Heuristic Approach of Berth Allocation and Quay Crane Scheduling for Sri Lanka Ports Authority

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DECLARATION

I hereby declare that this thesis was carried out by me for the degree of Master of Science / Information Technology under the guidance and supervision of Mr Saminda Premaratne. The previous works, articles and websites, which I have made use of, are acknowledged at the respective places in the text. For the present thesis, which I am submitting to the University, no degree or diploma or distinction has been conferred on me before, either in this or in any other University.

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ABSTRACT

Maximum utilization of resources is the key aspect for reducing the turnaround time of vessel calls for any container terminal. Among the various resources, effective utilization of berth and quay cranes are directly subscribed causes for the two important optimization problems arisen, which are the berth allocation and quay crane scheduling problems. The berth allocation problem deals with the generation of a berth plan, which determines a suitable berth and when a vessel has to berth alongside the quay. The quay crane scheduling problem illustrates the problem of allocating how many and which quay cranes will serve for each vessel. Given resolving the problems identified in quayside port operations, this project discusses the need for integrated optimization of Berth Allocation Problem (BAP) and Quay Crane Scheduling (QCS) under any circumstances. Online optimization of quayside resources is also a significant need in terms of unpredicted conditions. Therefore, in order to provide provision in discussing the research models associated with solving resource allocation for incoming vessels in port operations, this report surveys the current state of the art in relevant technologies and methods applicable in the industry. Hence, in this research survey, it is mainly focused on resource allocation problems which related to BAP, QCS and forecasting the vessel arrival patterns in Jaye Container Terminal (JCT) of Sri Lanka Ports Authority (SLPA).

Finally, in this project, an integrated heuristics based solution methodology is proposed that tackles both BAP and QCS problem. Also, the predictive analyzing model will be developed for forecasting the vessel arrival patterns to analyze the vessel calls using data mining techniques to improve the utilization and to achieve maximum productivity of SLPA simultaneously.

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Introduction of Berth Allocation and Quay Crane Scheduling for Sri Lanka Ports Authority

1.1 Prolegomena

Berth Allocation Problem (BAP) and Quay Crane Scheduling (QCS) is one of the major thinking areas which warrants management's attention to upstream the level of services rendered to the shipping community by the container terminal. Port operations primarily characterized into two sections as Quayside and Landside operations. Under the quayside operations, allocating berths known as berth allocation problem (BAP) and scheduling QCs for vessel operation are recognized as the main fundamental issues in the port operation [1][2].

Shipping applications are heterogeneous, distributed, complex, dynamic and large which essentially requires cutting edge technology to yield the efficiencies of port operations. Port operations primarily characterized into two sections as Quayside and Landside operations. Under the quayside operations, allocating berths known as BAP and scheduling QCs for vessel operation are recognized as the main fundamental issues in the port operation. Given the productivity and operational efficiency with a degree of services rendered, BAP and QCS are critically important factors due to rapid advances in container terminal management of any container terminal [3]. Based on this notation, container terminals employed with interactive tools to optimize the tasks of BAP and QCS with quick response.

1.2 Background and Motivation

Given the global trade, 80% of the volume and more than 70% of its value being carried out by on board ships and handled by seaports worldwide [4]. Among the seaports contributing to the world global trade, SLPA being the administrative body of the Port of Colombo is servicing towards the leading hub in the region. Ranked as the best port in South Asia, Port of Colombo is acknowledged as one of the most economical ports in the region serves to major shipping lines and feeder services operates all around the world. To cater such a demand, Port of Colombo presently operates three container terminals servicing as the main gateway for containerized cargo approaching its current per annum capacity, 7.5 million Twenty-foot Equivalent Units of steel containers (TEUs).

Port of Colombo is located in the Indian Ocean by 29 km away from south India and ideally positioned as a transhipment base, capable of serving both the eastbound and the westbound shipping services. Moreover, Port of Colombo located in one of the best strategic locations in the main shipping route connecting Europe, East and Southeast Asia, North and South continentals of America as well. This importance is attributed to its strategic location on a major shipping route and its competitiveness in comparison to other harbours in the region. Port of Colombo presently operates with two private born terminals named Colombo International Container Terminal (CICT) and South Asia Gateway Terminal (SAGT) along with one main state-owned Jaye Container Terminal (JCT). Hence, to sustain in the trade with private terminals operating in Colombo, JCT has to improve its level of services and increase the productivity in terminal operations to accommodate vessel types with deeper draft currently in service. Hence, to compete with other terminals and to improve the level of services rendered, JCT revising its present port operations by introducing potential tools and applying new models to strengthen its maritime trade between shipping communities.

In today's context, in the shipping industry, most of the ports have many terminals and competing with each other in achieving better productivity. Moreover, when container ship size increases, berth productivity becomes ever more important to ensure that the container ships can adhere to their sailing schedules. Furthermore, it's a prominence fact that with the development of Colombo Port City is likely to grow the economic growth faster in Sri Lanka as well as the Asian region in the coming decade and this will have a direct impact on shipping, ports and traffic of incoming container vessels. Therefore, having considering the rapid growth of demand is deal with the number of TEUs to handle; container terminals have to be ready to cope up the challengers by improving its level of services rendered for incoming vessels. Hence, the competition between container terminals has increased considerably in the region recently.

Hence, by introducing novel factors and approaches, it can efficiently allocate all berths and QCs fully utilized with its maximum capacity to expand its service level further to reduce the berth occupancy ratio of a particular vessel and if properly automated and streamlined, it will immensely contribute towards the total productivity of the terminal

1.3 Berth allocation problem (BAP) and Quay Crane scheduling (QCS)

Container terminals consist of a fixed number of berths and each berth can service only one vessel at a given time. To allocate a particular berth to a vessel, the berths must be long and deep enough to accommodate the incoming vessel. Once the incoming vessel being anchored for the services, then the vessel handling operation has to be performed. The turnaround time of the vessel depends on top of the base handling time and the base handling time depends on the quay crane capacity demand of quay crane-hours for the vessel and the number of quay cranes assigned to the vessel. There is a fixed number of quay cranes in the container terminal and each quay crane can only serve a subset of berths. Quay cranes are not allowed to cross one another since they run on tracks. Each vessel has a maximum (based on the length of the vessel) and minimum (due to contractual agreements) number of quay cranes that can be assigned to it and the quay cranes assigned to serve each ship and it is difficult to change during service. Furthermore, each vessel can only berth after its arrival time and when the assigned quay cranes become available to serve the vessel.

However, for berth allocation and quay crane scheduling, some container terminals still follow manual procedures. Accordingly, when preparing berthing allocations and quay crane scheduling manually, identified limitations and drawbacks are listed below,

- When preparing the berthing schedule manually, it is difficult to trace all considering factors one by one.
- Vessel arrival details can be misplaced or mistakes can occur while reading the details.
- When it is required to change the current berth allocations, all other connecting services have to reschedule one by one manually.
- Difficult to update all relevant parties when the schedule changes. (Ex. Vessel Agent, Pilots, Documentation centres, Operational Staff etc.)

- It is difficult to trace history records of berthing for vessels when it is required, as the historical records are kept in manually.
- Delays in publishing daily berthing schedule.

Therefore, by introducing a proper approach for these problems would contribute towards enhancement of day-to-day operational activities by increasing efficiency, accuracy and achieve maximum productivity on its own berths.

1.4 Statement of Research Problem

In this study, the heuristic approach has been carried out to present a method to solve the Berth allocation problem (BAP) and Quay Crane scheduling (QCS) in Jaye Container Terminal (JCT) of Sri Lanka Ports Authority (SLPA).

1.5 Aim and Objectives

1.5.1 Aim of the Study

The aim of this research project is to manage the available resources efficiently to provide services for an incoming vessel to SLPA.

1.5.2 Objectives

Besides being one of the most economical container terminals in the Asian region, JCT is reputed as its fast turnaround time. In order to minimize the turnaround time of an incoming vessel, JCT has to utilize its resources with maximum usage to provide quality services to minimize the berth occupancy time of incoming vessels. Therefore, in this study, the following objectives are addressed as specific objectives of the study.

- To improve the utilization of berthing resources.
- Increase the efficiency of Vessel operation activities.
- Minimize the Vessel waiting time at Outer harbour and turnaround time

  (Docking time at Colombo)
- To provide an up-to-date current status of berths.
- Giving facilities to authorized customers to get real-time information of

  Vessels at berth.

- Streamlining of day-to-day operations and the existing procedures will lead to an increase in staff productivity & satisfaction.
- Maintaining security levels by preventing unauthorized access.

Constrains considered when allocating berth to a particular vessel

- Current berth occupancy and the estimated time of completion of vessels (ETC) at berths.
- Current occupancy and status of Quay Cranes assigned to a particular berth.
- Estimated time of arrival of a Vessel. (ETA)
- Draft of the Vessel and depth of the berth.
- No. of boxes to be handled at port (No. of containers discharge and load)
- Special conditions and requirements to handle the operation (Number of Out of gage boxes (OOG), machinery, rail compartment & Engines etc.).
- Any special geographical conditions of the berth.
- Power of sea current and wind (special weather conditions).
- Terminal service agreements (TSA) with Vessel agents if any?

1.6 Scope of the Project

In view of the requirements of the SLPA, the Berth Allocation System has been identified as one of the important applications in the container terminal and the following functions have been identified as the project scope in order to enhance an efficiently addressed BAP and QCS in JCT.

1.6.1 Functions have been developed by the system

- Monthly Vessel arrival forecast schedule for JCT
- Automation of daily berthing allocation schedule.
- Web interface for Vessel Agents to enter their vessel arrivals details.

- Automation of publishing the daily berthing schedule via SLPA website.
- To Automate Quay Crane scheduling.

1.6.2 Identified problems that have been solved

Given the past approaches presented to solve BAP and QCS for CTs, the gaps identified between previous models with the heuristic approach of berth allocation and quay crane scheduling for JCT - SLPA are given below.

- The quay wall is not in a straight line.
- Depth of the quay area is uneven at JCT.
- Make, boom lengths and sizes of QCs are varied at JCT.
- Mainly JCT sign TSA's with shipping operators and most of the time berth allocation is prioritized based on TSA's.

Therefore, by implementing this approach, it will eliminate drawbacks of current manual procedures of allocating berths and quay crane scheduling for incoming vessels and resource allocation problems in quayside port operation of the seaport container terminal. These state-of-the-art concepts which have received the most attention in real-world port operations to improve the service level by decreasing berth occupancy ratio and increase customer satisfaction as well.

1.7 Overview of the Report

In this report, we illustrate the development of the implementation based research carried on. Chapter 01 includes the introduction and a summary with an overview of the research which emphasises the problems has been solved in berthing allocation in a container terminal whereas Chapter 02 discusses the literature survey done based on the topic. Chapter 03 has summarized the technologies of major areas and Chapter 04 is allocated for the topic of our approach. Chapter 05 includes the design and analysis of the research. Chapter 06 covers the implementation details where Chapter 07 evaluates the methods used in the implementation and the results obtained with the current manual system. Finally, Chapter 08 discusses the Conclusion and future developments for the solution.

Chapter 2

Literature Review

2.1 Introduction

This section illustrates a brief review of papers published from 2011 to 2017 in resolving BAP and QCS in container terminal operations based on the quay area. Given the previous work is done to explore the distinct factors and approaches of applying different models, techniques and mathematical and algorithmic methods affecting port operations in the quay area and its association.

2.2 Previous Approaches for Solving BAP and QCS

During the last decades, a number of integrated approaches have been presented by many researchers to solve the BAP and QCS. In addition, some researches presented environment-friendly solutions for BAP with minimal usage of power using continuous shore quay dealt to control emission levels of the environment. Moreover, some interesting mathematical approaches for obtaining sufficient resource utilization of quayside operations in transhipment hub ports and some algorithmic solution models for BAP and QCS have been introduced.

Problem Classification	Reference
Eco-friendly solutions with minimal usage of power	[5][6]
Integrated optimization for multiple resources	[1][2][3][7][8][9][10][11][12]
Mathematical and Algorithmic solution models	[5][6][7] [13][14][15]

Table 2.1: Overview of reviews of Literature Survey on Port Operations

2.2.1 Eco-Friendly Solutions with Minimal Usage of Power

J. Hou [5] presented a rolling – horizon strategies with a heuristic algorithm to solve ship line scheduling problem which is competent to enhance the efficiency of terminal operation with reduction of the emissions of Container Terminal (CT) and vessels line in berth and it had been applied to the decision support system for the container terminal and shipping lines as well.

In this approach, Jou Hou mainly focused on the fuel consumptions ratios of a particular vessel in connection with the berth allocation window provided by the CT. Since emission reduction and minimizing fuel consumption is directly connect with world green concept, this can be acknowledged as one of the positive approaches for reducing global warming situation. However, a heuristic-based genetic algorithm developed in this study is not clear enough to get the gravity of the approach used to solve the ship scheduling problem to describe in his paper.

X. Quan, Y. Du, and Q. Chen [6] in their study focuses on the berth allocation problem in the container terminal, considering fuel consumption and vessel emissions. Authors introduced a relationship between fuel consumption rate and the sailing speed of the vessel by obtaining vessel arrival times as constraints for allocating berths. Researchers introduced a more sophisticated model on berth allocation considering fuel consumption. Furthermore, having considered the fuel consumption calculation, they presented vessel emission calculation using emission factors

2.2.2 Integrated Optimization for Multiple Resources

N. Idris et al. [1] of Department of Mathematical Sciences, Faculty of Science Universiti Teknologi Malaysia, demonstrated "A Simultaneous Integrated Model of continuous Berth Allocation and Quay Crane (QC) Scheduling Problem". Here, authors have integrated both berth allocation and QC scheduling together to improve the efficiency of the CT.

The model formulated by authors for integrated berth allocation and QC scheduling is highly acceptable. However, in view of the QCs scheduling, authors have not been considered the no of containers (TEU's) hold in a particular Hold to handle (Loading and Discharging) which is one of the main factors considered for estimating the service time period of a particular QC in operation for the allocated vessel. Further, to obtain berthing programme scheduling, mainly First-Come-First-Serve (FCFS) and Large Vessel First (LVF) rules were chosen and the LVF was given the first priority. But for the best practice and a better solution, it is highly recommended to consider the Terminal Services Agreements (TSA's) for vessel berthing as well.

