a linear mathematical model for operational constraints and minimizing the total distance traveled by straddle carriers between the quays and the container yard, and determined the exact location assigned to each container without causing reshuffle. They proposed also a hybrid ant colony and genetic algorithm (HAC/GA) to solve the container storage problem at port terminal and made a comparison to CPLEX, the experiment showed that the HAC/GA's results are better than CPLEX's results [12].

Kun-Chih WU et al. (2009) proposed a tabu search algorithm to solve the container handling the static problem (arriving container is not allowed during the period of retrievals). Make a comparison with depth-first branch and bound (B&B) to check the efficiency. The results show that the average gap between tabu search and B&B is 0.4% and computational time is effective [13].

Shuding Kang and Weimin Wu (2015) designed a genetic algorithm to solve the container's location allocation problem (CLAP). They took 20ft normal containers and ignore the weight of containers. The proposed GA can provide the solution of the minimum number of reshuffles and the balance between the bays [14].

Jana Ries et al. (2014) introduced the fuzzy logic approach for import-dry containers with regards to minimizing relocation moves and distance traveled of the yard equipment. The experimental results show that the proposed fuzzy logic approach is a good strategy to assign any incoming container to a preferable location in the yard [15].

Mazen Hussein et al. (2012) identified that the reshuffling of containers according to weight has minimized the energy consumption by using Genetic Algorithm and Global Retrieval Heuristic approach [16]. This solution is reducing the cost just 5% only but for real world problem, the delivery time of the container is one of the most important factors to cost reduction.

Xiaoming Yang et al. (2015) developed a genetic algorithm to minimize the unbalance workload and unnecessary movement of yard crane in stacking area. The results of the experiment show the effectiveness and robustness of the genetic algorithm [17].

I.Ayachi et al. (2010) presented a genetic algorithm (GA) to determine an optimal containers arrangement which respects customers' delivery deadlines, reduces the re-handling of containers and minimizes the stop time of the container ship. The GA can solve the problem with different containers' types (dry, open side, open top, tank, empty and refrigerated). The proposed approach was compared to Last in First out (LIFO) algorithm and has recorded good results [18].

Mohammad Bazzazi et al. (2009) proposed an effective genetic algorithm (GA) to solve an extended storage space allocation problem to balance the workload between blocks in order to minimize the storage/retrieval times of containers. The obtained results from the extended model and proposed GA showed a relative gap about 5% between GA and optimum solution in term of the objective function value [19].

Luiz Antonio Carraro and Leandro Nunes de Castro (2012) proposed MRCLONALG (Metaheuristic Clonal Selection Algorithm) to minimize the number of reshuffles in container stacking operations involving piles of containers. The performance of proposed model was evaluated through simulation and compared the results with MRIP model. The MRIP model may always give an optimal solution but its computing time for large instances is too high. The proposed algorithm can give a competitive performance with a low computational cost in time [20].

Jonas Ahmt et al. (2015) proposed a new Mixed Integer Programming (MIP) model for the container positioning problem. They said that this model together with the rolling time horizon based solution is to date the most efficient mathematical programming model to solve this problem. This approach can better reflect the real application as to plan for containers for which the information about arrival or departure times is known with certainty [21].

Shell Ying Huang et al. (2014) proposed several algorithms for yard crane deployment among the rows of yard blocks in a container storage yard to minimize vehicle waiting times and the number of overflow jobs. They showed an experiment in two situations. (1) When the number of cranes is less than the number of yard blocks, deploying YCs in the proposition to the number of jobs in each row (3L-Pro-Jobs) is the best. (2) When the number of yard cranes is equal to or more than the number of yard blocks using the apparent workload approach, (3L-AW) will be performed best [22].

Kun-Chih Wu and Ching-Jung Ting (2012) identified two novel heuristic approaches for reducing container reshuffle operations at container yard. The first heuristic, Lowest Absolute Difference (LAD), relocates containers based on the difference of retrieval priorities between a reshuffled container and other containers. The second heuristic is Group Assignment Heuristic (GAH), addresses a group of reshuffled containers simultaneously according to their retrieval priorities. They compared proposed approaches with 02 other heuristic approaches including Reshuffle Index (RI) and expected number of additional relocations (ENAR). The result showed that the GAH outperforms other heuristics [23].

Kap Hwan Kim and Hong Bae Kim (1998) developed a cost model for the determination of the space requirement and the number of transfer cranes in import container yard to include the space cost, the fixed cost of transfer cranes which correspond to the investment cost, the variable cost of transfer cranes and outside truck which is related to the time spent for the transfer of containers. The experimental results showed that the optimal space amount decreases as the space cost increases but the optimal number of transfer cranes is insensitive to the change of the space cost. The optimal number of transfer cranes and the optimal space amount increase as the cost of outside trucks increases [24].

Xuan Qiu and Jasmine Siu Lee Lam (2014) proposed a Stackelberg game theoretic approach model for storage pricing- pickup problem in a dry port system for inbound containers to minimize its total cost. This model is solved analytically. After analyzing the proposed game model, the Stackelberg equilibrium solutions are obtained in closed-form [25].

Radh Moussi et al. (2011) identified a new algorithm using a genetic algorithm called GALUO (Genetic algorithm for loading and unloading operation) to minimize the total

travel time of lifting vehicles. Through this approach, they tried to minimize the container handling time at sea port terminal [26].

Azizi AB, Aziz & Azzizi Zakariya (2003) proposed a genetic algorithm technique to solve the container stacking problem where a prototype has been developed. The average optimal stacking result obtained range between 78-83%. Nature adaptation in GA gives a better way to solve container stacking and allocation problem. The simulation results provide further insight in predicting possible container arrangement and movement. Best optimization rate 85.6% is achieved [27].

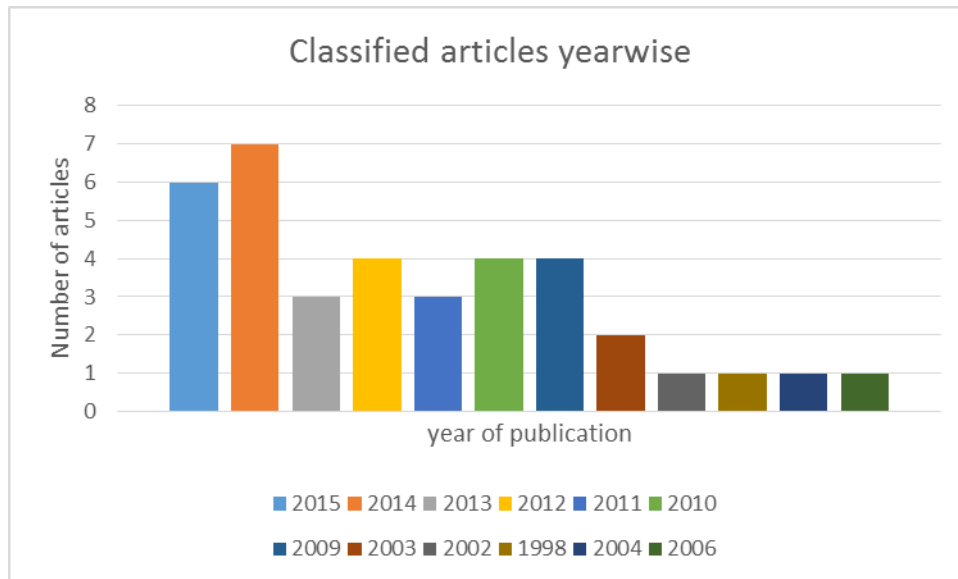
LIU Yan et al. (2010) proposed a fuzzy optimization model of storage space allocation and rolling-planning method is derived. The model took into account the uncertainty of departure time of import containers and arrival time of export container. For planning horizon, the problem is divided into two levels: the first level minimizes the unbalanced workloads among blocks using hybrid intelligence algorithm, the second level minimizes the number of blocks to which the same grouped containers are split. The results showed that the model reduced workload imbalance and speed up the vessel loading and discharging process [28].

Xie Xie et al. (2015) proposed a genetic algorithm for scheduling of cranes and minimize the reshuffling of products in the warehouse. The experimental results show that the genetic algorithm is much effective than other heuristic algorithm and generates a good solution within a short time if problem size is up to 100 [31].

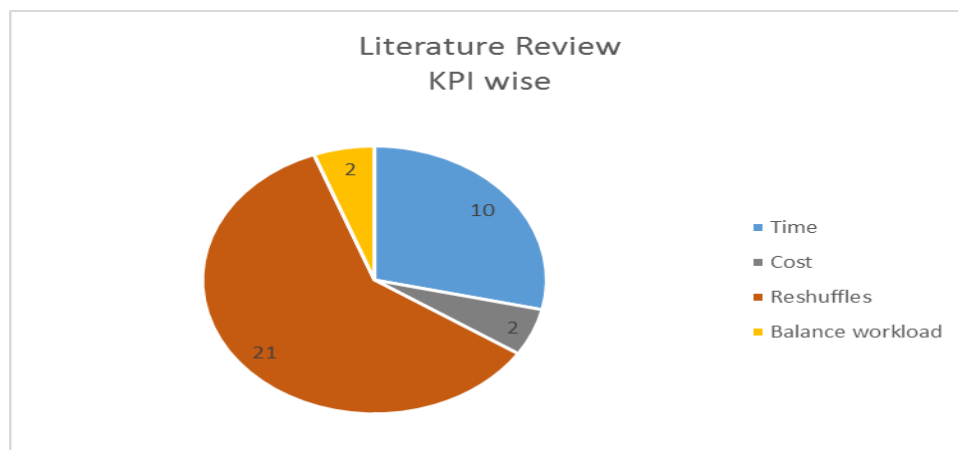
Lixin Tang et al. (2015) improved the existing static reshuffling model, developed five effective heuristics and analyzed the performance of these algorithms. A discrete-event simulation model was developed to animate the stacking, retrieving and reshuffling operations and to test the performance of the proposed heuristics and their extended versions in the dynamic environment with arrivals and retrievals of containers. For static & dynamic both problems, the results showed that the improved model can obtain optimal or feasible solutions more quickly than the existing model, and proposed extended five heuristics are superior to existing ones and consume very little time [33].

Wenbin HU et al. (2012) proposed a ship loading scheduling model to make the whole container ship loading plan by using the heuristic greedy algorithm to choose the container having least cost in the yard during every loading. Many experiments verified the utility of the heuristic greedy algorithm. A mathematical model was constructed to minimize container reshuffle rate on board, the center of gravity of the ship, holding appropriate trim and ensuring that the heavy containers stacking in the middle of the ship. The genetic algorithm with group coding and stacking strategy in the bay was taken as the resolution of the model. The results showed that the proposed model and the algorithm have a good performance [34].

Miguel A. Salido et al. (2009) developed a domain-independent planning tool for finding the best configuration of containers in a bay. The proposed tool minimized the number of relocations of containers in order to allocate all selected containers in an appropriate order to avoid further reshuffles [35].



Most of the articles which reviewed in this literature review are published in the year 2012 to 2015 (57%). The articles published in the year 2014 & 2015 are 13 out of 35 (37%) to be reviewed. The purpose of this selection is to investigate the most recent research work on given problem and suggested solutions. Through this, we can propose some new work as a contribution in this area.



We have focused 04 types of KPI's in this literature review. Most of them are on the minimization of the container's reshuffles. The few of them focused on cost minimization. So we have decided to focus on the cost minimization with unproductive moves. The unproductive move of the container is one of the main reasons which can increase the cost and time at seaport container terminal. It means cost and time depend on unproductive moves and unproductive moves depend on container stacking management. So we need to focus on container stacking system and its management to improve the performance of the seaport terminals.

CHAPTER 5

RESEARCH METHODOLOGY

5.1 RESEARCH QUESTIONS

The goal is to investigate the reason/s of unproductive moves of containers in the stacking yard area and propose a solution to handle the incoming containers in the yard by finding the most suitable and best possible location to avoid/minimize the costly repositioning of the containers in the yard. To achieve this goal, I have formulated two research questions.

RQ.1: What is the relationship between a number of unproductive moves of containers and cost of stacking system?

The aim of this question is to identify the relationship between the number of unproductive moves and container handling cost. Therefore, we will investigate the cost dependency on container's moves and propose a mathematical model to show the relationship between them.

In research studies, we have focused on those key factors which are relevant and integrated to storage area management. In this analysis, we have identified following types of factors like time, cost and balance workload and all these are integrated to another key factor which is reshuffles or unproductive moves. Most of the research studies in this review focused on optimization of container stacking and retrieval problem in the yard. The good management of storage yard will increase the efficiency of container handling flow process. Through this, the productivity of the container terminal will be increased and the ship's berthing time, container's loading and unloading time will also be decreased.

Hypothesis:

- **H0:** There is no relationship between the number of unproductive moves and the cost of stacking system.
- **H1:** There is a relationship between the number of unproductive moves and the cost of stacking system.

RQ.2: What is the impact of the genetic algorithm on minimizing unproductive moves?

This question is to investigate how a genetic algorithm can be helpful in this minimization problem. First, it can be investigated through literature review. After this, the genetic algorithm has been implemented on the simulation model to get the results. If results will be good then it means this algorithm has an impact on minimization of unproductive moves else not. We shall take a genetic algorithm with 150 initial population and get the fitness value of this algorithm. A discrete-event simulation model for container stacking system will be developed and integrated with GA to get the simulation based results. For the verification and validation of the results, it will be compared to another algorithm. A tabu search algorithm will be chosen for this purpose because TS is a simple and meta-heuristic search algorithm and it has used in some research work to minimize the container's reshuffles.

The genetic algorithm will create initial population randomly and assign fitness value to each gene in the population. After selection, crossover and mutation, a new population will be generated. Check the new fitness value of population and compare the new fitness value to

the maximum fitness value that is 150. If the maximum fitness will be achieved then this process will be stopped.

In this work, we will assign delivery dates from 01 to 05 (today to next four days) because container stacked in the yard without additional charges up to 05 days from the date of commerce and we have assumed that the containers have been stacked up to 05 days.

Hypothesis:

- **H0:** There is no impact of genetic algorithm to minimize the unproductive moves and the cost of stacking system.
- **H1:** There is an impact of genetic algorithm to minimize the unproductive moves and the cost of stacking system.

5.2 RESEARCH PROCESS

Our research process has some sub-processes to achieve the goal. This process will be based on literature review, formulate the Research Questions and proposed the solution to answer the questions. We have presented this process in figure 5.1.

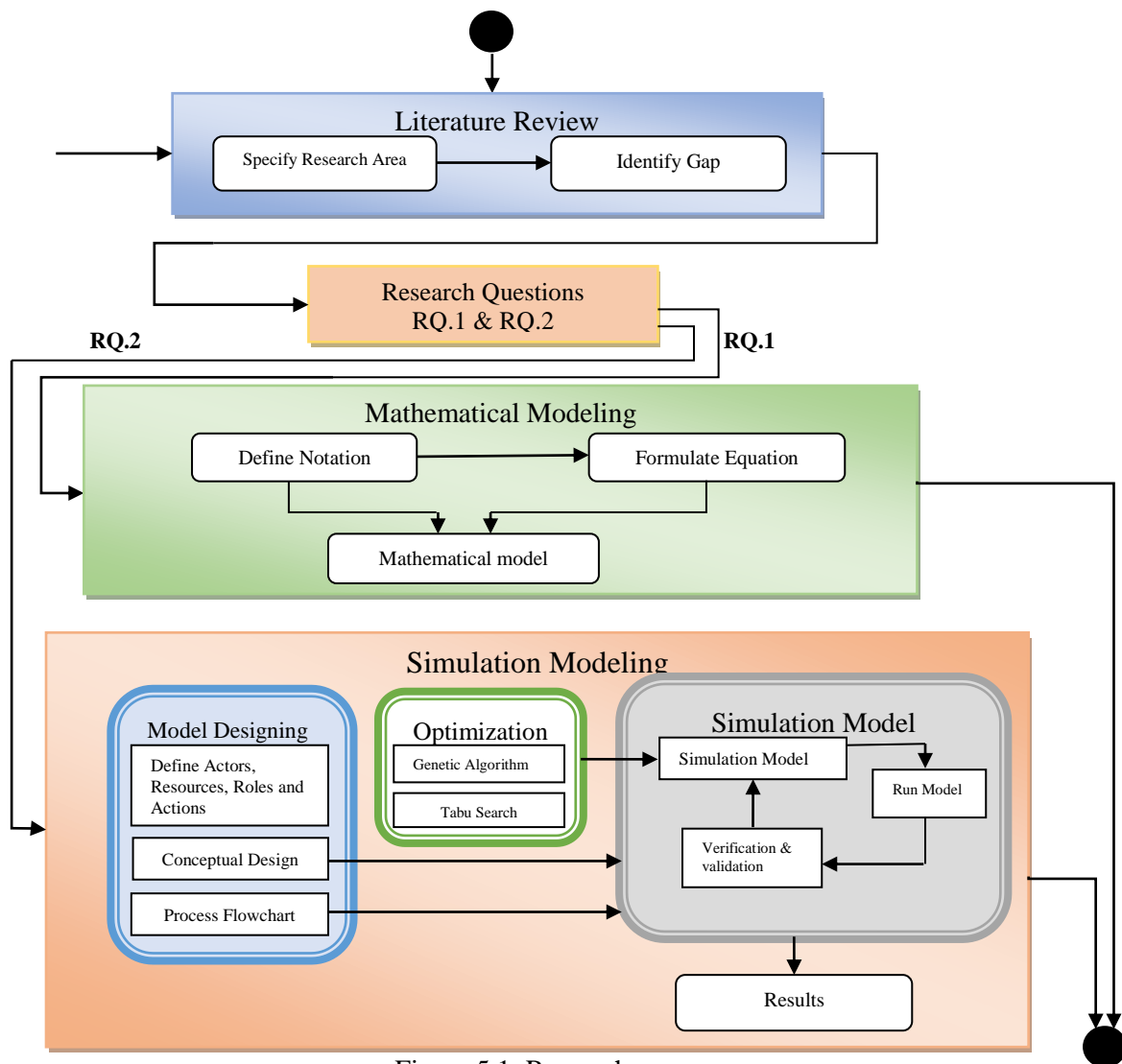


Figure 5.1: Research process

5.2.1 Domain Knowledge and Problem Identification

To gain knowledge about the domain, proposed solutions and identify the gap, we have performed the literature review. Through this step, we were able to formulate the research questions and to discuss the problem with Helsingborg port's authority.

5.2.2 Proposed Solution

We have proposed the solutions for answering the research questions (RQ.1 & RQ.2). First, we have proposed a mathematical model for cost minimization to answer the research question RQ.1. For RQ.1, we have defined the mathematical model in Chapter 5 and a simulation based results of GA in which the fitness value versus cost has been shown in Chapter 7. For RQ.2, We have developed a discrete event simulation model for container stacking system and integrate it with GA to optimize the solution. To achieve this goal, we use AnyLogic 7.2 simulation tool. A genetic algorithm is used to find the best possible solution and we have compared its results with tabu search's results to verify and validate the results. This solution has been explained in Chapter 5, 6 and 7.

5.3 METHODOLOGY

The methodology use in this thesis is a discrete-event simulation that consist of a simulation method for modeling to stack the containers in the yard and to avoid the further reshuffles. A genetic algorithm is used to calculate the maximum fitness of 150 containers to store at the best possible location in the yard. The delivery date is assign to each container before stacking in the yard. The tier level of stack is 3. So our solution will be based on the groups of 3 values. On that basis, we shall find the best possible location to store a container in the stack. There are some constraints to stack the container in efficient way. The containers with early delivery date will be stacked on upper tier and the late delivery container will be stacked on lower tier 1 or 2 in descending order in the yard. All 3 containers with same delivery date can be stacked in same stack. A mathematical model is purposed to show the relationship between the number of unproductive moves and container handling cost.

5.3.1 Simulation Method

Simulation is a program that uses step by step methods to explore the behavior of a mathematical model. It is used to predict the real world. The simulation method is one of the best options to solve the space related problems. A simulation model consists of objects and objects can interact with each other to perform a specific task. According to Lixin Tang et al. (2015), Simulation is a suitable tool for evaluating the algorithms or rules [33]. Hartmann, S. (2004) said that the simulation models as tools to evaluate the dynamic processes in a container terminal that allow to generate and analyze the statistics such as average productivity, waiting time, the number of re-shuffle moves in the stack and provide a testing environment for optimization algorithms [29]. There are two common types of simulation, one is a discrete-event simulation and another is a continuous simulation. In discrete-event simulation, the state variables change instantaneously at specific points within the specific simulated time. A discrete-event simulation can be used to solve the container stacking problem. Gamal Abd El-Nasser A. Said et al. (2015) stated that the discrete-event systems are well suited to represent various activities performed in container terminals and to optimize the solution for storage space allocation problem [4]. According to Sgouris P. Sgouridis et al. (2002), the simulation of incoming container handling in stacking is a discrete event problem [2].

5.3.2 Simulation tool selection

There are several free of cost and educational/personal learning simulation tools for discrete-event simulation. The professional or commercial versions of simulation tools are also available but not free of cost. We have conducted a review of different simulation tools to select the appropriate tool. First, we have compared three simulation tools (AnyLogic, Arena, and FlexSim) and select the best one and most suitable for our simulation model. The comparison of these three simulation tools is given in table 5.1. After review, we have selected the AnyLogic to develop our simulation model.

AnyLogic is a multimethod simulation modeling tool that supports agent-based, discrete-event and system dynamics simulation method. The main advantage of this simulation tool is that it allows the modeler to combine three simulation approaches (agent-based, discrete event and system dynamics) within the same model [39]. The platform of AnyLogic for simulation is Java. We can export the model as Java applet to run on a web page. The java is used as a programming language in this work. We have selected AnyLogic due to these reasons. According to Bin Li and Wen-feng Li (2010), the AnyLogic simulation tool is based on java and Eclipse framework that make it possess of outstanding open and compatibility

which brings sufficient flexibility and enable the user to capture complexity and heterogeneity of a problem at any desired level of detail.

5.3.3 Comparison of AnyLogic, Arena, and FlexSim

Feature/s	FlexSim	Arena	AnyLogic
Programming paradigm	Object oriented	Object oriented	Object oriented
Programming Language	C++	Visual Basic	Java
Discrete-event Based properties	Flowchart, Events	Flowchart, Events	Flowchart, Events
JAVA Extension	No	No	Extend models with java
Debugging	Yes	Yes	Yes
Data Analysis	Yes	Yes	Yes
Cost	Expensive	Very Expensive	Little Expensive
Help	Online videos and user manual are available.	Online data, tutorial, and users groups are available.	Training videos, lectures and online users group are available.

Table 5.1: Comparison of Simulation Tools

The comparison of three simulation tools has been shown in table 5.1. The main differences between these three simulation tools have been highlighted.

5.3.3.1 Comparison of execution time of simulators

We have compared the two types of operations execution time of above mentioned 3 simulators. One is a time require for delay block execution and another is how much time is required to create and destroy an entity. The FlexSim has taken much time for execution. The execution time to execute the delay block of Arena and AnyLogic is equal which is important for tool selection and to create and destroy entities execution time of Arena is half of the AnyLogic which has not much effect on the performance. AnyLogic is selected due to all these differences. The data has been taken from [46] as shown in figure 5.2.