In contrast, considering the whole approach presented for continuous berth allocation and QC scheduling can be recommended for any CT assuming that all constraints are in fair condition (equivalent depths in all berths and size of the QCs are same etc.).

In 2016, another integrated berth allocation and QC scheduling paper were presented by Alnaqbi et al. [2] of Engineering Systems and Management Masdar Institute of Science and Technology Abu Dhabi, UAE and introduced a mixed integer programming model for the problem. The main objective of the authors was formulating a model combines with hybrid and dynamic berth allocation and crane scheduling for a CT.

This approach ensures minimizing the port dwelling time of a particular vessel call by utilizing the berths and QC's efficiently. However, in this paper authors assumed that fixed number of QC's for each berth sensing that high amount of idle times of QCs can be occurred due to some reasons of calling vessels for a particular CT. While scheduling QCs, this model also not considered the long crane factor (number of TUE's to operate in a particular hold of the vessel bay).

El-boghdadly et al. [3] of School of Computing University of Portsmouth PO1 3HE, UK have been presented a paper to evolve an effective and robust composite dispatching rules to solve the berth allocation problem using Genetic Programming (GP) approach. Moreover, this paper also illustrated a new optimization method for the integrated berth allocation and QC's assignment problem, focused on minimizing the berth occupancy ratio for all incoming vessel.

Given the method presented to solve the problem is fair and acceptable. Here, authors have considered almost all the factors which have to consider when allocating berth and assigning a QC for a particular vessel. Moreover, authors have addressed the objectives of the paper by presenting effective models to minimize the port stay time and the waiting time for obtaining a suitable berth for a particular vessel. Further, in this approach firstly it will generate the vessel arrival schedule then the order of the vessels to berth are determined by the proposed GP model which gives most suitable berth for all incoming vessels effectively. However, authors have not considered the TSA and assumed the draft of the vessels are lower than the depth of the quay area and berth is in a straight line layout without any physical obstacles.

Aljasmi et al. [7] presented a paper in 2016 discussed the "study of the combination of static-hybrid berth allocation and crane scheduling". This paper addressed and introduced a method for calculating the vessel's handling time which leads to determining the berth occupancy time of all incoming vessels to CT. Moreover, the main objective of the presented paper is to minimize the overall processing time of the vessel at berth and defined the latest starting time for the next vessel in line for services.

The approach and the method proposed to minimize the processing time for a particular vessel is clearly described and Genetic Algorithm (GA) was presented as a solution approach. Here, authors have considered effects of vessel handling time and described a hybrid model which assumes that one vessel can be allocated to more than one berth. However, the number of QCs assigned in a fix for entire vessel operation leads to a dispute about the assigning long QC in vessel operation taken in to practice.

Focusing the improvement of the current processors of the operation R.T Cahyono et al. [8] presented a paper introducing a dynamic model for the berth and quay crane allocation for multiple berth positions and quay cranes for CT. In this paper, the authors proposed dynamic models for both berth allocation and multiple QCs scheduling simultaneously.

The framework presented by authors facilitate to capture the coordinates for multiple berthing positions and multiple quay cranes, and asynchronous berthing time for different berthing positions as well. In view of the dynamic allocation strategy using the Model Predictive Control (MPC) paradigm model developed, authors ensure to "improve the efficiency of the process where the total handling and waiting cost is reduced by approximately 20%" comparatively commonly practised method of FCFS (for allocating berth for a particular vessel process) combined with the density-based quay cranes allocation strategy.

In order to overcome berth allocation, quay crane scheduling and internal truck assignments to quay cranes, A. Karam et al. [9] proposes a solution to improve the efficiency of container operations in a container terminal. Authors addressed the delay caused by the internal movement of transporting containers between quayside and storage yard, resulting in low productivity in container operations due to a limited number of trucks available in a container terminal. This paper considers the number of internal trucks allocated for a particular vessel or a quay crane as a constraint when estimating the turnaround times of vessels. Authors proposed a mixed integer programming model to solve berth allocation problem, quay crane scheduling and internal trucks for each quay crane with a validation model to test against an existing approach is conducted under the condition that internal trucks are available.

Based on the redundancy policy, X Zhang et al. [10] proposed an integrated solution for BAP and QCS in 2014. Authors mainly considered about the uncertain factor of the vessel arrival time and a number of loaded/unloaded TEUs required to handle in container operation and the robust berth and quay cranes integrated scheduling problem. For the solution, authors presented a mixed integer programming model and the algorithm to solve the problem for BAP and QCS in container operation. Based on the produced simulation verifies the effectiveness of the model and also illustrated the obvious improvement of the anti-interfering ability of the solutions on the uncertain situation.

However, although how strong the plan is, authors discussed some extreme emergencies, that is not capable to eliminate the effects of uncertainty.

N Umang et al. [11] described exact and heuristic methods to solve the berth allocation problem in bulk ports. Although this paper did not contribute to container port operations, authors studied the dynamic hybrid berth allocation problem with the objective to minimize the total service times of the vessels. They proposed “two exact methods based on mixed integer programming and generalized set partitioning, and a heuristic method based on squeaky wheel optimization, explicitly considering the cargo type on the vessel. The formulations are compared through extensive numerical experiments based on instances inspired by real bulk port data”. The results indicated that the set partitioning method and the heuristic method could be used to obtain near-optimal solutions for even larger problem size. Therefore, this approached is useful when considering the BAP in container terminal also.

In 2013, to reduce the turnaround time of a container vessel “a heuristics-based solution to the continuous berth allocation and crane assignment problem” proposed by Elwany et al.[12]. To achieve maximum productivity, the authors discussed the plans on effective ways of utilization berths and quay cranes in a container terminal. In this paper, an integrated heuristics-based solution methodology is proposed to handle both BAP and QCS problems simultaneously. Authors proposed high-quality solutions in a reasonable computational time suggesting its suitability for practical use.

2.2.3 Mathematical and Algorithmic Solution Models

Although the authors illustrate their solutions in mathematical and algorithmic models, literature review papers [1] [2] [7] are aligned with section **2.2.2** in this report, since these solutions are integrated optimization solutions.

Paper presented by M Liu et al. [13] focused on the maximum utilization of resource allocation, especially for container transhipment hub ports. While addressing the resource utilization, the authors pointed out the interconnection between the landside and quayside operations of a container terminal. Also, the authors highlighted the temporary yard stowage required for transhipment containers as one of the major factors to the operational cost. Hence, authors introduced a compact mixed integer linear programming model to maximize the resource allocation of a container terminal.

To formulate the model, identified constraints have been listed along with the assumptions by authors. By going through the list, authors, shown their level of knowledge captured for formulating an efficient model for resource utilization problems in container terminals. Furthermore, authors were able to describe the solution for each and every constraint identified and demonstrated the possible expected outcomes to solve the problem. Therefore, this can be identified as one of the best approaches to present a paper in a dominating manner among other papers.

In 2012, an Algorithm for Continuous Berth Allocation with Quay Crane Dynamic Allocation was presented by X Chen et al. [14]. In this paper, authors presented a solution for continuous berth allocation problem for the container terminal assuming that quay cranes being dynamically allocated and propose new berth allocation model. Authors developed an algorithm to solve the BAP with quay cranes being dynamically allocated in the right position.

This approach can be identified as a reliable model with computing experiments illustrated that the model and algorithm are more efficient and able to complete the container operation within the period of the expected time of completion. Based on the literature, this model and algorithm can be recommended to use when the demand for the services is high.

A. Arram et al. [15] presented a paper focused on solving birth allocation problem by using Bird Mating Optimizer (BMO) algorithm. For this paper, authors applied one of the natural optimization behaviours as a technique to formulate a model to solve the berth allocation problem in a container terminal. Hence, to generate a solution authors used three behaviors of bird species to breed brood were "two parent mating, multi-parents mating, and mutation" According to the paper, BMO has been applied to solve in many optimization problems such as "population-based stochastic search techniques, extraction of maximum power point in solar cells and parameter estimation of fuel cell polarization curve etc.,"

The method used to solve the berth allocation problem is an interesting one, authors able to found the combinations of bird mating behaviours and matched with the requirement categories of a berth to a particular incoming vessel. The method they proposed is more understandable for the readers hence the accuracy of the results are acceptable. Therefore, this paper can be rated as highly acceptable for solve the berth allocation problem in a container terminal although they haven't mentioned about constraints and the assumptions in their paper.

2.3 Discussion of Previous Approaches

This summarized report discussed the reviewed literature on resource allocation in quayside container operation. Researchers mainly pointed their models and algorithms and introduced methods based on optimizing the BAP and QCS in a container terminal. Accordingly, discussion of the reviews are categorized as follows,

2.3.1 Eco-Friendly Solutions with Minimal Usage of Power

Reviewing papers listed as [5] and [6], this type of models can be considered as productive models for resource allocation problem of a container operation while coping up with minimizing the fuel emission ratio and eco green energy consumptions. Therefore, this type of researchers must be motivated since port operation release high rate of emissions to the atmosphere. Finally, this nature of papers can be chosen as inventions providers for environment-friendly solutions with minimal usage of power for berth allocation problem.

2.3.2 Integrated Optimization for Multiple Resources

By considering the papers reviewed on this study of research, it has been observed that many researchers are presented their solutions as integrated optimization for multiple resources. With these integrated solutions, comparing with the papers discussed above [1 ~ 3], the approach presented by Alnaqbi et al. [2] is more or less equal compared with the paper [1] reviewed in this report and these models could be efficiently used for a CT with minimal factors taken place to considered when allocating berths and QCs scheduling for a particular vessel call. Furthermore, the paper presented by El-boghdadly et al. [3] clearly presented and addressed the most important factor of allocating berth for a particular vessel with a heuristic approach determined with GP model. Therefore, this approach can be applied for allocating berth and QC scheduling for most of the CT operate under these conditions.

In paper [7], the main contribution was the consideration of berth allocation with allocating multiple QCs and determined vessel processing time which effects to the next vessel to berth. When considers the papers of [7~10], the approaches and solutions presented are fairly acceptable as authors consider more constraints when developing the model with simultaneous berth allocation, quay crane assignments and internal truck assignments to quay cranes problems in a container terminal. The insufficient number of internal trucks may cause a delay in transporting containers between the quayside and the storage yard, resulting in low productivity of the quay cranes which in turn affects the handling times of vessels. While most of the related studies assume that internal trucks are always available, this paper considers the limited availability of internal trucks when estimating the handling times of vessels. A mixed integer programming model is proposed to simultaneously solve the berth allocation problem, quay crane scheduling problem, and assignments of the internal truck to each quay crane. Authors proposed a validation model test the integrity against an existing approach is conducted under the condition that internal trucks are available. On the other hand, although how strong the plan is, authors discussed some extreme emergencies, that is not capable to eliminate the effects of uncertainty.

Heuristics-based solutions were presented in [11] and [12] to solve the continuous berth allocation and crane assignment problem in bulk and container ports respectively. Although these approaches are considered as sensible approaches, with the assumptions considered to proposed heuristic approach for solve berth allocation problem and quay crane scheduling cannot applicable in JCT.

2.3.3 Mathematical and Algorithmic Solution Models

The papers illustrate their solutions with Mathematical and Algorithmic models are more interesting and can be rated as the best solutions for the BAP and QCS. However, to formulate these type of solutions, authors have to consider all the constraints and facts before allocating resources which assures maximum utilization and the productivity of the container terminal.

2.4 Identified Gaps between Past and Present Approaches

Although there are many achievements obtained by introducing interactive tools for BAP and QCS in the recent past, most of the important rules and constraints are not incorporated. Therefore, it still exists the gap between implemented models and the practical usage of berth allocation and quay crane schedules for incoming vessels.

In view of the past approaches presented to solve BAP and QCS for CTs, the gaps identified between previous models are given below.

- Since the quay wall is not in a straight line, these approaches are not applicable.
- Depth of the quay area is uneven.
- Make, boom lengths and sizes of QCs are varied.
- Mainly container terminals sign TSA with shipping operators and most of the time berth allocation is prioritized based on TSA's.
- Review approaches did not consider the estimated breakdown time factor occurs in order to calculate QCs.

Therefore, a new approach and a method required to solve the berth allocation and QCs scheduling problem for SLPA

2.5 Summary

Container terminals use a large variety of resources and equipment to serve incoming vessels. Berth and Quay Cranes are the most limited and expensive resources for container terminals. Therefore, achieving maximum utilization for these two resources through better planning is critical to achieving the overall maximum productivity for the whole terminal.

To solve the problem of utilization of such a limited and most vital resources, mathematical formulations have been developed to model the berth allocation and quay crane scheduling problems. In general, the resulting models are mixed integer programming formulations and cannot be solved for instances of practical scenarios. Therefore, the technology used to develop the solution to solve the problem of BAP and QCS in JCT has been illustrated in the next chapter.

Chapter 3

Technologies used to develop the solution

3.1 Introduction

This chapter illustrates the methodologies and techniques which have been used to develop the system. Considering the complexity of BAP and QCS process for the incoming vessels, a series of activities were used to find new suitable berth and resources for the vessel. Therefore, to implement this system in more attractive and efficiently, few tools, technologies were used. The details of the implementation environment, hardware infrastructure, development strategies, tools used, database and the Application development architecture are described in this chapter.

3.2 Implementation Environment

A web-based application is developed as a solution for the BAP and QCS problems and to provide interfaces for both internal and external users of SLPA. Hardware infrastructure basically divided into two categories as Server and Client environment.

3.2.1 Server Environment

Since the solution is based on web-based development with centralised client-server architecture, identified minimum hardware and software requirement for hosting the server side application are listed as follows,

- Intel Core I7 processor
- RAM 16GB
- 1TB HDD
- Network speed 1Gb Ethernet
- Window Server 2016 with IIS 8
- PHP version 7
- My SQL 5

3.2.2 Client Environment

Minimum Hardware and Software configuration required to access the system are listed as follows,

- Intel Core I3 Processor
- 8 GB RAM
- 500 MB HDD
- Network access and card support 100Mbps
- Windows 10 OS 64bit
- The latest version of Firefox
- The latest version of Chrome

3.3 Technologies and Development tools used for the solution

To develop decision support utilities and web-based solution for the BAP and QCS, following technologies and tools were used.