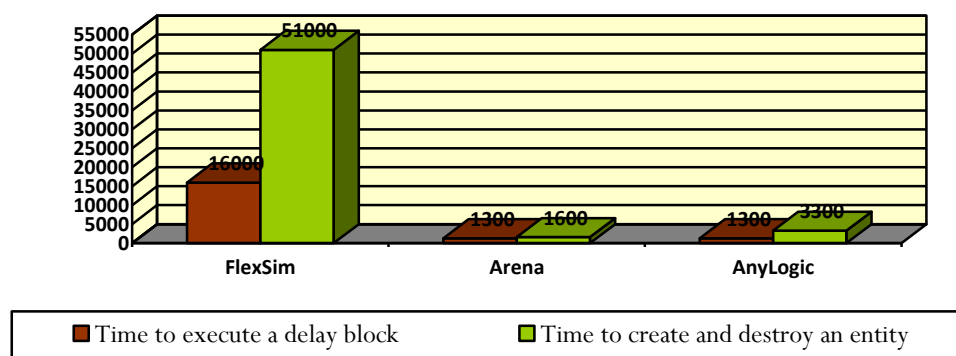


Figure 5.2: Comparison of execution time of 03 simulators

5.4 Genetic Algorithm Implementation

The idea to implement the biological principle of natural evolution into artificial systems was introduced three decades ago. Genetic algorithm (GA) was proposed by John Holland in his book “Adaptation in Natural and Artificial Systems” in 1975. The genetic algorithm is based on Darwin’s theory of evolution in which it is stated that the strongest species can only survive. It is an adaptive heuristic search evolutionary algorithm that based on the natural selection principle to evolve a set of solutions to get an optimal solution. A genetic algorithm is a machine learning approach to solving an optimization problem that is based on natural selection. A genetic algorithm’s solution is called a single chromosome or collection of chromosomes which referred as a population. A chromosome is the composition of genes and values of genes can be either numerical, binary, string, it depends on the problem. A fitness function will be performed on the population to measure the appropriateness of GA based solution with given problem. The GA results have been improved in the evolution procedure gradually.

5.4.1 Why GA is better than other optimization algorithms

A genetic algorithm is not only powerful but easy to use as most of the work can be encapsulated into a single component, requiring users to define a fitness function that is used to determine how good a particular random solution is relative to other solutions. Hua-An Lu (2013), stated that the genetic algorithm can work better than other optimization algorithms because they are less likely to be led astray by local optima [36]. According to Xiaoming Yang et al. (2015), the genetic algorithm is a well-known heuristic algorithm which is effective and robust in solving space allocation problems [17]. Azizi AB Aziz and Azizi Zakaria (2003) said that a genetic algorithm is applied to a search space which is normally too large to be exhaustively searched [27]. According to Phatchara Sriphrabu et al. (2013), a genetic algorithm (GA) can solve containers’ location assignment and minimize the lifting time of container [1]. Xie Xie et al. (2015) stated that a genetic algorithm can improve the efficiency of cranes and minimize the reshuffling in stacking area [31].

There are following steps involved in a genetic algorithm to get an optimal solution.

1. Initial Population

First, the initial population with size 150 is generated randomly. For this purpose, the delivery date will be considered. The delivery dates will be assigned from today to next 4 days (total 5 days) because 5 days are free of charges to each individual.

2. Fitness Evaluation

Evaluate the fitness $f(x)$ of each individual x in the population. In this case, to check the fitness of each delivery date of the incoming container and calculate the fitness value and check that the current solution is fit as the desired solution. We need to compare the delivery date of all incoming containers before stacking and after this, store at best location with no need to reshuffle or may be few reshuffles required. If condition satisfied then put the container at the best location in the yard. The fitness value is a measure of quality and is use to compare the solution with others solutions. At the end of the result, we will get a good solution with higher fitness value.

3. Selection

A biological process to select the parents for a new generation. Two parent chromosomes are selected according to their fitness. If the fitness of a chromosome is high then selection's chances are high.

The main purpose of this step is to improve the overall fitness of population constantly. It helps to discard the bad individuals and keep the best individuals in the population. The fitter individuals will be selected for next generation.

Generally, three types of selection, Roulette wheel selection, Rank based selection and Tournament selection are used to identify the best individuals in the current population. According to Vishnu Raja P. et al. (2013), the tournament selection method produced the best output in fixed number of generations [47]. The tournament selection is a robust selection mechanism. This selection method will take the individuals randomly from population and the best individuals will be selected for parents from multiple tournaments. We have selected tournament selection method for selection purpose in this work. We need to set the tournament size. If tournament size is small then best fitness will be gradually increased and achieved on later generations but if the tournament size will be 4 to 6 then high fitness results will be achieved faster else not. It means to achieve the best results of GA earlier then the tournament size will be set at 4 to 6.

4. Crossover

The crossover is a genetic operator that chooses two parents chromosomes for interchanging their one part before or after the cross point. The crossover point is selected randomly. In this case, it gets the first part from father chromosome (Chromosome 1) and the second part from mother chromosome (Chromosome 2). The duplicate numbers (Dates) are divided into new sequence randomly. It performs crossover the parents with crossover probability to form a new chromosome (offspring). If crossover probability is 100% then all offspring are made by crossover. If crossover probability is 0% then whole new generation / offspring (child) is same like parents (copy of parents).

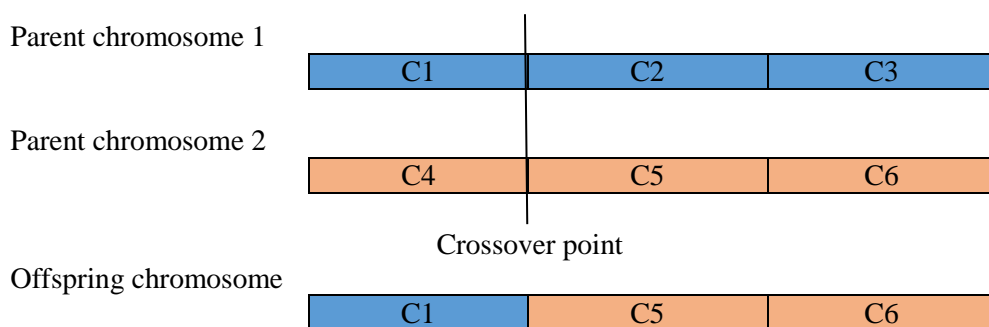
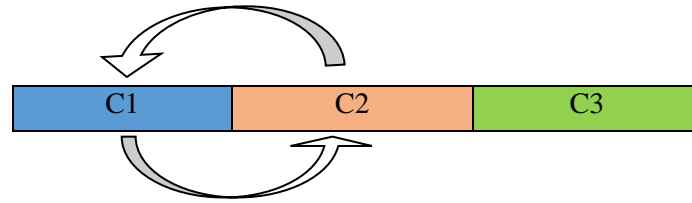


Figure 5.3: Single point crossover

5. Mutation

Two genes are selected randomly from the chromosome and swapped. It works little bit change at random to an individual genome. If mutation rate/probability is 100 % then the whole individual is changed and if it is 0% then nothing is changed.

a) Before Mutation



b) After mutation



Figure 5.4: Mutation

The selection's process of chromosomes for next generation is based on Darwin evolution rule, a chromosome with higher fitness value will have a great probability of selection in the next generation. This process of generating new population will be repeated with step-2 (Fitness Evaluation) until the stop condition will be satisfied. The stop condition set in this algorithm is maximum fitness value which is 150. Our solution length is 150 because we are handling 150 containers (dates) and sequence depends on 03 values pair (a stack has 3 tier). In this sequence, first one value is higher than or equal to other two values, the second one is higher than or equal to the third one. This sequence will be repeated until 150 values.

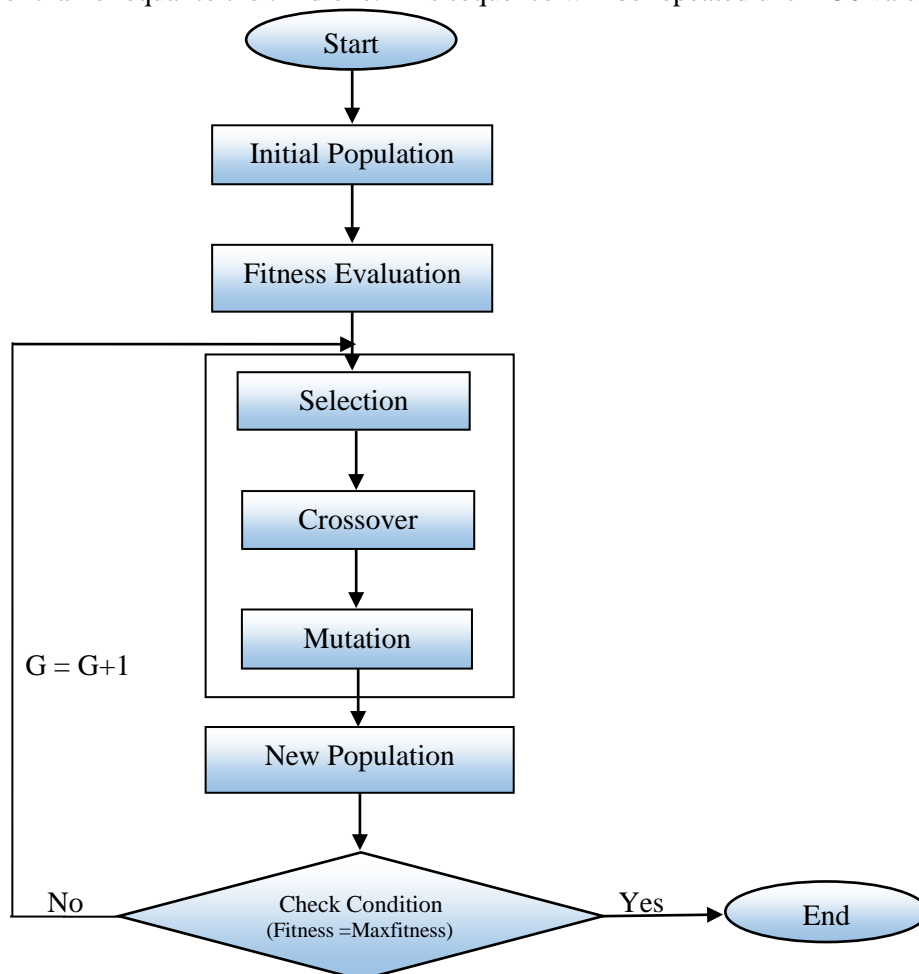


Figure 5.5: Genetic Algorithm Flowchart

5.4.2 Parameters of Genetic Algorithm

The following parameters and their values will be set for the genetic algorithm to get maximum fitness value. To check the best fitness value, we tried to change different parameter's values like mutation rate, crossover rate and tournament size. After the test, we have set these values finally because the best result is achieved on these parameters as compared to other values. The number of generations depends on the maximum fitness value achieved.