3.3.1 Data Mining Technologies

Data mining model had been used for the process of forecasting vessel arrival schedule for JCT and to allocate resources for a vessel since it is nontrivial, implicit and potentially useful patterns or knowledge from previous vessel calls requesting a suitable berth and resources for the vessel operation. Extracted knowledge from the Data warehouse has been used to offer suggestions for Berthing Manager and Duty Manager to make the resources ready and available to perform the vessel operation when the vessel is ready to berth for the services.

Using the information stored in the data warehouse; data mining often provides solutions for BAP and QCS of a container terminal. Therefore, Data mining tools had been used to achieve forecast the vessel arrival schedule for JCT. Accordingly, the resource allocation problem can be solved effectively, since it consumes more time to solve in the traditional way.

- **Weka**

Weka had been used for analyzing data, it contains tools for data preprocessing, classification, regression, clustering, association rules, and visualization. It is also well-suited for developing new machine learning schemes.

3.3.2 Web-Based Technologies

- **PHP Language:**

Hypertext Preprocessor (PHP) is used to develop the applications since PHP is a server-side scripting language designed for Web development. PHP v7 is used for developing the application.

- **Joomla Framework:**

The system is based on the Joomla Core framework. Joomla component development architecture compile with Model View Controller (MVC). This gives more dynamic architecture to develop the system. Based on Joomla core the system has been used the legacy Object Relational Mapping (ORM) on Joomla when doing the DB queries. Also, Joomla framework has been utilized to session handling and log file maintenance.

3.3.3 Development tools

- **Sublime:**

Sublime text 3 was used as the Integrated Development Environment (IDE) for this project. Sublime text is one of the most popular code editors available today and it is adored by many programmers for its speed, simplicity and rich plugin ecosystem. Sublime has been installed with all syntax checker features and this gives developer friendly environment.

- **Apache:**

Apache is the most widely used web server software and Apache 2 was used as the web server of this project. Apache is an open source freely available software which is a fast, reliable and secure. It can be highly customized to meet the needs of many different environments by using extensions and modules.

- **MySQL:**

MySQL is an Oracle-backed open source Relational Database Management System (RDBMS) based on Structured Query Language (SQL). MySQL runs on virtually all platforms, including Linux, UNIX and Windows. Although it can be used in a wide range of applications, MySQL is more often associated with web applications and online publishing.

MySQL is based on a client-server model. The core of MySQL is MySQL server, which handles all of the database instructions (or commands). MySQL server is available as a separate program for use in a client-server networked environment and as a library that can be embedded (or linked) into separate applications.

- **PHPMyAdmin:**

This is an open source tool to query the database values and execute SQL statements.

- **Web browsers debug tools:**

Firefox and Chrome developer tools are used in the implementation process. These tools provide many debugging features of error handling when the issues arrive at the system.

3.4 Application Development Architecture

The system was developed using the Model View Controller (MVC) architecture. This includes the module based development which is a software design pattern for developing software applications.

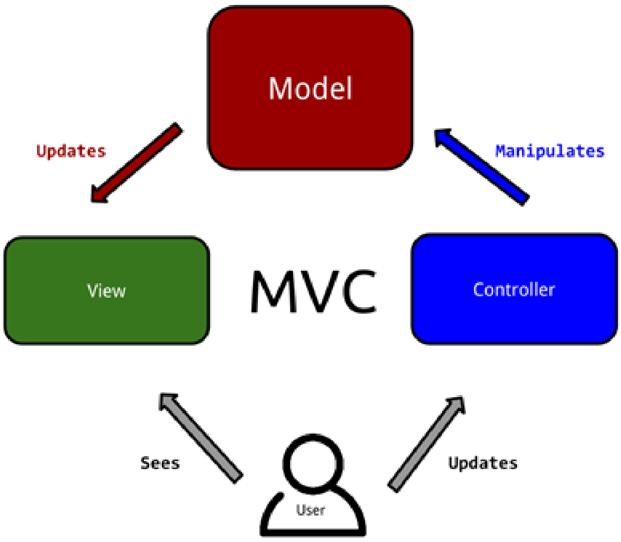


Figure 3.1: MVC Architecture

Model: The model is responsible for managing the data of the application. It responds to the request from the view and it also responds to instructions from the controller to update itself. [16]

Controller: The controller is responsible for responding to the user input and performs interactions on the data model objects. The controller receives the input, it validates the input and then performs the business operation that modifies the state of the data model. [16]

View: It means a presentation of data in a particular format, triggered by a controller's decision to present the data. They are script-based templating systems like JSP, ASP, PHP and very easy to integrate with AJAX technology. [16]

3.5 Summary

This chapter illustrated the hardware infrastructure, software, technologies and tools used to develop the implementation environment to solve the BAP and QCS of the SLPA. The technology and tools described are widely used to develop similar complex systems. To solve the BAP and QCS which are limited and most vital resources, a model of the heuristically approached system has been developed for SLPA to manage the quayside operation effectively. To manage the quayside operation, the approached used to solve the problem of BAP and QCS in JCT has been illustrated in the next chapter.

Chapter 4

Approach

4.1 Introduction

This chapter is focused on the selected approach and the way the technology is adapted in terms of its users, inputs, outputs, process and constraints applicable to provide a solution for BAP and QCS in SLPA.

4.2 Heuristic Approached

To solve the BAP and QCS problems, a web-based application has been developed to receive data from the shipping line agents and it facilitates the berth planner to schedule suitable berths. Provision has been arranged to the Duty manager and the Vessel planner to notify the Berth planner whenever there is a delay in vessel operations and long crane or heavy quay crane assigned according to the vessel operation plan.

Following steps are considered as the outline of a heuristic approach to solve BAP and QCS.

- Shortlist incoming vessel arrival for next 72Hrs.
- Identify key factors of allocating berth by considering the physical conditions of the quay wall and the vessel

- Scheduling quay cranes according to stevedoring and turnaround time of the vessel.
- Consider TSA agreements if any
- Any other constraints applicable to the process

4.3 Decision Support Utility and Web-based application for BAP and QCS

Following processes have been identified as the outline of the decision support utilities and web-based application to solve BAP and QCS.

- Produce monthly vessel arrival forecast schedule for incoming vessels to JCT
- Develop user interfaces for each category of users to enter and update the information of vessel calls
- Allocate Berth and Quay crane resources for a particular vessel call
- Calculate estimated time for complete vessel operation
- To publish daily berthing schedule programme

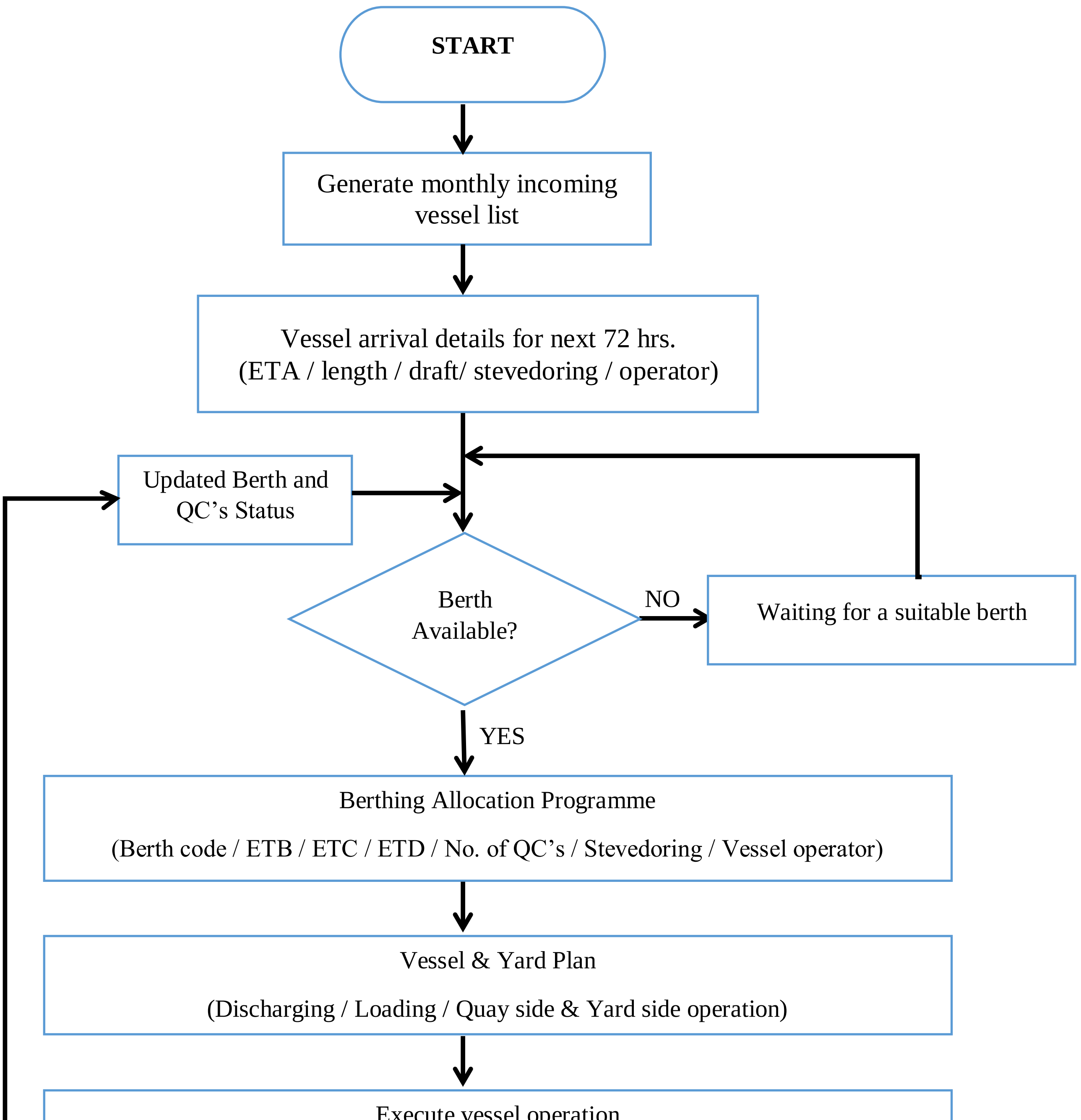

START
Generate monthly incoming vessel list
Vessel arrival details for next 72 hrs.
(ETA / length / draft/ stevedoring / operator)
Updated Berth and QC's Status
Berth Available?
NO
Waiting for a suitable berth
YES
Berthing Allocation Programme
(Berth code / ETB / ETC / ETD / No. of QC's / Stevedoring / Vessel operator)
Vessel & Yard Plan
(Discharging / Loading / Quay side & Yard side operation)
Execute vessel operation

Figure 4.1: Flow Chart to Illustrate the Outline of the Approach

4.4 The main stakeholders of the system

The system collaborates with five active actors in one cooperate system. Following user, roles are available in the system.

- Administrator
- Berthing Manager
- Shipping line agent
- Duty manager
- Vessel planner

According to the System, functions of the User roles can be categorized as follows,

Administrator:

- Secure login to the system
- User Management
- View/Generate a summary report
- View berthing schedule

Berthing Manager:

- View/Generate a summary report
- Secure login to the system
- View monthly vessel arrival list

- View berthing schedule
- Assign/update no. of cranes for berthing schedule
- Update berthing time of vessel and allocate a berthing number
- Add the list of gantry cranes and their status
- Update berthing schedule
- The update time of completion of vessel operations
- Manage quay information (including its length, name etc.)
- View quay cranes schedule

Shipping Line Agent:

- Information delay or changes of vessel
- Generate/view summary reports based on vessel arrival
- View berthing schedule on the web site
- Submit vessel arrival details
- Secure login to the system

Duty manager:

- Secure login to the system
- View berthing schedule
- Update, changes or delay in completion of vessel operations

Vessel planner:

- View quay cranes schedule
- View berthing schedule
- Secure login to the system
- Allocate no of jobs to quay crane
- Record quay cranes information
- Update crane planning and description of vessels

4.5 Process

Details of the incoming vessels arrivals are updated by the shipping line agent. Once vessel arrivals are confirmed in 72 hours, 48 hours and 24 hours before the arrival by the shipping line agent respectively, then system shortlisted the vessels to be birth at SLPA and the Berthing Manager process the automated vessel berthing schedule using the system. Then Duty Manager and the Vessel Planner will notify any delays in vessel operations due to any circumstance and the no. of TEU's are allocated to the heavy crane or the long crane to the Berth Planner. When the Berth Planner is notified, then the automated berthing schedule is amended by changing the estimated time of completion and the time of availability of the particular berth to for the next vessel aligned in the list. Finally, the Shipping Line agent can view his vessels details and progress of vessel operations and also the berthing schedule.

4.6 Summary

This chapter described how to adopt the technology for the approach of solving the BAB and QCS of the problem domain. Our approach is mainly based on the web-based application. It gives the opportunity to add vessel details, automate the berth scheduling and notification system. Next chapter describes the design and analysis of the solution.

Chapter 5

Analysis and Design

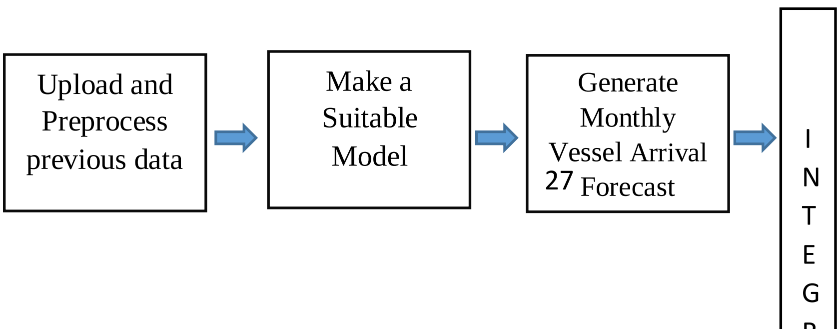
5.1 Introduction

The Approach of the solution for the problem domain has been described in the previous chapter. In this chapter, a detailed description of the system by describing and analyzing each module of the system is described. Further, high-level system design diagrams are included to provide a description of the process clearly.