Parameter	Value
Population Size	150
Crossover rate	0.5
Mutation rate	0.016
Tournament Size	5
Elitism	True

Table 5.2: GA parameters with values

5.5 Tabu Search selection for comparison to the GA

Tabu Search was developed by Fred W. Glover in 1986. It is a simple and metaheuristic search method. It enhances the performance of local search to iteratively move from potential solution to improved solution. According to Hua-An Lu (2013), tabu search is one of the popular meta-heuristics for solving large-scale problems in many fields. Tabu search is based on the establishment of moves from current solution to one of its neighbours without a tabu limitation [36]. It is a global optimization searching method that move from potential solution to the best possible solution and will be continued until the condition has been satisfied. A tabu list is used to avoid the repetition of the same solution and to maintain by using tabu moves to get the best solution. A standard tabu list is used as a circular list of fixed length. It cannot prevent to repeat the same solution always. If the best candidate has a high fitness value than the current best candidate. So it is set as a new best candidate. This process will be continue until the user defined condition has been met. The insertion and swapped methods have been used in the neighborhood search to move from potential solution to the best possible solution. Tabu search is used for mathematical optimization. Kun-Chih WU et al. (2009) said that the tabu search method can minimize the container reshuffling during container retrieval from yard [13].

5.6 Mathematical Model for cost management

A mathematical model is an abstract model that uses mathematical language to describe the behavior of a system [48]. Eykhoff (1974) has defined a mathematical model as a representation of the essential aspects of an existing system which presents knowledge of that system in usable form. The mathematical equation has expressed the relationship between the variables and the equal sign between them has been showed that these two things are equal [49]. A mathematical model is a set of mathematical statements and virtually serves as a door opener towards the “mathematical universe” where powerful mathematical methods become applicable to originally non-mathematical problem [50]. We have introduced a mathematical model to express the relationship between container handling cost and container’s reshuffles (RQ.1). This model shows that the container handling cost in the stacking yard is directly proportional to a number of moves (actual moves + unproductive moves) of containers. If the number of container’s reshuffles increases then cost will also increase. When a container will be handled more than one time then each handling cost will be added more than one time. To minimize the cost, we need to reduce the unproductive moves of containers. Through this, the port’s authority can reduce the container handling cost and the container handling charges also.

Notations

The notations used in this mathematical model are listed as follows.

M	Total number of moves of containers in the yard
C	Total cost of stacking system in the yard
$M \propto C$	
(If number of moves increases then the cost of stacking will also be increased)	
C _c	Container handling cost
EC	Extra/Reshuffle container handling cost
C _i	Incoming container into the yard
C _s	Total containers handle to stack in yard
C _R	Containers need to reshuffle in yard
C _{st}	Stacked container in the yard
AC	Actual cost to handle the containers

$$\forall C_i \in C_s$$

$$C_i = 1, 2, 3, 4, 5 \dots 150$$

$$\forall C_R \in C_s$$

$$C_R = 1, 2, 3 \dots n$$

To calculate the total number of moves during stacking

$$M = C_s + C_R \quad (5.1)$$

To calculate the total container handling cost for stacking, equation (5.1) is multiply by container cost in equation (5.2).

$$C = C_c * M \quad (5.2)$$

To calculate the extra cost, multiply the no. of reshuffles containers with container handling cost.

$$EC = C_c * C_R \quad (5.3)$$

To calculate the extra cost in percentage, extra moves cost divided by Equation (5.2) and multiply by 100.

$$\% EC = \frac{C_R * C_c}{C} * 100 \quad (5.4)$$

To calculate the actual cost of container handling during stacking without extra moves.

$$AC = C - EC \quad (5.5)$$

To put the values of C from equation (5.2) and EC from equation (5.3) into the equation (5.5).

$$AC = (C_c * M) - (C_R * C_c)$$

To put the value of M from eq. (5.1) in the equation (5.5),

$$AC = (C_c * (C_s + C_R)) - (C_R * C_c)$$

$$AC = C_c * C_s \quad (5.6)$$

Equation (5.6) is showing the total container handling cost is equal to the actual cost of container stacking without unproductive moves. It means that the unproductive moves affect the handling cost and one major factor to increase the cost. The cost is directly proportional to the number of moves of the containers.

This mathematical equation (5.6) has shown that there is a relationship between the number of unproductive moves of containers and cost of container stacking in the yard. This relationship has also been shown in the simulation based results of genetic algorithm (Chapter 7). If we shall use the results of GA like fitness value, cost or unproductive moves in this mathematical model then the results will be shown that the unproductive moves and cost are directly proportional to each other.

5.7 Conceptual Design Model

A model is used to represent the whole process of data flow graphically by using flowchart and design. A conceptual model is used to take understanding about the whole system, its workflow and interaction between the subsystems. We have explained the whole process of our discrete-event simulation-based model of container stacking system in this section.

5.7.1 Process Flow Diagram

This diagram shows the whole process of container handling for stacking in the yard of a seaport container terminal to avoid the unproductive moves. The yard crane checks that if the container is available to store in the yard the pick it up and move to the yard. After this, it will check the first empty storage location. If location is good and no need to further moves then put it at that location else check another location until the best possible location found and store the container. The second condition is, if no more containers are available for storage then wait for next incoming container. It will check the number of incoming containers. If a total number of incoming containers is 150 then stop the whole process. No need to handle further containers because we are handling 150 containers in this work.

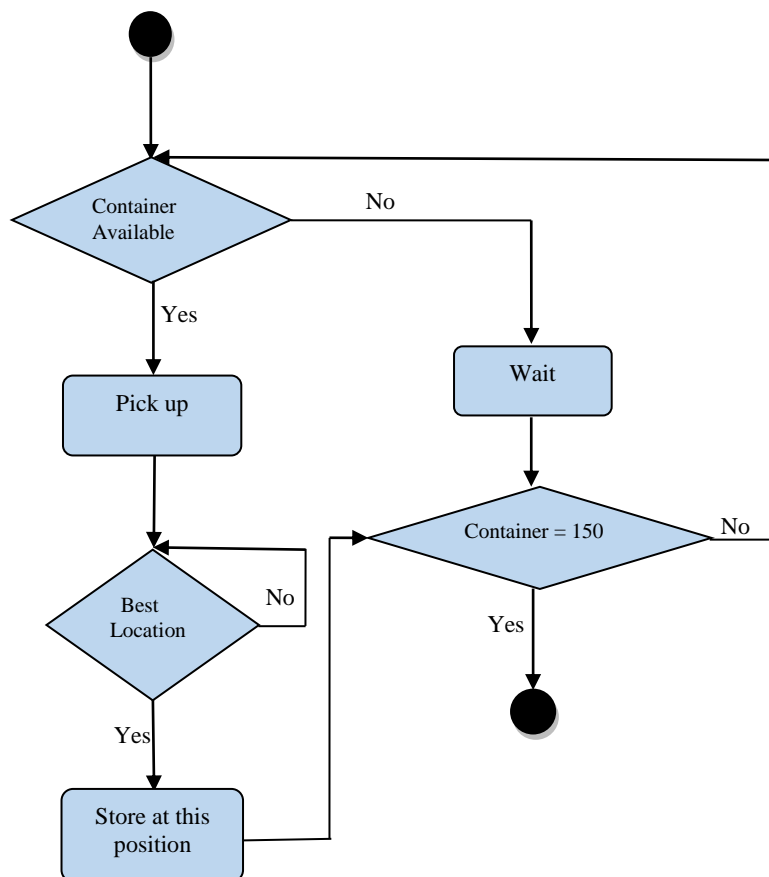


Figure 5.6: Container handling process

5.7.2 Sequence Diagram

The diagram shows the whole process of container storage in the yard. When AGV come with the container in the yard area and the crane pick up the container and store it into the best possible location where no need to reshuffle or minimum reshuffles require.

The AGV send a request to container agent to pick up the incoming container. Container agent requests to resource unit / yard crane to check the delivery date of the container. The yard crane finds the best possible location to store the container in the storage system. After finding the best possible location, the crane will inform about a location in the yard to container agent. Container agent sends a request to the yard crane, to pick up and puts that location. The yard crane will store the container and update the storage system. After this, storage system will inform to crane that action is complete. The crane will inform to container agent that action successful. At the end, container agent informs to AGV that operation is successful.

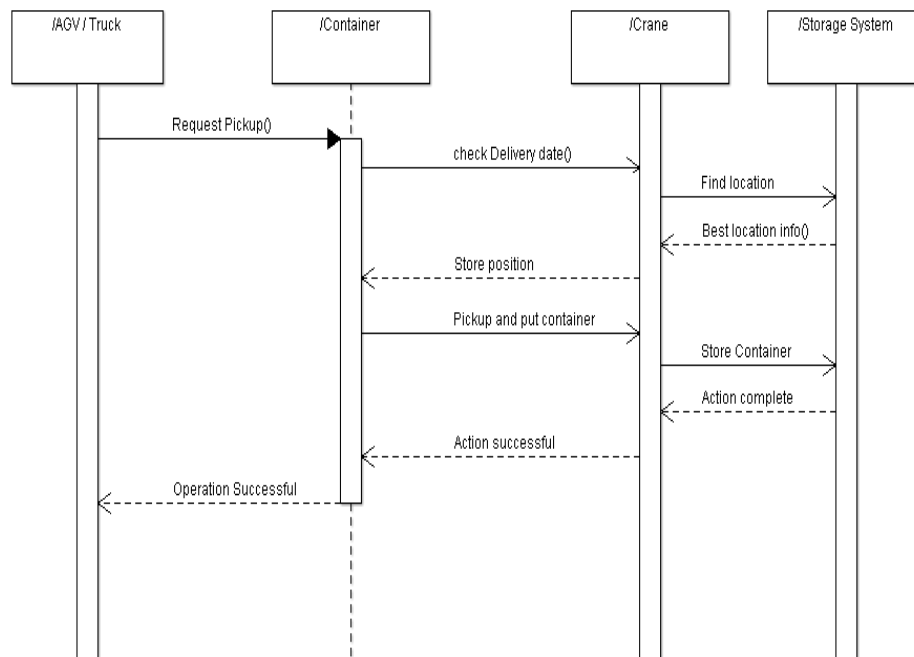


Figure 5.7: Sequence diagram of container stacking in yard

CHAPTER 6

SIMULATION EXPERIMENT

6.1 Simulation Model

After the model designing, we need to make a model for implementation of the design. So we have generated a discrete-event simulation model for a single container stacking block in the yard of a seaport terminal. The block size has been from 100 to 200 containers normally. So we have taken 150 containers an average size. For this purpose, we have used AnyLogic 7.2 simulator.

In this model, we have showed that the AGV's come with the containers and put the containers outside of the yard. The yard crane picks up the containers and stored in the yard. The delivery truck retrieves the containers from yard for further delivery. We have integrated our model with Genetic Algorithm. In this model, the number of containers depend on the population size of GA which is 150. If we shall increase or decrease the population size of GA then the number of containers will also be increased or decreased. The delivery trucks retrieve only those containers from the yard for further delivery whose delivery date will be today according to GA results.

AGV

AGV's are resources those travel within the terminal area and used to move the containers from one place to another place within the terminal. For this purpose, we have 05 AGV's in this model just to assume the environment of the terminal. These are used to load the container and move from the seaside to yard area.

Yard Crane

A single yard crane is taken as a resource unit in this model and it will pick up the containers from outside of yard to store in the yard. The storage process will continue up to 150 containers. After this, the crane will be stopped in the yard.

Delivery truck

The delivery trucks are taken as the resources of the terminal. The waiting place to retrieve the containers for delivery is the truck stand. When the container retrieval time will be started then the truck will go into the yard, load the container and delivered it. For this purpose, we have taken 03 trucks in this model to show the retrieval and delivery process.

Container

The number of containers depend on population size of genetic algorithm. There are 150 containers stacked outside of the yard to show the in-out flow process of containers in the yard. The containers are taken as agents in this model. The AGV's come with containers outside of the yard. The crane picks up the container and stored in the yard. The containers whose today delivery date according to GA result will be delivered by trucks for further delivery.

6.2 Input parameters for simulation

The simulation model has based on some parameters. We need to define these parameters with their types and values to achieve the goal. The following parameter will be set for this simulation model.