5.2 Phases of the System

The solution is designed in three separate phases and integrated into the implementation. The three phases are,

1. Decision support utilities for forecast vessel arrival schedule at JCT
2. Allocate a suitable berth for incoming vessel call at SLPA
3. Allocate quay cranes to perform quayside operation



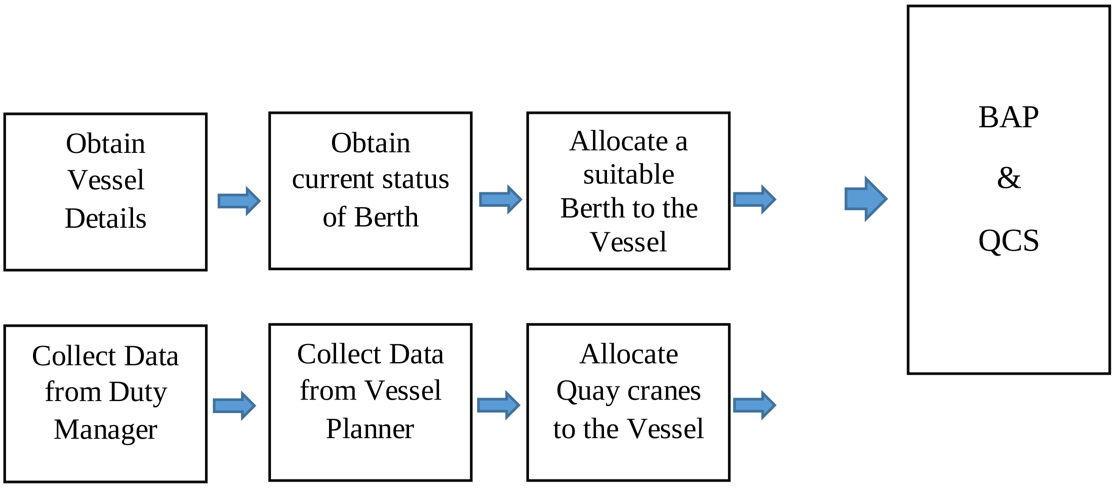


Figure 5.1: High-Level Design of the Solution

5.3 Use Case Diagrams of the main actors of the system

A graphical representation of the main actors are shown below,

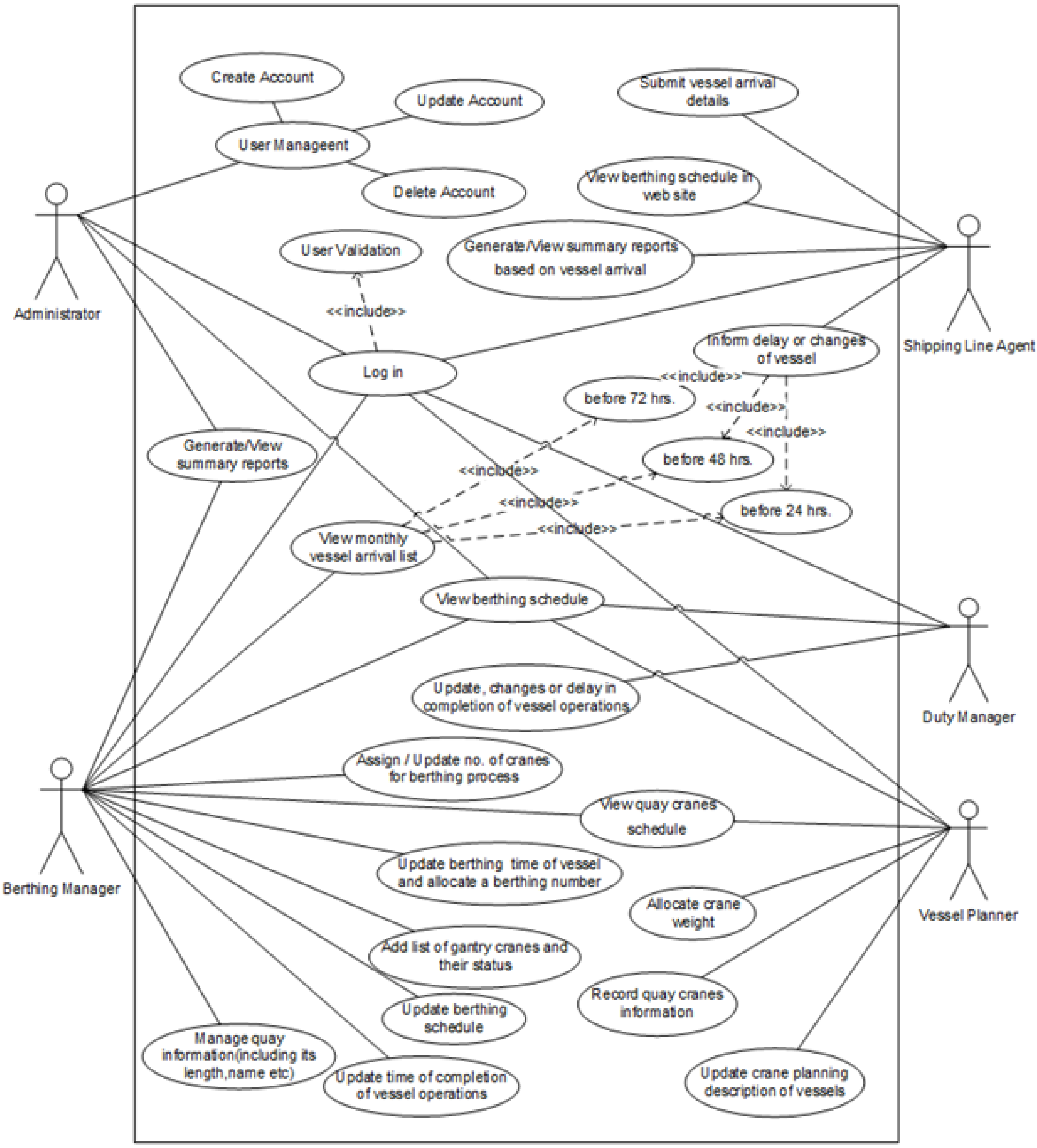


Figure 5.2: Use Case Diagram of the System

As illustrated in Figure 5.2 – Use Case Diagram of the System, a detailed description of user roles are as follows,

5.2.1 Use Case of Shipping Line Agent

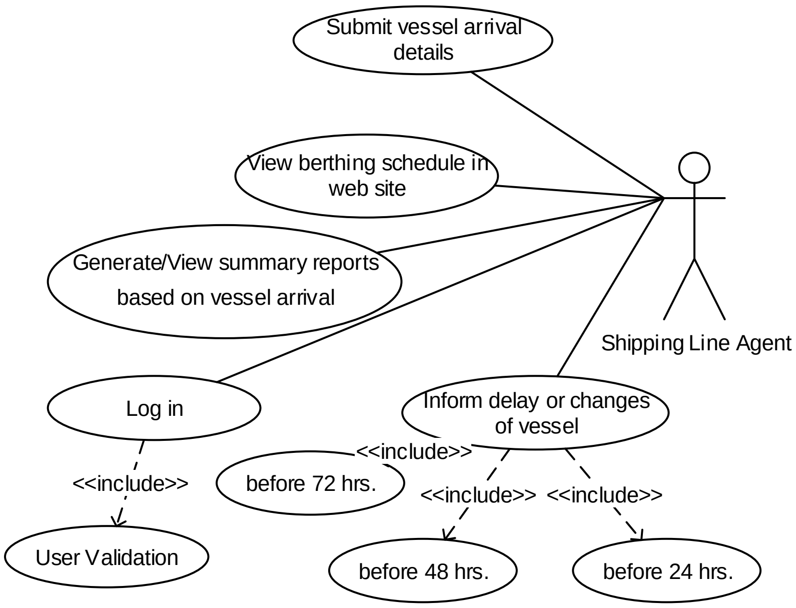


Figure 5.3: Shipping line Agent

- **Use case: Submit vessel arrival details**

Diagram:

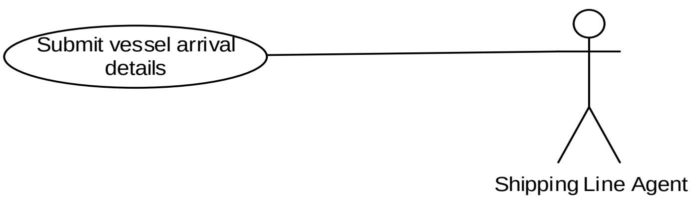


Figure 5.4: Submit vessel details

Brief Description:

The Shipping Line Agent accesses the Online Vessel Details submission, fill the vessel details and send the form.

Initial Step-By-Step Description:

Before initiating this use case, the Shipping Line Agent has to browse the online web application

- The Shipping Line Agent login to the system by entering user name and password.
- The system displays the correct form.
- The Shipping Line Agent fill the form and send the details form.

- **Use case: Delay or changes of vessel details**

  Diagram:

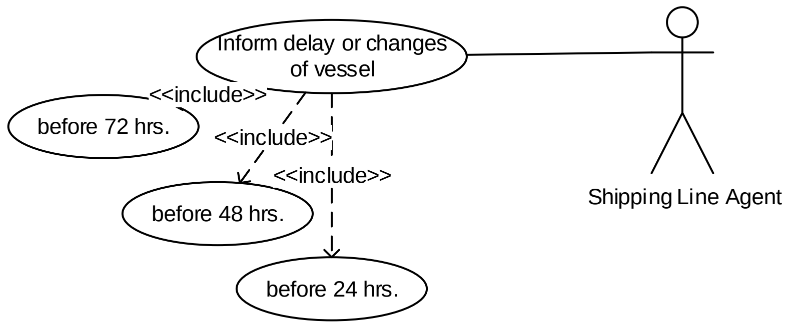


Figure 5.5: Update changes or delays of vessel arrivals

Brief Description:

The Shipping Line Agent accesses the Online Vessel Details modification form, fill the modification details and send the form.

Initial Step-By-Step Description:

Before initiating this use case, the Shipping Line Agent has to browse the online web application and redirect to the vessel details updating form.

- The Shipping Line Agent login to the system by entering user name and password.
- The system displays the correct form.
- The Shipping Line Agent modify the vessel details the form and send the details form.

- **Use case: View berthing schedule on the web site**

  Diagram:

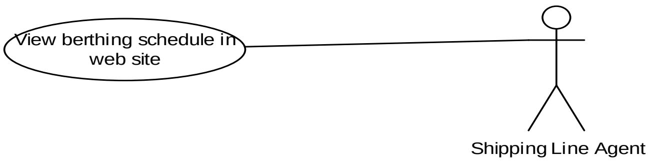


Figure 5.6: View Berthing Schedule

Brief Description:

By accesses slpa.lk web site, Shipping Agent can find vessel arrival details as soon as possible.

Initial Step-By-Step Description:

1. Go to www.slpa.lk web site.
2. Find berthing schedule.

5.2.2 Berthing Manager Use Case

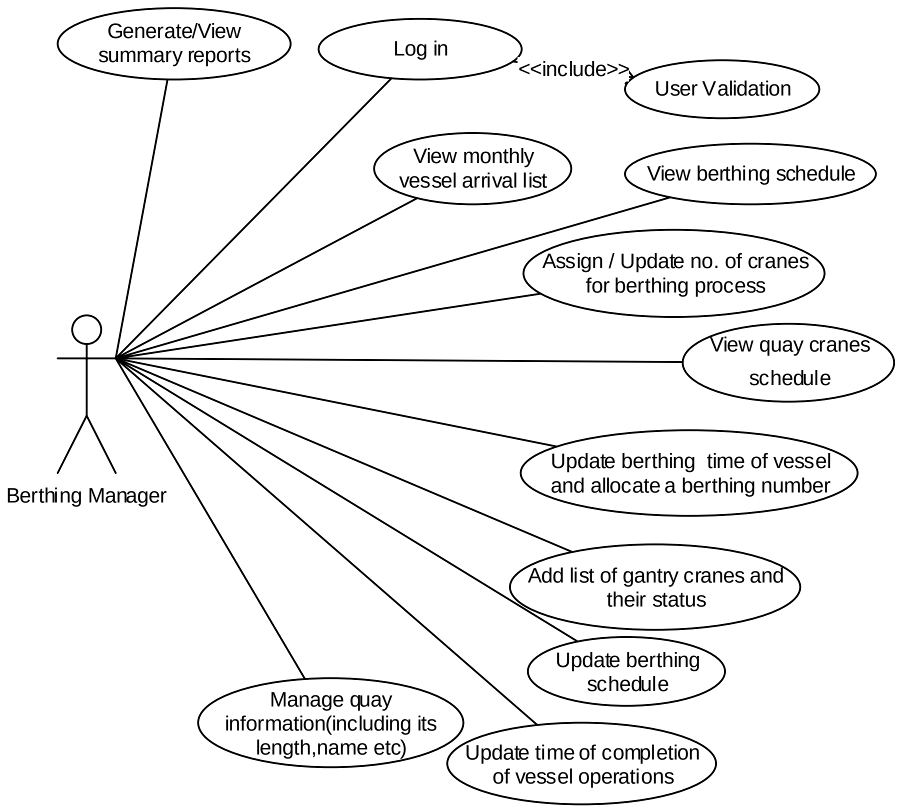


Figure 5.7: Berthing manager use case

- **Use case: View the monthly arrival list**

  Diagram:

Figure 5.8: View vessel arrival list

Brief Description:

The Berthing Manager accesses the Vessel Arrival List form and the user can list out whole vessel arrival list of the correct date period.

Initial Step-By-Step Description:

Before initiating this use case, the Berthing Manager has to login to the system and then go to the vessel list form.

- The Berthing Manager login to the system by entering the user name and password.
- The System displays the correct form.
- Then go to the Vessel Arrival List form by changing the date range.

- **Use case: Update berthing time of vessel and allocate berth number**

  Diagram:

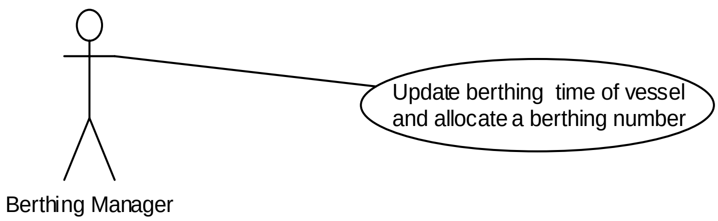


Figure 5.9: Update berthing time

Brief Description:

The Berthing Manager can modify the system generated berthing schedule for any reason.