Input	Sample value	Type	Explanation
Container id	1-150	Integer	Each container has allocated a number
Row	2	Integer	Total number of rows
Stack / Column	30	Integer	Total number of stack in one row
Tier	3	Integer	Maximum height of stack
Incoming Container	150	Integer	Total containers for stacking based on population size of GA.
Slot	180	Integer	Total slots in the yard

Table 6.1: Input parameters for simulation model

We have developed a discrete event simulation model for container stacking in the yard. There are 03 types of resources which are used in this model. One is AGV that come with the container and to put it outside of the yard. The second one is Yard crane that pick the container and store in the yard and third is a delivery truck that retrieve the container from the yard and go outside the terminal for delivery.

The following parameters will be set for these three types of resource in the model.

Resource	No. of units	Type	Speed	Task
AGV	5	Moving	10 meters/sec	After task completion, check another task. If no more tasks then return to home.
Yard Crane	1	Moving	10 meters/sec	If task complete, then stay there and wait for next task.
Truck	3	Moving	10 meters/sec	After task completion, If no more tasks then return to home

Table 6.2: Parameters for resources in simulation model

6.3 Run Experiment

In this experiment, when we run the Genetic Algorithm to get best fitness results, the best fitness value will increae gradually and get maximum value befor the 25th generation. The results will be mentioned in the form of table and figure. The tournament size of GA affect the better results on the number of generations. If tournament size is small then best fitness

will be gradually increased and achieved on later generations but if the tournament size will be 4 to 6 then results are good else not.

Resource Name	Number of Units	Meantime (sec)	Total time (sec)	Tasks performed
AGV	1	8.442	270.133	32
	2	8.302	257.347	31
	3	8.883	257.597	29
	4	8.87	266.098	30
	5	8.947	250.512	28
Yard Crane	1	2.582	387.30	150
Truck	1	6.016	42.113	7
	2	6.320	44.238	7
	3	6.606	39.633	6

Table 6.3: Resources performed tasks and total time spend

The table 6.3 shows that the resources used in simulation model have performed their tasks at above mentioned time and mean time. The yard crane has minimum mean time to handle a container in the yard that is 2.582 seconds. The AGV's required maximum time to complete the task that is more than 8 seconds.

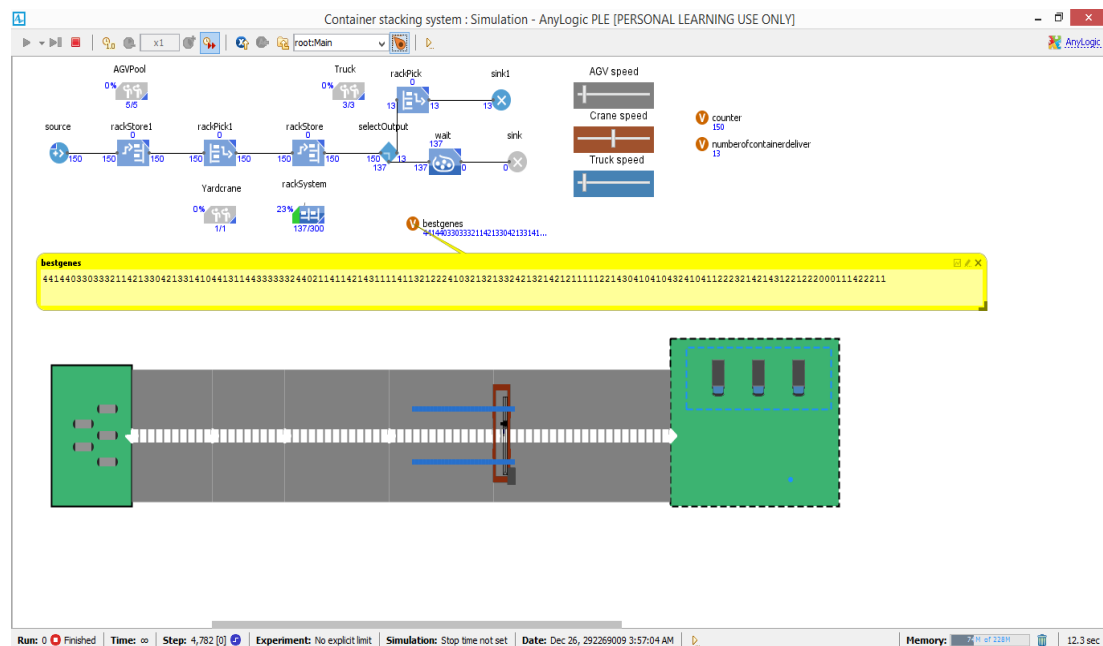


Figure 6.1: A 2D view of CSS model with best GA results

A 2D view of our discrete-event simulation model, a best result obtained by GA and a complete process flow of containers have been shown in figure 6.1. There are 3 speed

controllers to control the speed of resources (AGV's, yard crane and trucks) and to make the simulation model more efficient.

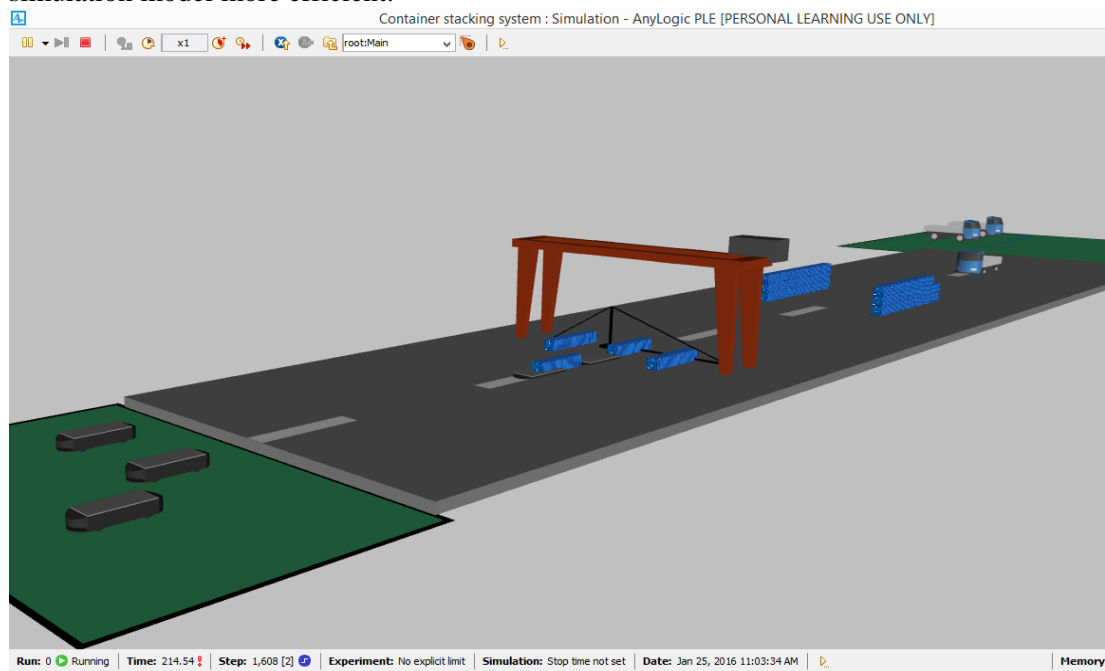


Figure 6.2: A 3D view of the movement of AGV, yard crane and truck in the yard area

In figure 6.2, the AGV with container is going to the yard, the yard crane is picking up the container to stack in the yard and the truck is coming to retrieve the container that has today delivery date for further delivery.

CHAPTER 7

RESULTS

In the figure 7.1, we have showed the simulation based results of GA. The fitness values and cost versus the number of generations has also been shown in the figure. The fitness value of GA is increasing gradually and the cost is decreasing gradually until the best results for container stacking problem has been acheived.

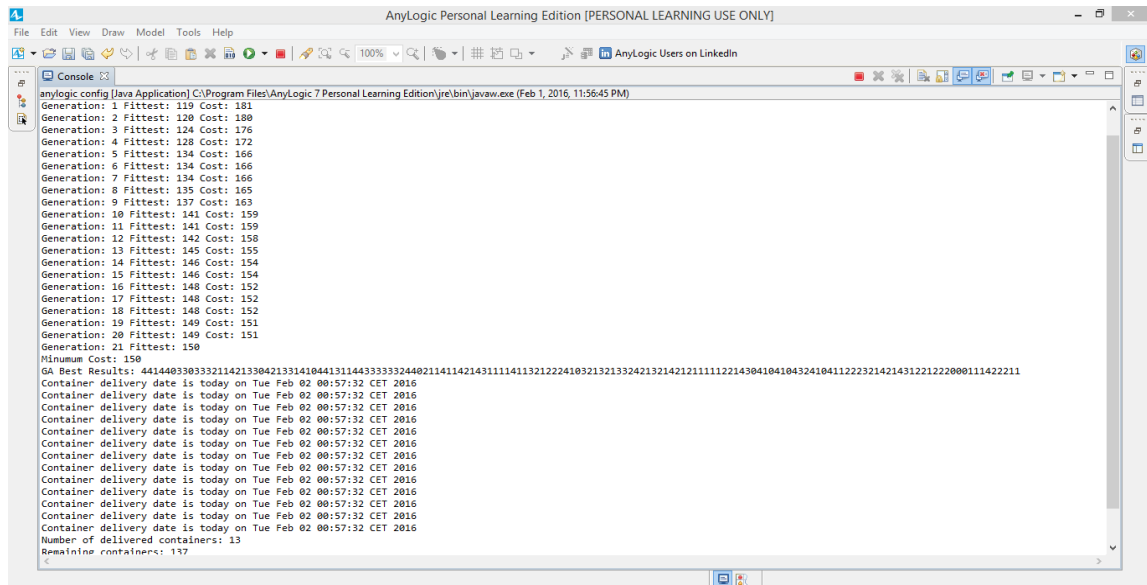


Figure 7.1: Simulation based results of GA

The number of 0's in GA results has been shown that the container has today delivery date. The 13 containers have today delivery date and the 137 containers will remained in the yard.

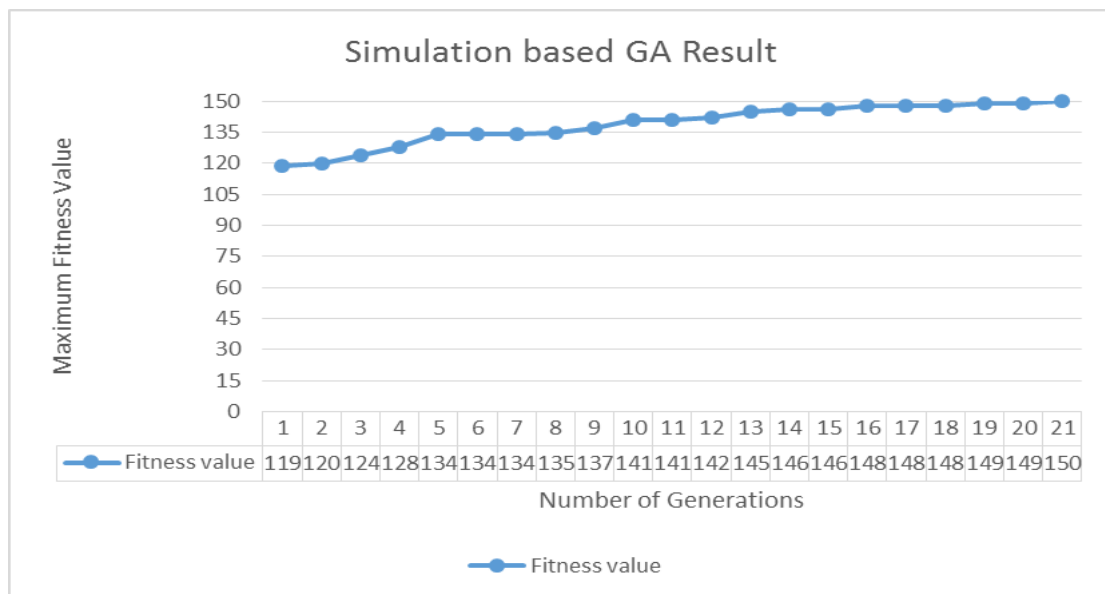


Figure 7.2: GA fitness value versus generations

The number of containers in the discrete-event CSS simulation model depend on population size of genetic algorithm which is 150, so the maximum fitness value will be 150 as shown

in figure 7.2. If we increase or decrease the population size of GA then the number of containers will also be increased or decreased. we have achieved maximum fitness value 150 out of 150 (100%) at 21th generation. This value is showing the high accuracy and efficiency of the genetic algorithm to solve this problem in a good way and give a best optimal solution. In this problem, we have 150 containers for storage and 50 stacks with 3 tiers. This solution showed that all stacks are correctly stacked the containers without reshuffles.

Best genes in GA:

441 440 330 333 211 421 330 421 331 410 441 311 443 333 332 440 211 411
 421 431 111 411 321 222 410 321 321 332 421 321 421 211 111 221 430 410
 410 432 410 411 222 321 421 431 221 222 000 111 422 211

Maximum Fitness = 150

Minimum Cost = 150

The results obtained from simulation model by using GA and containers have assigned the best locations in the yard block. The yard layout with stack and tier is mentioned in the below table.

Stack Number	Tier1	Tier 2	Tier 3
1	4	4	1
2	4	4	0
3	3	3	0
4	3	3	3
5	2	1	1
6	4	2	1
7	3	3	0
8	4	2	1
9	3	3	1
10	4	1	0
11	4	4	1
12	3	1	1
13	4	4	3
14	3	3	3
15	3	3	2
16	4	4	0
17	2	1	1
18	4	1	1
19	4	2	1
20	4	3	1
21	1	1	1
22	4	1	1
23	3	2	1
24	2	2	2
25	4	1	0
26	3	2	1
27	3	2	1
28	3	3	2
29	4	2	1
30	3	2	1
31	4	2	1
32	2	1	1
33	1	1	1
34	2	2	1
35	4	3	0

36	4	1	0
37	4	1	0
38	4	3	2
39	4	1	0
40	4	1	1
41	2	2	2
42	3	2	1
43	4	2	1
44	4	3	1
45	2	2	1
46	2	2	2
47	0	0	0
48	1	1	1
49	4	2	2
50	2	1	1

Table 7.1: Best stacking result achieved by GA

Result's Comparison between GA and Tabu Search

The figure 7.3 is showing the comparison of fitness value of Genetic Algorithm and accuracy value of Tabu Search for container stacking problem to find best possible location. The experiment has been performed upto 50 generations and get the results. The GA has obtained maximum fitness value 150 out of 150 at 21th generation. Tabu Search has obtained maximum accuracy level 120 out of 150 at 16th iteration. We have performed experiment up to 10000 iterations to check the maximum accuracy of Tabu Search but maximum accuracy level 150 has not been achieved. The accuracy of TS is low as compared to fitness value of GA. The genetic algorithm has obtained maximum fitness value before the 25th generation. The results are shown that the GA has performed better than TS for the container stacking problem in this scenario.

Generation No.	GA Fitness value	TS Accuracy value
1	119	100
2	120	100
3	124	108
4	128	108
5	134	108
6	134	108
7	134	108
8	135	108
9	137	108
10	141	109
11	141	109
12	142	109
13	145	109
14	146	109
15	146	109
16	148	120
17	148	120
18	148	120
19	149	120
20	149	120
21	150	120
22	150	120

23	150	120
24	150	120
25	150	120
26	150	120
27	150	120
28	150	120
29	150	120
30	150	120
31	150	120
32	150	120
33	150	120
34	150	120
35	150	120
36	150	120
37	150	120
38	150	120
39	150	120
40	150	120
41	150	120
42	150	120
43	150	120
44	150	120
45	150	120
46	150	120
47	150	120
48	150	120
49	150	120
50	150	120

Table 7.2: Results of GA and Tabu Search Comparison

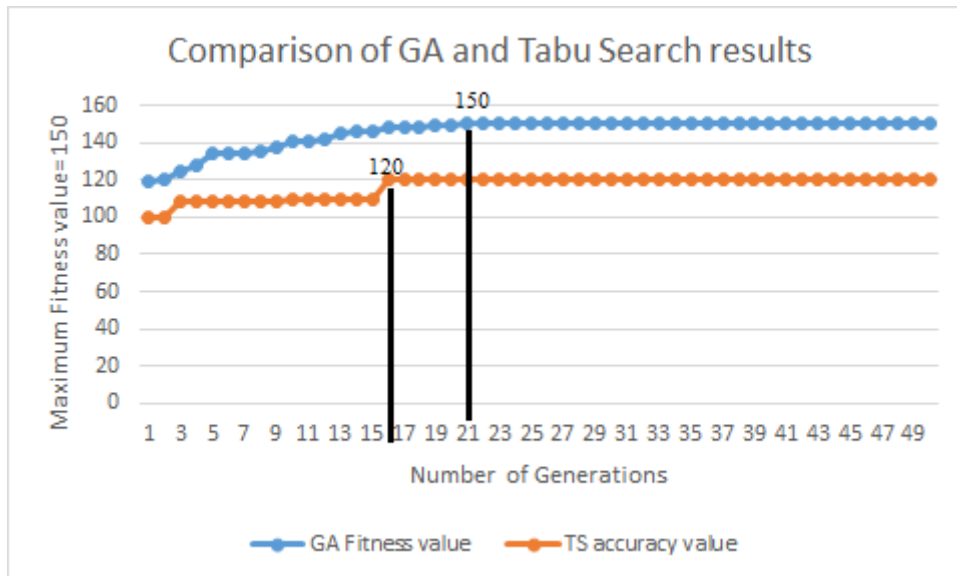


Figure 7.3: Comparison of GA and Tabu Search results

Fitness value versus Cost of Genetic Algorithm

We have performed an experiment on the developed simulation model by using genetic algorithm and get the fitness values and cost up to maximum fitness value. The values of

fitness and cost both are mentioned in table 7.2 and figure 7.4. The result is showing the relationship between fitness value and cost. For example, fitness value is 119, it means 119 values are on correct place and 31 values need to be changed or reshuffled. So we need to handle these 31 value two times, so cost will also be two times.

Generation Number	Fitness Value	Cost
1	119	181
2	120	180
3	124	176
4	128	172
5	134	166
6	134	166
7	134	166
8	135	165
9	137	163
10	141	159
11	141	159
12	142	158
13	145	155
14	146	154
15	146	154
16	148	152
17	148	152
18	148	152
19	149	151
20	149	151
21	150	150

Table 7.3: Fitness value and cost achieved by GA

If fitness value is high then the cost will be low and vice versa. The high fitness value shows that the number of unproductive moves is less.

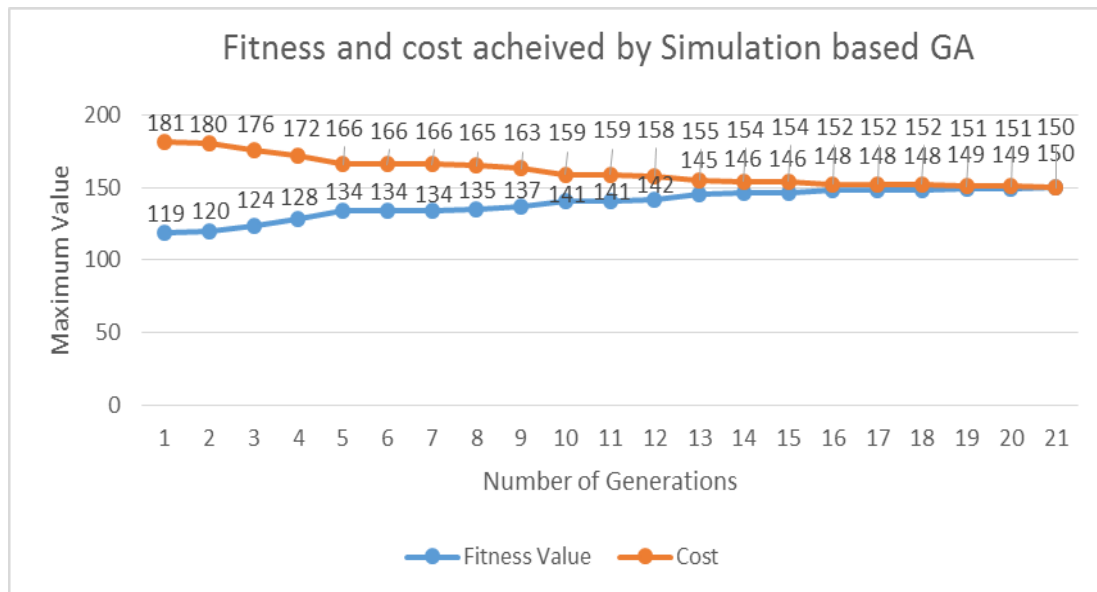


Figure 7.4: Fitness and cost relationship by GA

These results are showing that if the number of unproductive moves have been minimized then the cost will also be reduced. These experimental results are also answering the RQ.1 which is about the relationship between the number of unproductive moves and cost, and RQ.2 that is the impact of a genetic algorithm on the number of unproductive moves. The high fitness value is achieved by using GA has been answered the both research questions.

T-Test

A student t-test has been performed on the data about the fitness value and the cost obtained by simulation-based GA results those are shown in table 7.3 to test the hypothesis.

	<i>Variable 1</i>	<i>Variable 2</i>
Mean	138.952381	161.047619
Variance	95.84761905	95.84761905
Observations	21	21
Pooled Variance	95.84761905	
Hypothesized Mean Difference	0	
Df	40	
t Stat	-7.313119513	
P(T<=t) one-tail	3.44875E-09	
t Critical one-tail	1.683851013	
P(T<=t) two-tail	6.89749E-09	
t Critical two-tail	2.02107539	

Table 7.4: A student t-test

According to rule, If the value of $t_{Stat} < -t$ or $t_{Stat} > t$, It means null hypothesis (H_0) is rejected. In this case

$t_{Stat} = -7.31$

$t_{Critical\ two\ tail} = 2.02$

$t_{Stat} < -t$

$-7.31 < -2.02$

The result has been shown that the null hypothesis (H_0) is rejected. It means there is a relationship between the fitness value and the cost. If fitness value is high then unproductive moves are low and vice versa. So unproductive moves and cost have a relationship.

High fitness = Low cost

Low unproductive moves = Low cost

It means cost and unproductive moves are directly proportional to each other. This result also showed that the mathematical model for cost and number of moves is correct.

CHAPTER 8

VALIDATION AND VERIFICATION

For the verification and validation of our results, we followed the different parameters which are mentioned here.

Debugging

The debugger of AnyLogic 7.2 is a powerful tool that pauses the simulation at a certain place where any error has been occurred due to the mentioned variables, states of resources and agent.

Modular Testing

To test the working of our simulation model and its modules. First, the model was tested under the inputs. Each module or resource like

- The AGV's have been come with the container on the right path to the yard, put the container outside of the yard and go back to pick another container if available.
- The yard crane's parts (frame, hock and moving) are integrated to each other well and working with each other in good way. The yard crane is pickig up the container from outside of the yard and stack in the yard.
- The delivery truck will be retirved only the containers having today delivery dates.
- The results showed that all modules were executing as what was to be predictable.