Initial Step-By-Step Description:

Before initiating this use case, the Berthing Manager has to login to the system and then go to the berthing schedule form.

- The Berthing Manager login to the system by entering the user name and password.
- The System displays the berthing schedule form.
- Select the system generated berthing schedule and change the date and time.
- Submit changes to update the schedule.

- **Use case: Add a list of quay cranes and their status**

  Diagram:

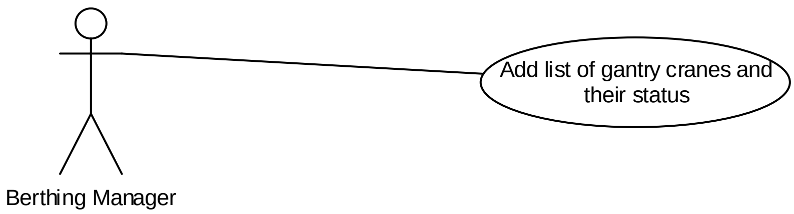


Figure 5.10: Add quay crane list

Brief Description:

The Berthing Manager can assign a number of cranes to the corresponding vessel.

Initial Step-By-Step Description:

Before initiating this use case, the Berthing Manager has to login to the system and then select the correct vessel before allocating the cranes.

- The Berthing Manager login to the system by entering a user name and password.
- Then visit the cranes scheduling form
- Allocate no of cranes considering the total no of containers have to load and discharge.

- **Use case: Update time of completion of vessel operation**

  Diagram:

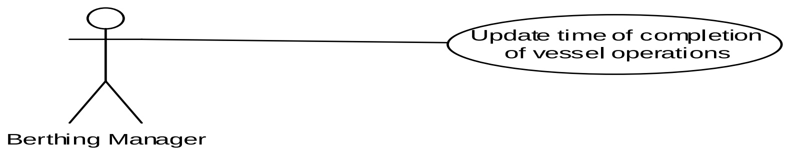


Figure 5.11: Update time

Brief Description:

The system automatically calculates, when manager triggers the calculation function. If the berthing manager needs to modify that calculating completion time for any reason, it is possible to change.

Initial Step-By-Step Description:

Before initiating this use case, the Berthing Manager has to confirm how many loading and discharging containers going to be operate corresponding.

- The Berthing Manager login to the system by entering the user name and password.
- Then visit the completion time scheduling form
- Then modify system generated completion time.

5.2.3 Vessel Planner Use Case

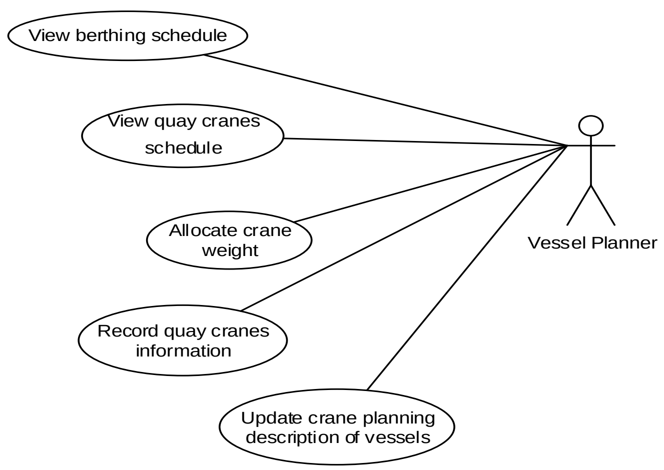


Figure 5.12: Vessel planner

- **Use case: View berthing schedule**

  Diagram:

Figure 5.13: View berth schedule

Brief Description:

The system automatically calculates the berthing schedule program after triggering berthing process and this schedule can view vessel planner.

- **Use case: View quay crane schedule**

  Diagram:

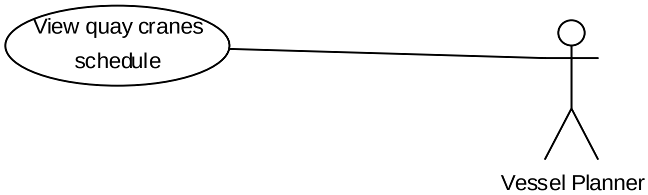


Figure 5.14: View quay cranes

Brief Description:

In first, vessel planner can view berthing manager generated a schedule and then vessel planer has accessibility to modify crane schedule.

- **Use case: Record quay crane information**

  Diagram:

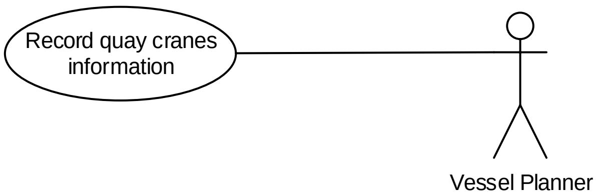


Figure 5.15: Record quay cranes

Brief Description:

The Vessel Planner accesses the quay crane details submission form and fill the crane details and send the form.

Initial Step-By-Step Description:

Before initiating this use case, The Vessel Planner login to the system by entering the user name and password.

- The Vessel Planner first visits the crane's detail form and fill the crane details one by one.
- Then submit the form.

- **Use case: Update crane planning description of the vessel**
  Diagram:

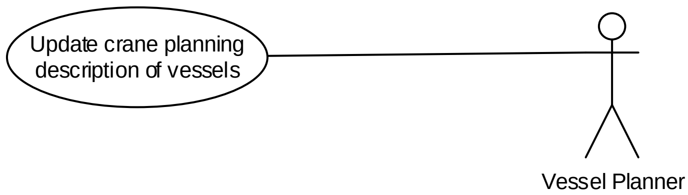


Figure 5.16: Update crane

Brief Description:

The Vessel Planner accesses the quay crane schedule form and modifies cranes schedule.

Initial Step-By-Step Description:

Before initiating this use case, The Vessel Planner login to the system by entering the user name and password.

- The Vessel Planner first visits the quay crane schedule form.
- Modify the crane schedule.
- Then submit the form.

5.2.4 Duty Manager Use Case

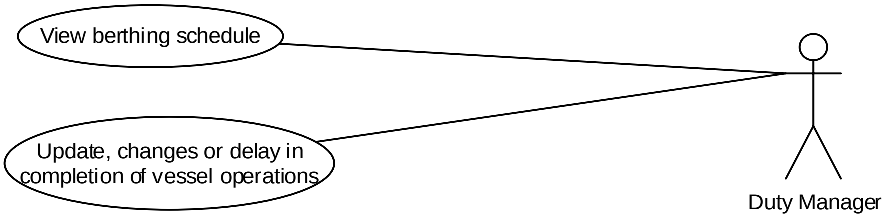


Figure 5.17: Duty manager

- **Use case: View berthing schedule**

  Diagram:

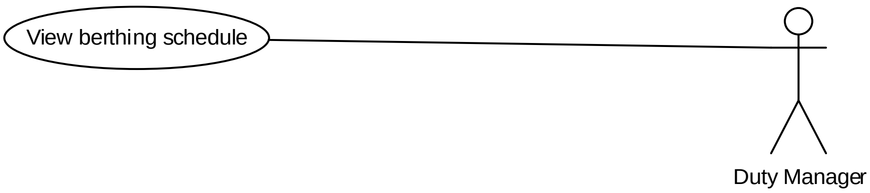


Figure 5.18: Berthing schedule View

Brief Description:

The system automatically calculates the berthing schedule program after triggering berthing process and this schedule can view Duty Manager.

- **Use case: Update changes or delay in completion of vessel operation**

  Diagram:

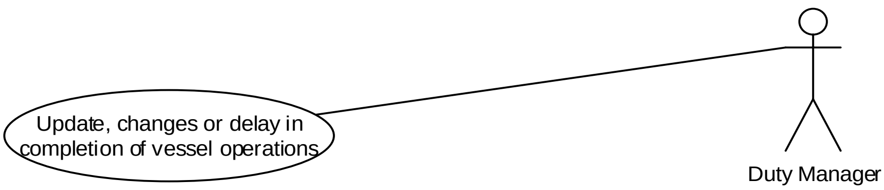


Figure 5.19: Update vessel operations

Brief Description:

The Duty Manager accesses the quay crane schedule form and modifies cranes schedule when a crane was damaged in any reason.

Initial Step-By-Step Description:

Before initiating this use case, The Duty Manager login to the system by entering the user name and password.

- The Duty Manager first visits the quay crane schedule form.
- Modify crane schedule status with any remarks.
- Then submit the form.

5.3 Design Diagrams of the system

All other relevant diagrams of analyzed the requirements, designed processers and user interfaces of web-based application development included in Appendix A. Accordingly, the application has been developed to interact with the system users.

5.4 Summary

This chapter shows the designing and analysis part of the application. There are mainly four modules in the system which are Berth Planner module, Shipping Line agent module, Vessel Planner module and Duty Manager Module. Next chapter illustrates the implementation of the solution in details.

Chapter 6
Implementation

6.1 Introduction

This chapter describes the process of formulating a suitable model to generate monthly vessel arrival forecast schedule and the integration of data mining model to the developed system. Furthermore, this chapter illustrates the implementation of web-based modules, processors and functionalities of the system to solve BAP and QCS in SLPA, since the previous chapter demonstrated the designing diagrams as an entity-relationship model, use case diagram and class diagrams, a clear idea was to obtain for the implementation and development process.

6.2 Implementation of a model for monthly vessel arrival forecast schedule

Predictive analysis of monthly vessel arrival forecasting schedule approach had been done by analyzing the data collected from the previous vessel calls for the services at JCT. To analyze the data, Weka offers ultimate provisions in all forms requires to formulate a suitable model of generating monthly vessel arrival forecast schedule for all of its berthing points at JCT. While formulation the model, identified main points are as follows,

- Data Preparations
  Data Preparation had been done by collecting, cleaning, and consolidating data primarily for analysis.
- Data selection and transformation
  Data Selection had been done to retrieve data relevant to the analysis and data had been transformed or consolidated into forms appropriate for mining, by performing aggregation operations.
- Clustering
  Clustering had been done to form identify a group of features that are very similar to each other but are highly different from the objects in other clusters.

6.2.1 Data Preparation and Preprocessing

To formulate a model, previous vessel calling and berth allocation data had been collected from SLPA. Since collected data had many numbers of missing and in completed noisy values, it had been filtered and replaced missing values using Weka as shown in Figure 6.1. Then unwanted attributes are removed and preprocessed using Weka tools, sample preprocessed data are shown in Figure 6.2

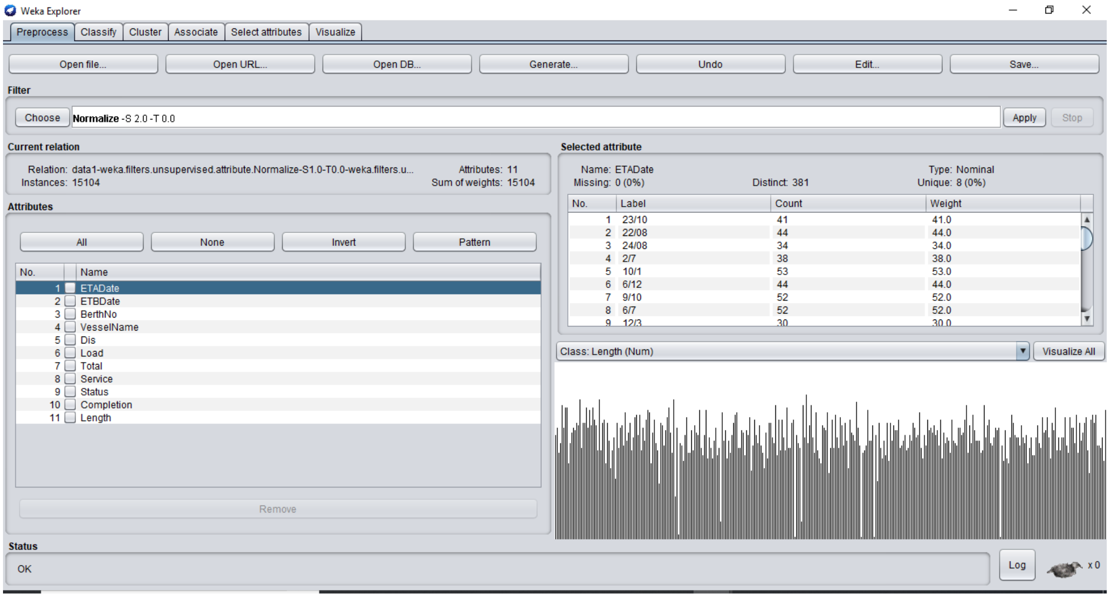


Figure 6.1: Weka GUI

Viewer

Relation: data1-weka.filters.unsupervised.attribute.Normalize-S1.0-T0.0-weka.filters.unsupervised.attrib

No.	1: ETADate Nominal	2: ETBDate Nominal	3: BerthNo Nominal	4: VesselName Nominal	5: Service Nominal	6: Status Nominal	7: Completion Nominal	8: **Length** Numeric
1	23/10	1/0	JCT2	FEEDER-4	TUT	F	C	0.0058...
2	22/08	4/9	JCT3	MALDIVE CA...	MLE	F	C	0.0064...
3	24/08	4/19	JCT3	NORASIA AL...	SGX-W	M	C	0.00964
4	2/7	5/9	JCT4	CMA CGM W...	WAX-E/B	M	C	0.0089...
5	10/1	12/20	JCT2	MSC IDIL	HAL	F	C	0.0068...
6	6/12	8/22	JCT2	KRIPA	SEAC...	M	C	0.0067...
7	9/10	6/28	JCT2	CAPE MARTIN	INDUS...	M	C	0.0110...
8	6/7	7/8	JCT1	ST.JOHN GL...	TUT	F	C	0.0076...
9	12/3	4/17	JCT2	ACHIEVER	CC	F	C	0.0079...
10	2/2	7/23	JCT2	FLORA DEL...	ASEA-W	M	C	0.0083...
11	28/12	3/9	JCT2	HATSU PRIMA	CIX	M	C	0.0090...
12	31/05	10/15	JCT3	PUNJAB SE...	PDS-W	M	C	0.0146...
13	15/03	12/4	JCT2	HOWRAH B...	INFEX-...	M	C	0.0112...
14	18/02	12/4	JCT3	APL CHIWAN	REX	M	C	0.0149...
15	23/05	1/3	JCT4	YM WEST	CGX	M	C	0.0137...
16	18/12	3/26	JCT2	ZIM ALABAMA	MEMX-E	M	C	0.0130...
17	23/06	7/27	JCT1	MOL ABILITY	KEX	M	C	0.0073...
18	27/09	6/1	JCT3	APL CYPRINE	SZX	M	C	0.0137...
19	31/01	6/27	JCT2	CMA CGM V...	WAX-E	M	C	0.0119...
20	1/1	1/1	JCT1	LAMPHUN N...	CC/HAL	M	C	0.0065...
21	1/1	1/1	JCT1	KHALEEJ EX...	CO	F	C	0.0079...
22	1/1	1/1	JCT1	YM INTELIG...	CSI	M	C	0.0086...
23	1/1	1/1	JCT1	YM INTELIG...	CSI	M	C	0.0086...
24	1/1	1/1	JCT1	CMA CGM IM...	WAX-E/B	M	C	0.0085...
25	1/1	1/1	JCT1	ZIM JAMAICA	EMX-E	M	C	0.0126

Figure 6.2: Sample of preprocessed generated by Weka

6.2.2 Data selection and transformation

In the data selection and transform section, we used filters bundled up with Weka named as unsupervised attribute normalize filter. With these filters and tools, it had been managed to get the following two figures named as Figure 6.3 and Figure 6.4.