Sensitivity Test

To test the results of our simulation model during verification and validation, we followed the student t-test with significance level 0.5. We have tested the fitness value and cost as data and found that the results of this simulation experiment were consistent to our intentions.

Results verification & validation

The verification and validation on the results obtained by genetic algorithm has been performed to test that the GA's results are better than TS or not. A comparison has been made between GA's results and Tabu Search algorithm's results.

To verify the internal validity threat that was the effect of population size on the GA result for the RQ.2, we have also performed multiple runs experiment on GA to increase the population size 300 and 600 instead of 150 to check the impact of the change in the population size on the performance of GA. The results showed that the increase in population size has no much impact on the performance of GA. It means that there is no internal validity threat.

CHAPTER 9

ANALYSIS AND DISCUSSION

We summarize the analysis on the basis of literature review and answers to the research questions. The literature has been reviewed and found the most important 04 KPI's (Time, cost, workload balance and unproductive moves), the integration between these KPI's and dependency of three KPI's on a single one KPI (Reshuffling/unproductive moves). They purposed different heuristics approaches and their solutions. The researchers have been focused on minimizing the problems in the yard at seaport terminal and make it well-panned and efficient. They tried to minimize the reshuffles by focusing on unnecessary movement of yard crane, more than one yard cranes in a single block, container handled by weight, yard layout, yard crane scheduling etc.

For RQ.1, we have proposed a mathematical model to show that the cost is directly proportional to the number of moves of containers. A genetic algorithm with 150 population size and high fitness value parameters has been used to get the best fitness value and container handling cost to stack the containers in the yard. The high fitness value means low number of unproductive moves and low cost. It means that the cost and number of unproductive moves is directly proportional to each other and both of them are inversely proportional to fitness value.

For RQ.2, We have checked the impact of the genetic algorithm on unproductive moves of the containers. For this purpose, we have developed a discrete-event simulation model by using AnyLogic 7.2 simulation tool and a genetic algorithm to optimize the solution. A yard crane, 5 AGV's and 3 trucks have been used as the resources of the terminal to the flow of container handling and stacking in the yard area. We have integrated the genetic algorithm and simulation model and get the simulation based results. The number of containers depends on the population size of GA. If the population size has been increased or decreased then the number of containers will also be increased or decreased. The AGV's will come with the container to the yard area and the yard crane pick up the container and stack in the yard. The trucks are waiting to retrieve the container at truck stand and only those containers have been delivered whose today delivery date according to GA best optimize solution. The GA has been achieved maximum fitness value 150 at 21th generation. The best results of GA will be helpful to minimize the unproductive moves. A tabu search has been chosen to compare with the GA because the tabu search is a simple heuristic algorithm to optimize the solution and some researchers used it to minimize the unproductive moves. The tabu search has been achieved the accuracy level 120 out of 150 at 16th generation. We have run the experiment up to 10000 iterations but the maximum accuracy value 150 has not been achieved. The results of the comparison between GA and TS have been shown that the GA has obtained the high fitness value and low cost earlier than the tabu search. We have performed a t-test to test the hypothesis. The t-test's result proved that the hypothesis (H1) is true. The genetic algorithm has an impact on minimization of unproductive moves. The handling cost and number of unproductive moves have a relationship also.

CHAPTER 10

CONCLUSION AND FUTURE WORK

The purpose of this work was to investigate and propose a solution for container stacking system in the yard of seaport container terminal to minimize the unproductive moves and facilitate the yard area management to reduce the container handling cost and save the time. We have considered a single yard crane within a single block area of 150 inbound containers and 180 storage positions. The yard area of Helsingborg port, Sweden has been visited to investigate the problem and to collect the information.

To explore the key challenges for container stacking and suggested solutions in the literature, we have conducted a literature review. Most of the articles are taken from previous 3 years (2012-2015). In this literature review, we have found 4 main KPI's (Time, Cost, Workload, and Reshuffles). All these KPI's are interrelated to each other and in most of the cases, 03 KPI's depend on the most important one which is unproductive moves/reshuffles. Different optimization techniques like LP, MIP, GA, TS and SA has been used to optimize the solutions. The 21 out of 35 selected articles for literature review has been focused on minimization of container reshuffles and showed the importance of the problem and need to solve it. A few articles has been focused on cost which is important for the port's authority and customers. So we have been focused on both of them (unproductive moves and cost) in this work.

We have proposed a mathematical model to show the cost dependency on the number of moves of the containers. If a container is handled more than one time then the handling cost will be multiplied by the number of times to handle the container. To minimize the cost, we have focused on minimization of unproductive moves and well-arranged stacking system in the yard. In the first part of the problem, we have investigated the relationship between the cost and containers' moves. A student t-test with a significance level of 0.05 was performed to check the validity of results those showed that the hypothesis null (Cost and unproductive moves have no relation) is false. The cost depends on the number of moves.

The second one is to investigate the impact of GA to minimize the unproductive moves and to test it by performing experiment on the simulation model of container stacking system. The genetic algorithm was tested on different parametric values and choose the best of them to get high fitness of the population. The highest fitness is achieved before the 25th generation. These results can save the time and memory utilization of the system. A discrete-event simulation model has been developed and integrate it to the genetic algorithm. The number of containers depend on the population size of GA which is 150. If we shall increase or decrease the population size of GA then the number of containers will also be increased or decreased. The genetic algorithm has achieved the maximum fitness value up to 100% to enhance the accuracy in container stacking system. The delivery trucks retrieve only those containers from the yard for further delivery whose delivery date is today according to GA best results.

The simulation based GA's results have been shown that the GA has an impact on the minimization of unproductive moves and the high accuracy in delivery dates of containers is achieved. The cost and time both factors are affected due to the inefficiency of this stacking system. We can minimize these factors indirectly through the improvement of the third one which is unproductive moves. We have made a comparison between the results of Genetic Algorithm and Tabu Search on the same problem to test the performance and to find which one is the best to solve this problem. This comparison has been shown that the GA has performed well to solve the container stacking problem and provided an optimal solution.

The results has been shown that a genetic algorithm with given parameters can handle container according to delivery dates in well-manner and it is helpful to solve the container reshuffles problem.

The future work in this field on the basis of present information is to expand the model for whole yard area that can handle the outbound and transshipment containers with inbound containers and containers having different properties. The second one is time as a key factor that will be taken into the account and tried to minimize it. We would like to improve the proposed mathematical model for cost management also.

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Appendix A

Classified data from Literature review on Container Stacking in yard

Article	Author/s Name	Main/Purposed Work	Method/Technique	Performance Evaluation	Results/Conclusion	KPI
1	Phatchara Sriphrabu, Kanchana Sethanan, Banchar Arnonkijpanich	To assign location to container , minimize total lifting time and increase service efficiency	Genetic Algorithm	A simulation model based on GA is efficient than a model based on FIFO rule.	Positioning containers affect the operation time of the container terminal	Time delay minimization
2	Sgouris P. Sgouridis, Demos C. Angelides	Simulation based analysis of handling Inbound container	Simulation Model to solve discrete event problem	Average turnaround time does not exceed than 30 minutes	Service level improvement (Layout changes, Equipment investments, Working shift policies)	
3	Chuqian Zhang, Jiyin Liu, Yat-wah Wan, Kata G. Murty, Richard K. Linn	Storage Space Allocation problem in yard of container terminal	Linear integer programming model	With short computational time, the workload imbalance is reduce	Reduce the workload imbalance in the yard	
4	Gamal Abd El-Nasser A. Said, El-Sayed M. El-Horbaty	Simulation Model for optimization of storage space allocation	- Discrete-event simulation model, - Flexsim Simulator	Results show the effectiveness of proposed discrete event simulation model	54% reduction in container handling time at Alexandria port by optimizing the storage space allocation problem.	
5	Riadh MOUSSI, Ndeye Fatma NDIAYE, Adnan YASSINE	Minimize distance between berthing location and stacking location using GA and new modeling	Mathematical programming model -Branch and bound -ILOG CPLEX	Minimize the unloading time of container	Minimize the unloading time of container from vessels	
6	Nathan Huynh, Jose M. Vidal	Agent-based approach to model yard cranes for analysis of truck turn time with service strategy	- Agent-based simulation model - NetLogo	The result of average waiting time and maximum waiting time of a truck is better than other methods.	Identify suitable utility functions	
7	Niraj Ramesh Dayama, Mohan Krishnamoorthy, Andreas Ernst, Vishnu Narayanan, Narayan Rangaraj	Solve the container stacking problem with route distance minimization and stack rearrangement	- MIP formulation (1. Continuous time MIP formulation, 2. Discrete sequence formulation) -Modeling of VSR (Vertical stack rearrangement) costs	The application of Theorem 1 and 2 has led to novel cross-over of constraints b/w routing and stacking performs best among all options explored	Minimize total efforts/ time of the yard crane	
26	Riadh MOUSSI, Adnan YASSINE, Ali KANSOU, Thierry	Schedule of lifting vehicles with time window	Genetic Algorithm	A static model to organize the routing of lifting vehicles to load/unload a fixed no. of containers at the terminal.	Transfer of containers within a short duration.	

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	GALINHO					
38	Jose Maria A. Pangilinan, Gerrit K. Janssens, Etsuko Nishimura	Parametric analysis of evolutionary algorithm for storage location of outbound containers at seaport terminal	Genetic Algorithm	A sensitivity analysis of single and multi-objective cases for loading schedules. -LIFO is better than FIFO if storage utilization is higher than 25%. -NSGA's results are better than SPEA2.	Non-dominated Genetic Algorithm generates faster handling time and less re-handled container as compared to SPEA2 (Strength Pareto Evolutionary Algorithm 2).	
36	Hua-An Lu	Container-based model for export container retrieval sequences in a yard block	-Mathematical model -Tabu Search Algorithm	Proposed model and TS algorithm achieve good results for retrieval sequence of containers and minimize the duration/time of crane's movement in yard	Avoid possible reshuffles of containers in yard block	
8	Ceyhun GUven, Deniz Tursel Eliyi	Increase the efficiency of yard by minimizing the storage, retrieval time and dwell time	-Simulation Model -Two dynamic strategies compare	-Policy 1 Random stacking for base case and comparison -By using policy 2, the number of reshuffles can be reduced by 95%.	Reduce the no. of reshuffling of containers to improve the efficiency of the yard.	
9	Amir Hossein Gharehgozli, Yugang Yu, Rene de Koster, Jan Tijmen Udding	Decision-tree heuristic to minimize the number of reshuffles for incoming containers at yard	-Heuristic Algorithm -DP Model	Minimize the reshuffling of containers in yard	Proposed heuristic performs better than common heuristic	
10	Chuanya Chen, Wen-Jing Hsu, Shell-Ying Huang	Simulation and optimization of container yard operation (A Survey)	-DP (Dynamic Programming) Model	Minimize reshuffling	Analytical-based modeling and simulation- based modeling	
11	Wei Jiang, Yun Dong, Lixin Tang	Simulation study on reshuffling problem in logistics operations of CT Yard	Static and dynamic simulation	Real-time decision making for incoming containers to assign a preferable location in the yard.	Well-managed stacking and retrieval of container	Containers' reshuffling minimization
12	Ndeye Fatma NDIAYE, Adnan YASSINE, Ibrahima DIARRASSOUBA	Hybrid Ant Colony and Genetic Algorithm to minimize distance between quays and yard at terminal	-Hybrid Ant Colony with Genetic Algorithm (HAC/GA), -Linear mathematical model	HCA/GA has average percentage deviation 0.199% and 20 optimal results out of 48 instances.	-Minimize the total distance by SC between quays and container yard. -The exact location assigned to each container without causing reshuffle.	
13	Kun-Vhieh WU, Ching-Jung TING, Rafael HERNANDEZ	Storage position of reshuffled containers during static retrieval	Tabu Search	-Tabu search compare with Branch & Bound algorithm -The computation time of B&B is over the time limit of an hour if stacks are more than 10.	Comparison of TS and B&B shows the average gap is 0.4% in tested instances. -Results of TS acceptable for large problem sets.	
14	Shuding Kang, Weimin	Genetic algorithm to solve	Genetic Algorithm	-The global optimum solution is obtained at	-Minimum number of reshuffles	

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	Wu	container's location allocation problem in storage yard		72th generation out of 100 generations. --The minimum reshuffles and minimum range of bays are zero.	-Balance between bays
15	Jana Ries, Rosa G. Gonzalez-Ramirez, Pablo Miranda	Fuzzy Logic Model to minimize relocation moves of containers in yard	-Rule based approach -Fuzzy Logic framework	The fuzzy logic approach is a good strategy for the container stacking problem	Real-time decision making for incoming containers to assign a preferable location in the yard.
16	Mazen Hussein, Matthew E. H. Petering	Reshuffling of containers according to weight	-Genetic Algorithm -Global Retrieval Heuristic approach (GRH)	Find the best possible location for relocating container	-GRH and GA are effective tools to solve this block relocation problem with weights.
17	Xiaoming Yang, Ning Zhao, Zhicheng Bian, Jiaqi Chai, Chao Mi	Intelligent storage determining method for inbound containers in terminals	-MOIPM (Multi-objective integer programming model) -Genetic Algorithm	Results show the effectiveness and robustness of Genetic Algorithm	Minimize unbalance workload and utilization of yard cranes
18	I. Ayachi, R. Kammarti, M. Ksouri, P. Borne	Determine an optimal container's arrangement	Genetic Algorithm	Solution generated by GA is better than LIFO approach, especially when population size grows.	Different container types are handled by GA efficiently
19	Mohammad Bazzazi, Nima Safaei, Nikbakht Javadian	Genetic algorithm to solve storage space allocation problem	Genetic Algorithm	GA provide good results for large size example instead of branch and bound.	Minimize the workload between blocks in order to minimize the storage/retrieval time of containers.
20	Luiz Antonio Carraro, Leandro Nunes de Castro	Clonal Selection Algorithm to minimize reshuffling in stacking operations	MRCLONALG	Obtain competitive performance with low computational cost in time	Minimize the number of reshuffles in container stacking operations.
21	Jonas Ahmt, Jonas Skott Sigtenb jerggaard, Richard Martin Lusby, Jesper Larsen, David Ryan	A new approach to the container positioning problem	Mixed integer programming Time-discretized Model	This approach is better than other approaches if arrival or departure time is known.	The proposed methodology can solve more realistic problem instances with mathematical programming model.
22	Shell Ying Huang, Ya Li, Meimei Lau, Teck Chin Tay	Yard crane deployment in container terminals	-Proportional Distribution Algorithm -Least cost distribution method	The 3-level yard crane deployment scheme is much better than the yard block based ILCH (improved least cost heuristic) for all scenarios.	Minimize the vehicle waiting times and the number of overflow jobs.
23	Kun-Chih Wu, Ching-Jung Ting	Heuristic approaches for minimizing reshuffle operations at container yard	-LAD (Lowest Absolute Difference) -GAH (Group Assignment Heuristic)	-Compare proposed approaches to RI (Reshuffle Index) and ENAR (Expected number of additional relocations) -Proposed approaches results are better than	-GAH is best than other approaches. -GAH is suggested as constructive heuristic for generating initial solutions in other metaheuristic algorithms.

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				existing approaches		
32	Miguel A. Salido, Oscar Sapena, Mario Rodriguez, Federico Barber	A planning tool for minimizing reshuffles in container terminal	Domain-dependent heuristic planning (Proposed an algorithm using heuristic approach)	Easy access to containers at expected time of transfer	Minimize the number of relocations of containers to arrange in order and to avoid further reshuffles.	
27	AZIZI AB. AZIZ, AZIZI ZAKARIA	Container stacking and retrieval prototype simulation using genetic algorithm	Genetic Algorithm	Best optimization rate is 85.6% achieved.	A genetic algorithm can solve a container stacking and allocation problem in better way.	
33	Lixin Tang, Wei Jiang, Jiyin Liu	Proposed a solution for static and dynamic reshuffling problem for containers in a bay	Heuristic Approach Reshuffle Index (RI)	Proposed model can optimize the problem in low time than MRIP model	Improved model can obtain optimal solution more quickly than existing model	
34	Wenbin HU, Zhengbing HU, Lei SHI, Peng LUO, Wei SONG	Combinatorial optimization and strategy for ship stowage and loading schedule of container terminal	-Genetic Algorithm -Heuristic Greedy Algorithm	Proposed model and algorithm have good performance.	The ship stowage problem was reasonably abstracted. (Minimize reshuffle rate on board and the center of gravity)	
35	Miguel A. Salido, Oscar Sapena, Federico Barber	An artificial intelligence planning tool for container stacking problem	Domain-independent planning tool	The yard-bay with 5 tiers generates fewer reshuffles than yard-bays with 4 tiers on this configuration.	Proposed planner minimizes the number of necessary reshuffles of containers in the yard.	
24	Kap Hwan Kim, Hong Bae Kim	Cost model of optimal storage space and number of transfer cranes for import containers	Cost Model	1. The optimal space amount decreases as the space cost increases, but the optimal number of transfer cranes is insensitive to the change of the space cost. 2. Both the optimal number of transfer cranes and the optimal space amount increase as the cost of outside trucks increases.	-The cost model consists of space cost, the transfer crane cost, and the outside truck cost. -The optimal solution to the change of cost parameters is investigated to minimize operational cost and waiting-cost of external trucks.	Cost minimization
25	Xuan Qiu, Jasmine Siu Lee Lam	Optimal storage pricing and pickup scheduling for inbound container	Stackelberg game model	The solutions are obtained in closed form.	Storage pricing problem is first time discussed in the dry port system. Stackelberg game model is first constructed for studying this problem.	
28	Liu Yan, Kang Hai-gui, Zhou Peng-fei	Fuzzy optimization of storage space allocation at container terminal	-Hybrid Intelligent algorithm (Rolling plan approach) -Lingo 9.0	Minimize the imbalance workload among blocks	Reduce workload imbalance in the yard	Balanced Workload
31	Xie Xie, Yongyue Zheng, Yanping Li	Genetic algorithm and its performance analysis for scheduling	Genetic Algorithm MILP model	Proposed GA is effective and efficient	The efficiency of the crane is improved in the warehouse.	

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		a single crane				
30	Yang J. H., Kim, K. H.	Storage method to minimize the relocations of block stacking systems	-Mathematical Model -Genetic Algorithm -Dynamic Programming	-A mathematical model for the static problem. -Dynamic programming and GA is used for static and dynamic both cases -The algorithm for locating inventories should be developed for each type of product	The storage location was determined in a way that the number of relocations during the retrieval operation is minimized.	Computation time

Appendix B

Literature reviewed studies with KPI's Publishing Year wise distribution

No.	KPI	2015	2014	2013	2012	2011	2010	2009	2006	2003	2002	1998	Total
1	Time	1	1	2		2	1		1	1	1		10
2	Cost		1									1	02
3	Reshuffles	4	5	1	4	1	1	4		1			21
4	Balance Workload	1					1						02
Total		6	7	3	4	3	3	4	1	2	1	1	35

Glossary

CCS	Container Stacking System
DES	Discrete Event Simulation
GA	Genetic Algorithm
TS	Tabu Search
AGV	Automated Guided Vehicle
YC	Yard crane
RTG	Rubber-tired Gantry crane
ARTG	Automated Rubber-tired Gantry crane
TEU	Twenty-foot Equivalent Unit

Note: If anybody has need a source code of this simulation model then send an email to me at Fahmeem_abbas@yahoo.com. I shall provide it to you.

Rejoinder Document

Master Thesis Title:	Intelligent Container Stacking System
Student Name:	Faheem Abbas
Student id:	Faab14@student.bth.se
Social Security No.	8008181672

Questions and Answers

Q.1: Why tabu search has been selected to compare with a genetic algorithm?

Answer: The answer to this question has been explained in section 5.5 of the thesis.

- Tabu search is a simple and metaheuristic search method that enhances the performance of local search to iteratively move from potential solution to improved solution.
- According to Hua-An Lu (2013), tabu search is one of the popular meta-heuristics for solving large-scale problems in many fields.
- Kun-Chih WU et al. (2009) said that the tabu search method can minimize the container reshuffling during container retrieval from the yard.
- In some research work, the tabu search has been used for container handling problem in the yard.

Q.2: In Simulation tool comparison, the execution time to execute the delay block of Arena and AnyLogic is equal and to create and destroy entities execution time of Arena is half of the AnyLogic. Explain about selection of AnyLogic?

Answer: The motivation about the selection of AnyLogic simulation tool is mentioned in relevant section 5.3.4.

- The execution time to execute the delay block of Arena and AnyLogic is equal which is important for selection and to create and destroy entities execution time of Arena is half of the AnyLogic which has not much effect on the performance.
- The cost of AnyLogic Simulation tool is less as compared to Arena. In future, if I shall need to use some features of the professional edition to enhance the model then it is easy for me to pay for its license.
- Java is used as a programming language for AnyLogic. I was using java as a programming language for simulation model and GA source code and it's easy to integrate them.
- We can use a simulation model build in AnyLogic as a stand-alone or web application and we can extend it to Java.

Q.3: What is the meaning of formulating the equation in a mathematical model?

Answer: A mathematical equation is formulated by using the defined notations and mathematical symbols.

- An equation says that two things are equal [1].
- The formulate means to state or express in systematic terms or prepare according to a formula or to develop as a method or system [2].
- A formula is a special type of equation that shows the relationship between different variables [1].
- In our mathematical model, we have defined some notations and to use these notations and mathematical symbols to formulate the equation/s. Through these equations, we have showed the final result in form of a final equation.

Q.4: Explain the integration of the simulation model with GA?

Answer: The proposed simulation model has been integrated with GA. In the simulation model,

- The number of containers depends on the population size of the genetic algorithm.
- In genetic algorithm, the first population has been assigned random values then after the implementation of the algorithm, we can get the population with best fitness values. According to the best GA results, each container has been assigned a value and the yard crane has been stacked the containers in the yard according to that value. The delivery trucks are waiting at the truck stand to retrieve the container on their turns. If a container has today delivery date then the delivery truck will come to retrieve that container from the yard and go for further delivery.
- The simulation based GA's results have been shown in the run experiment and result section of thesis work. (Figure 6.1 and Figure 7.1)
- To test the integration of simulation model and GA, we have increased and decreased the population size of GA, the number of containers has also been increased and decreased according to the population size of GA.

Q.5: No information about the tournament size in GA has been found in this work?

Answer: In selection method of GA, the tournament size has been explained and it has also been explain its effects on the results in the run experiment (Section 6.3).

Q.6: Why time not take to handle as a problem in this work?

Answer: We have three main KPI's (time, cost and container reshuffles). The cost and time both are depending on the container reshuffles in the yard (as explained in the introduction and problem description already). So we have selected this container reshuffles problem. By solving this problem, we can minimize the cost (if a container has been handled more than one time in the yard then the handling cost will be increased that times) and the time (the ship's berthing time will be reduced for outbound containers and we can avoid late delivery of inbound containers). In this problem, we have also been handled the cost as a secondary issue

because in preliminary investigation, it has been found that there is little work on cost in this field. The main focus on time factor will be handled in the future work.

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