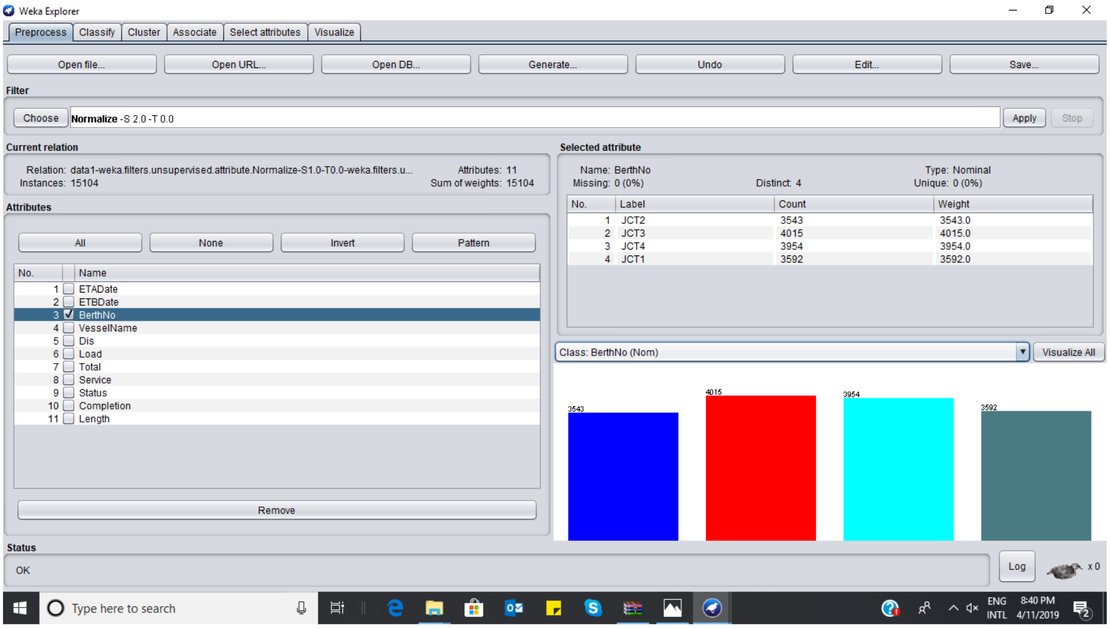


Figure 6.3: View generated by Weka

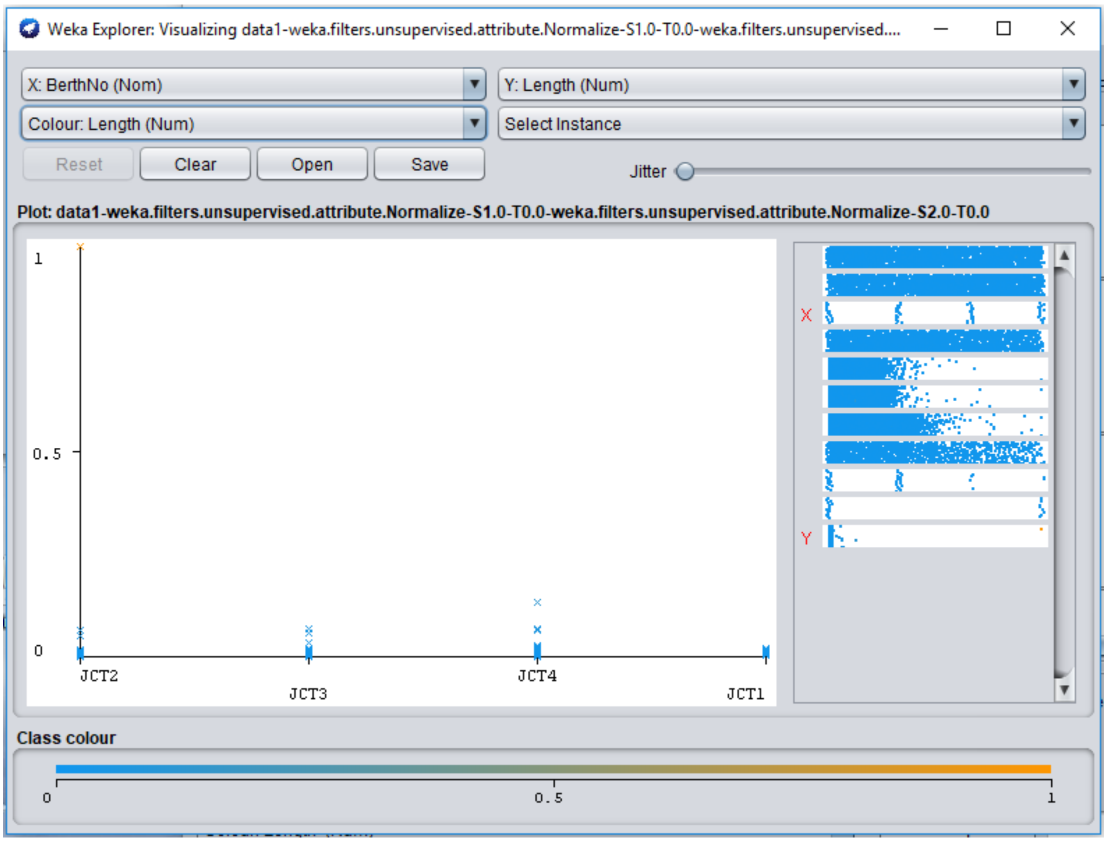


Figure 6.4: Visual generated by Weka reference to Berth No's

6.2.3 Clustering used for formulating a model

To build up a model, K-mean clustering algorithm had been used with Euclidian distance function to measure the distance from the cluster centroids. The data set has been divided into 4 segments. Selection of segments are shown in Figure 6.5 and identified clusters are shown in Figure 6.6.

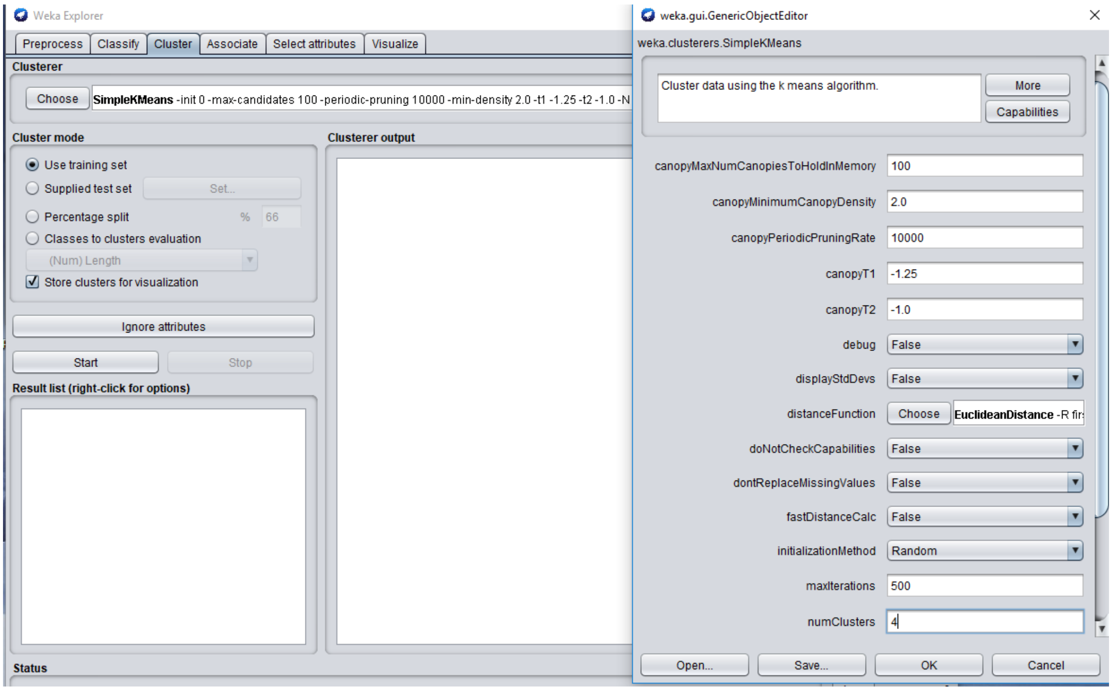


Figure 6.5: Segmentation of Clusters

```
=== Run information ===
Scheme:       weka.clusterers.SimpleKMeans -init 0 -max-candidates 100 -periodic-pruning 10000 -min-density 2.0 -t1 -1.25 -t2 -1.0 -N 4 -A "weka.core.EuclideanDistance -R first-last" -I 500 -num-slots 1 -S 10
Relation:     data1-weka.filters.unsupervised.attribute.Normalize-S1.0-T0.0-weka.filters.unsupervised.attribute.Normalize-S2.0-T0.0
Instances:    15104
Attributes:   11
              ETADate
              ETBDate
              VesselName
              Dis
              Load
              Total
              Service
              Status
              Completion
              Length
Ignored:
              BerthNo
Test mode:    Classes to clusters evaluation on training data
=== Clustering model (full training set) ===
kMeans
======
Number of iterations: 19
Within cluster sum of squared errors: 58477.73473307637

Initial starting points (random):
Cluster 0: 14/01,14/01,'APL SOKHNA',0.032167,0.52854,0.560706,LWX,M,C,0.011538
Cluster 1: 12/11,12/11,'YONG XING',0,0.051088,0.051088,CG,F,C,0.007892
Cluster 2: 7/2,7/2,'CONTI ASIA',0.031536,0.189215,0.220751,FAX-W,M,C,0.008192
Cluster 3: 16/06,16/06,'ANL ESPRIT',0.195522,0.198675,0.394197,NEMO,M,C,0.01039

Missing values globally replaced with mean/mode
Final cluster centroids:
                          Cluster#
Attribute          Full Data        0          1          2          3
                   (15104.0)   (2130.0)   (2391.0)   (6271.0)   (4312.0)
=====================================================================================================
ETADate                9/2      14/01      12/11        7/2      16/06
ETBDate                9/2      14/01      12/11        7/2      16/06
VesselName      OEL EXPRESS APL GUANGZHOU   OEL EXPRESS   CONTI ASIA  RAJIV GANDHI
Dis                 0.1098     0.2603     0.0967     0.0484      0.132
Load                0.1606     0.3465     0.1523     0.0782      0.193
Total               0.2699     0.6068     0.2487     0.1258     0.3247
Service                CIX        LWX        TUT        CIX       NEMO
Status                   M          M          F          M          M
Completion               C          C          C          C          C
Length               0.011     0.0127     0.0077      0.011     0.0118

Time taken to build model (full training data) : 0.13 seconds
=== Model and evaluation on training set ===
Clustered Instances
0      2130 ( 14%)
1      2391 ( 16%)
2      6271 ( 42%)
3      4312 ( 29%)

Class attribute: BerthNo
Classes to Clusters:
   0    1    2    3  <-- assigned to cluster
  392  545 1549 1057 | JCT2
  797  250 1676 1292 | JCT3
  707  310 1658 1279 | JCT4
  234 1286 1388  684 | JCT1

Cluster 0 <-- JCT3
Cluster 1 <-- JCT1
Cluster 2 <-- JCT2
Cluster 3 <-- JCT4
Incorrectly clustered instances :   10193.0    67.4854 %
```

Figure 6.6: Evaluation of Clusters generated by Weka

6.3 Implementation of web-based application modules

Five modules are developed in the system namely, Berth planner module, Shipping line agent module, Administrator module, Vessel Planner module and Duty Manager Module. The integrated system is developed by implementing and integrating every module of use cases.

6.3.1 Implementation of Berth planner module

Main functionalities of the Berth Planner module are as follows. The use case and activity diagrams related to the functionalities of this module are included in Chapter 5 as figure 5.7 to figure 5.12.

- Login

  In this use case Berth Planner can log in to the system, and login of the Duty manager and the Vessel planner are also created considering the same use case.

- Logout

  In this use case Berth Planner can log out from the system and the Duty manager and the Vessel planner can log out in the same manner.

- Review Vessel Submission

  When the shipping line agent add a ship, the berth planner must review the ship to the system

- Schedule the berth

  The main functionality of the system where berth planner can schedule and allocate four berths JCT No.1, JCT No.2, JCT No.3, and JCT No.4 to the incoming vessels using an automatic algorithm or manual drag and drop system.

- Edit berth allocation details

  Berth planner can edit vessel details and berth allocation details when the estimated time for the operation changes due to an unavoidable circumstance in

  the terminal such as a breakdown in the quay crane.

- View berth allocation details

Berth planner, Vessel planner and Duty manager can view the berth allocation details.

- Read messages

  Berth planner can read the messages which are sent by the vessel planner or duty manager about the progress of the vessel operations and any delays.
- Print berth schedule

  Berth planner, Vessel planner and Duty manager can print the berthing schedule which is scheduled by the Berth planner.
- Change profile details

  In the system, they can change their user name and their password.
- View current berth schedule

  Berth planner, Vessel planner and Duty manager can view the berth allocation details.

6.3.2 Implementation of Shipping Line agent module

In shipping line agent module, the following functions are facilitated.

- Register

  Shipping line agents can register to the system.
- Login

  In this use case, Shipping Line Agent can log in to the system.
- Submit vessel details

  Shipping line agents can submit vessel details to the server.
- Edit vessel submission details

  Shipping line agent can edit vessel details 24 hours before the arrival of the vessel.
- Confirm vessel details

  Shipping line agents can confirm the vessel submission at three stages namely 72 hours, 48 hours and 24 hours before the arrival of the vessel.
- View current berth schedule

  Berth planner, Vessel planner and Duty manager can view the berth allocation details.
- View submitted vessel status

Shipping line agents can view the status of the submitted ships

Ex: - Estimated time remaining for the completion of vessel operations.

- Change profile details

  In the system, they can change their user name and their password.
- Print berth schedule

  Shipping line agent can print the berthing schedule which is scheduled by the Berth planner.

6.3.3 Implementation of Admin module

The admin module controls all the login parties and controls them. It confirms the registered shipping line agents and all the berth details and shipping lines added through the admin module.

6.3.4 Implementation of the Duty Manager and Vessel Planner Module.

Vessel planner and Duty Manager can log into the system using this module and similar facilities are provided to both. Functionalities of this module are implemented as follows.

- Login

  In this use case, the Vessel Planner can log in to the system.
- View current berth schedule

  Berth planner, Vessel planner and Duty manager can view the berth allocation details.
- Notify berth planner

  Duty Manager can notify the berth planner through the system when there is a delay in vessel operation. (Loading and Discharging process of the containers). Vessel Planner will notify the actual number of quay cranes assigned for the Vessel operation along with the crane which allocated the most number of work to be done (Long Crane or Heavy Crane) to berthing Manager

6.4 Summary

The implementation section depicts how each use case is implemented and the functionalities described under each use case. Each module has an interconnection with the system to give a better output to the user. Next chapter explains about the evaluation of the proposed solution.

Chapter 7

Evaluation

7.1 Introduction

This chapter depicts the testing and evaluation of different functionalities of the system developed to overcome the Berth Allocation Problem and to maximize utilization of Quay Cranes in Jaye Container Terminal of SLPA. Description to state the decision support utilities generated using data mining technologies, the functionality of berth allocation and quay crane scheduling, testing procedures of a web application with expected outputs and the results are discussed in this chapter as follows,

7.2 Evaluation of Decision support Utilities

Vessel arrival forecast and quay crane allocation functions are the main two functions introduced with the solution and these functions are lined up under the Decision support utilities of the developed system. Among these, vessel arrival forecast function can be identified as the core of the solution. To generate the monthly vessel arrival forecast schedule, it has been used a specific model formulated by Weka data mining tool. To build up a suitable model, previous vessel arrival data had been used. Accordingly, monthly vessel arrival forecast schedule for a particular berth at JCT was generated by using monthly vessel call booking list.

Accuracy of the monthly vessel arrival forecast schedule had been evaluated by comparing the automated berth allocation schedule for the particular date and it is found that over 90% was inaccuracy level of the results obtained from both decision support utility formulated using data mining tool.

Sample Monthly vessel arrival forecast schedule generated for the month of March as shown in Figure 7.1

Considering the quay crane scheduling function lined up under decision support utilities of the system provides the provision for adjusting the no of quay cranes assigned for a particular vessel. Accordingly, the completion time of the Vessel had been subjected to change with the original berthing planed generated by the system. Sample quay crane scheduling options are shown in Figure 7.2.

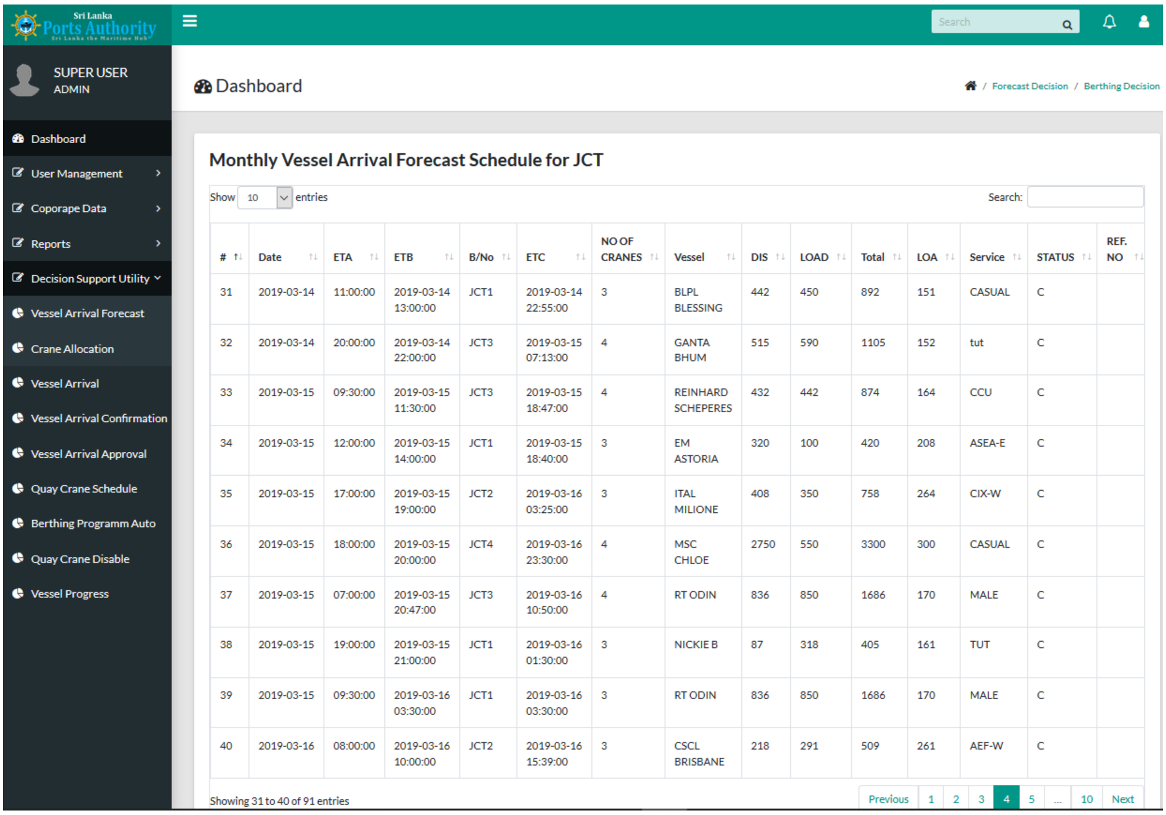


Figure 7.1: Sample of Monthly vessel arrival forecast schedule

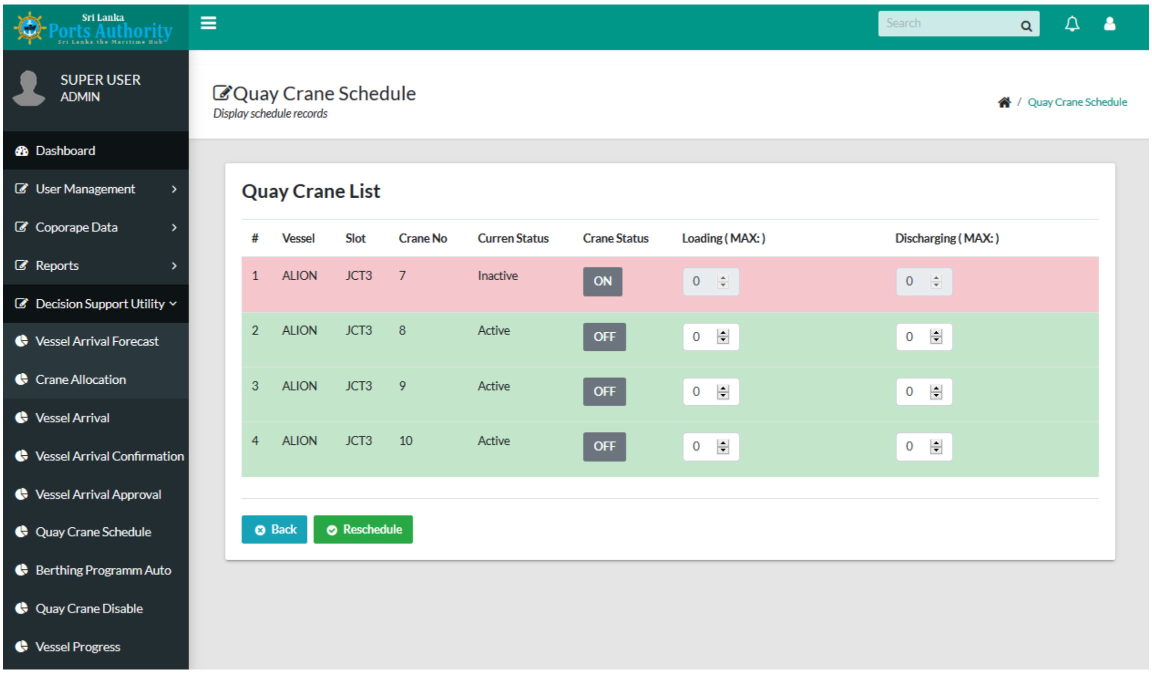


Figure 7.2: Sample of Quay Crane Scheduling for a Particular Vessel

7.3 Testing of the web application.

Description	Test Procedure	Expected output	Result
User Registration	Enter registration details	Direct to relevant screen	Achieved
	Incomplete registration form filling	Notify all field required	Achieved
User Login	Not entered the relevant password	Notify Username or password entered is wrong	Achieved
	Not entered a relevant username	Notify Username or password entered is wrong	Achieved
	Enter incorrect username and password	Notify Username or password entered is wrong	Achieved
	Enter correct username and password	Direct to the relevant screen	Achieved
Add vessel	Enter all details	Direct to relevant screen	Achieved
	Incomplete form filling	Remain on the same screen	Achieved
	Enter same vessel details	Remain on the same screen	Achieved

Edit vessels	Input relevant details	Edit vessel details and redirect to the home page.	Achieved
Add vessel arrivals	Enter all details	Direct to the relevant screen	Achieved
	Incomplete form filling	Remain on the same screen	Achieved
	Enter same vessel details	Remain on the same screen	Achieved
Edit vessel arrivals	Input relevant details	Edit vessel details and redirect to the home page.	Achieved
Notification	Vessel Arrival Notification confirmed (before 72 hours / 48 hours / 24 hours) by the shipping line agent.	Confirm vessel arrival details	Achieved
	Quay Cranes details to Berth Manager by Duty Manager And Vessel Planner	Notify delays or Long Crane information	Achieved
Add vessel progress	Add relevant data about the vessel progress	Add the data entry to a table	Achieved
Edit vessel progress	Input relevant details	Edit vessel progress details and redirect to the home page.	Achieved
Messaging	If a message is sent by the Berth Planner, Duty Manager or Vessel Planner	It is added to the common chat room real-time.	Achieved
Edit profile	If the user edits his first name, last name, or email address	It is updated and connects to the profile details page.	Achieved
Change password	If old password is incorrect	Do not proceed	Achieved
	If the old password entered is correct and relevant new password is set	It is updated and connects to the profile details page.	Achieved
Vessel arrival approval	Vessel arrival approved by the berth planner	The vessel is added to the berth scheduling list.	Achieved
Schedule the berths	When berth planner is scheduling the berths through drag and drop	Berth Schedule is updated	Achieved

Table 7.3: Acceptance test of web application

7.4 Evaluation of the Berthing Schedule Automation Function.

This function is identified as one of the main functions of the solution for the BAP used in the daily allocation of the berth at JCT. Part of the web application functions, this function had been

Evaluation is done by comparing the accuracy of the Berthing Schedule generated by the system with the Berthing Schedule prepared by the Berthing manager by his expert knowledge and the experience. The automation process of BAP and QCS are a very complicating task since the high human interventions are involved when allocating resources for the incoming vessel call. However, results generated from the system assured over 90% of accuracy over the Berthing Schedule Programme prepared by the Berthing Manager by using his expert knowledge of the problem domain. Sample of an automated process and the output of the berthing programme generated by the systems shown in Figure 7.4 and Figure 7.5 respectively and the manually prepared berthing programme for 15th March 2019 shown in Figure 7.6.

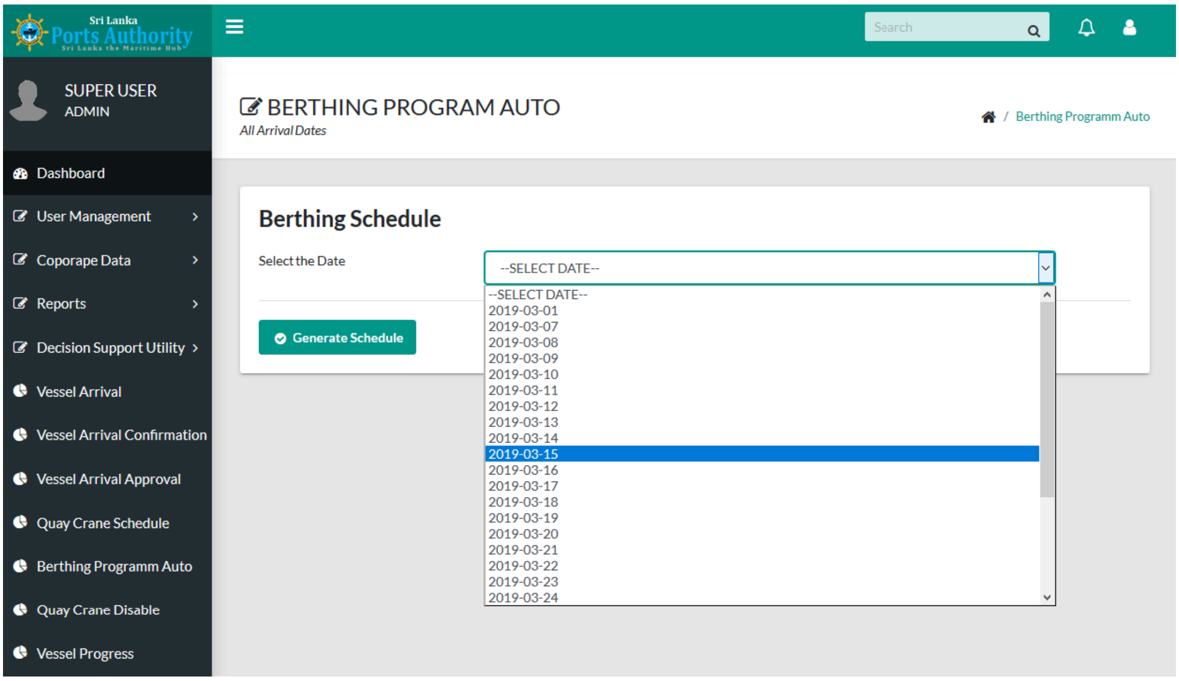
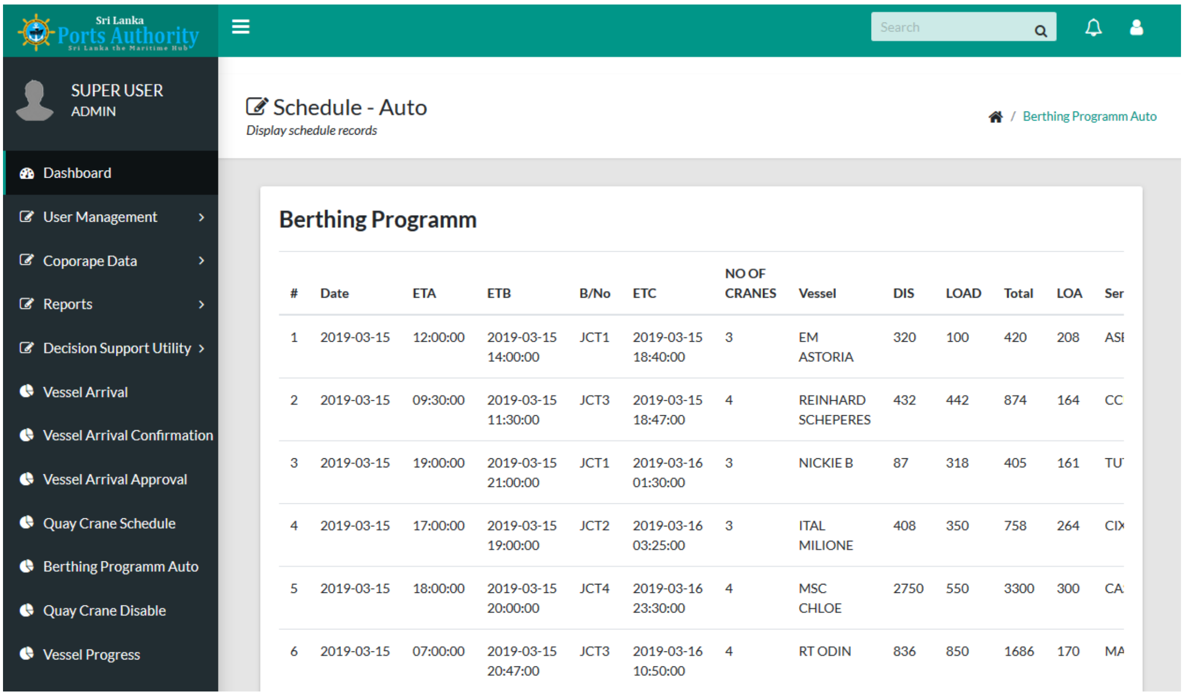


Figure 7.4: Sample of Automation Process



#	Date	ETA	ETB	B/No	ETC	NO OF CRANES	Vessel	DIS	LOAD	Total	LOA	Ser
1	2019-03-15	12:00:00	2019-03-15 14:00:00	JCT1	2019-03-15 18:40:00	3	EM ASTORIA	320	100	420	208	ASI
2	2019-03-15	09:30:00	2019-03-15 11:30:00	JCT3	2019-03-15 18:47:00	4	REINHARD SCHEPERES	432	442	874	164	CC
3	2019-03-15	19:00:00	2019-03-15 21:00:00	JCT1	2019-03-16 01:30:00	3	NICKIE B	87	318	405	161	TU
4	2019-03-15	17:00:00	2019-03-15 19:00:00	JCT2	2019-03-16 03:25:00	3	ITAL MILIONE	408	350	758	264	CIX
5	2019-03-15	18:00:00	2019-03-15 20:00:00	JCT4	2019-03-16 23:30:00	4	MSC CHLOE	2750	550	3300	300	CA
6	2019-03-15	07:00:00	2019-03-15 20:47:00	JCT3	2019-03-16 10:50:00	4	RT ODIN	836	850	1686	170	MA

Figure 7.5: Sample of Automated Berthing Schedule Programme for JCT

OD/JCT/PLN/BP/FO/02

Jaya Container Terminal

Sri Lanka Ports Authority

DIR. (P/O) / COM / Dy.COM

12-Apr-19

Berthing Programme	From	15-Mar-19	To	16-Mar-19

J08, J09, J17 & J18 RELEASED FOR MECHANICAL/ELECTRICAL REPAIRS/ SERVICES

Date	ETA	ETB	B/No.	Vessel	Dis	Load	TTL	LOA	Service	STA.	Ref. No.	Remarks	ETC
15/03	AT BERTH		4MN	GANTA BHUM	44	443	487	152M	TUT	F	GTB407NJ	DELMAGE	1400-15/03
			1MN	REINHARD SCHEPERS	432	442	874	165M	CC	F	RHS060NJ	FAR	2200-15/03
			2MS	EM ASTORIA	320	100	420	208M	ASEA-E	ML	EMAS2IE1J	CMA CGM, DFT. 11.5M	2000-15/03
	1700-15/03	1800-15/03	3MN	ITAL MILIONE	408	350	758	264M	CIX-W	ML	MLNEW127J	DFT. 12.85M	0300-16/03
	1800-15/03	1900-15/03	4MS	MSC CHLOE	2750	550	3300	300M	CASUAL	ML	MHOL910AJ	DFT. 13.4M, BERTHING PORT SIDE TO QUAY, TO BE SHIFTED TO JCT-2MS AROUND 1500-16/03, P/C	
	1930-15/03	2030-15/03	2MN	NICKE B	410	600	1010	162M	TUT	F	NKB19021J	SEACON	1200-16/03
	0200-16/03	0500-16/03	3MN	MSC BOSPHORUS	1275	900	2175	300M	INGWE-W	ML	MBSP909AJ	DFT. 13.7M	0700-17/03
16/03	0600-16/03	0700-16/03	2MS	CSCL BRISBANE	218	250	468	261M	AEF-W	ML	COSB175WJ	COSCO, DFT. 11.6M	1400-16/03
	0600-16/03	0800-16/03	UCT2	OEL HIND	606	400	1006	184M	IBS	ML	OEHN1905NJ	TRANSWORLD GLS, TO BE SHIFTED TO JCT 1MS AROOND 2200-16/03, P/C	
	0800-16/03	1400-16/03	1MS	NORDMED	290	75	365	208M	ASEA-E	ML	NMED2KE1J	CMA, DFT. 11.3M	2100-16/03
	EX-4MS	1600-16/03	2MS	MSC CHLOE	BBF	BBF	1500	300M	CASUAL	ML	MHOL910AJ	DFT. 11.3M	1300-17/03
	1700-16/03	1800-16/03	4MS	XIN SHANGHAI	800	2000	2800	336M	IMED	ML	XNSH112WJ	COSCO, DFT. 14.25M	0400-18/03

Figure 7.6: Sample of Manually prepared Berthing Schedule for JCT

7.5 Summary

Berthing schedule generated by the system was compared and it is realized that the results are more than 70% accurate with berthing schedule prepared by manually with the expert knowledge of Berthing Manager of JCT with the existing manually prepared berthing schedule. Further, according to the results obtained for the test cases, most of the functionalities expected through the system are successfully achieved. Discussing the success of the system, its limitations and further developments in details are included in the next chapter.

Chapter 8

Conclusion & Future Developments

8.1 Introduction

This chapter analyses the overall achievements and findings of the system developed to solve the BAP and QCS in SLPA and discusses the further modifications that can be done to the system after evaluating the final product.

8.2 Conclusion

Since with the introduction of standard steel container boxes for global freight transport, its usage has been in continuous growth in world trade in the past two decades. This growth in container transport led to increasing service demands at container terminals who now have to serve No. of vessels per day. Container terminals handle thousands of load and unload containers per day, and they have to do so in a timely manner in order to reduce the turnaround time that ships have to spend at the terminal and thus gaining a competitive advantage over its neighbouring ports in the region. This competitive advantage would help the terminal increase its customers and thus its profit.

In an increasingly competitive international shipping industry environment, the imperative need and search for efficient, cost-effective techniques, particularly through an application of computer and communication technology has dramatically intensified. Hence, the need for a computerized system that dynamically adapts to changing environment is apparent as there is a limited number of berths and resources available in a container terminal to be assigned for a number of vessels waiting in a queue.

To achieve the required productivity, the system was developed to overcome the BAP and maximize QCS in JCT. Since JCT is the only state-owned terminal in Colombo port, systems currently used in the port have to be substituted with the modern technological approaches to compete with the private terminals in the port. Moreover, the quay wall of the terminals does not lie on a straight. Therefore, the existing berth planning software developed assuming the quay wall is as straight, which cannot be applied on JCT. Currently, the berth allocation process is a manual process in JCT which requires a lot of effort and time. Hence, this system was developed to partially automate the process and to provide a platform through which Berth Planner can communicate with all required parties namely, Shipping Line Agent, Vessel Planner, and Duty Manager.

According to the evaluation of the system, all the modules of the system are successfully implemented. At this phase of development, the functionality of generating the berth plan is partially automated. In the current manual process practised by the Berth Planner in JCT has to find the vessel details on a particular day and draw the berth plan accordingly. The data regarding the vessels to arrive are submitted by the shipping line agent. Generated berth plan and the progress of the vessel operations can be viewed by the Shipping Line Agent, Duty Manager, Vessel planner and both Vessel Planner and Duty Manager can notify any delays in vessel operations to the Berth Planner through the system.

Accordingly, it is obvious that the system is a fine solution to the berth allocation problem in Jaye Container Terminal of Port of Colombo.

8.3 Further work

Although the system sends notifications to the Shipping Line Agents reminding them to confirm the vessel arrivals, 72 hours, 48 hours and 24 hours before the vessel arrives, those notifications are not real-time. The other factors that require to automate the process cannot be obtained by this system automatically. Therefore, real-time notification is expected to be implemented as further work of this project. Moreover, since complete automation of the berthing schedule requires machine learning and requires more time and knowledge for the implementation, full automation is expected to be added to the system through further developments.

8.4 Summary

In conclusion, the developed web application is an acceptable solution for BAP and QCS in JCT. Real-time notifications system and full automation of the berth allocation process can be depicted as further developments of the project. References, abbreviations and the appendixes can be found in the next sections.

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Abbreviations

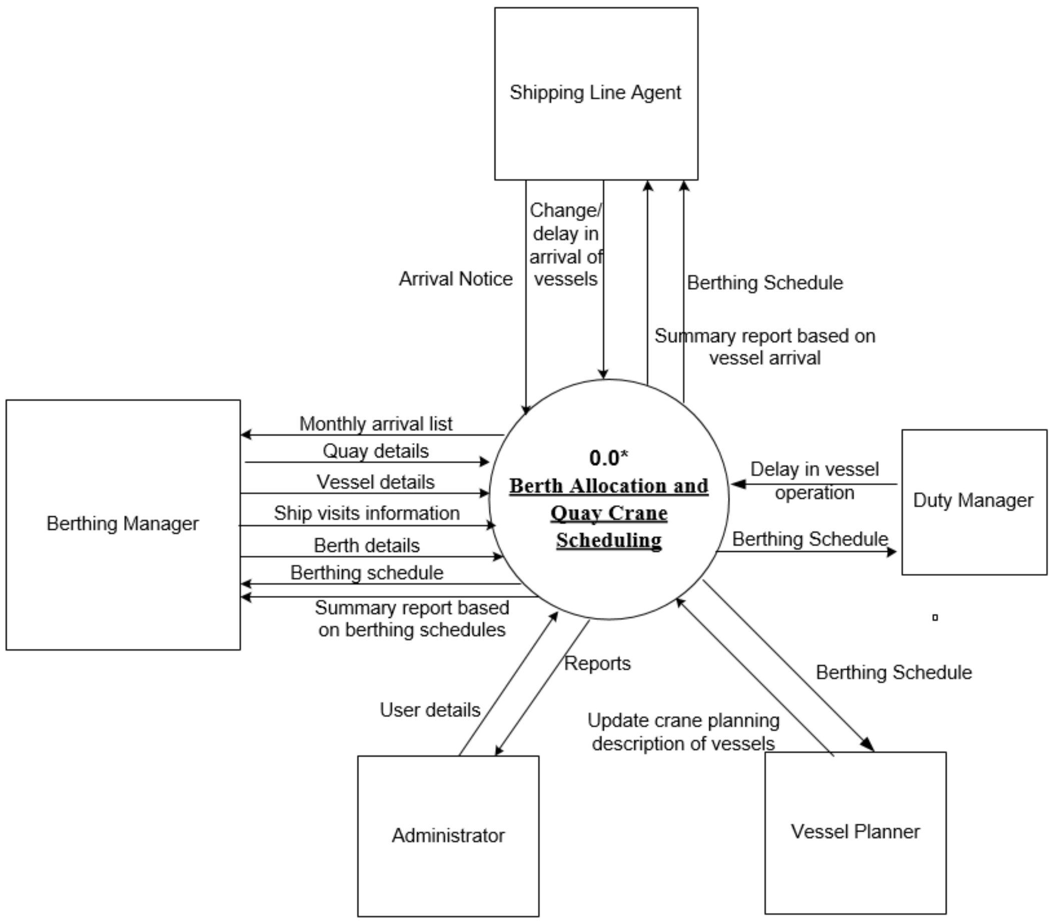
BAP	-	Berth Allocation Problem
QCS	-	Quay Crane Scheduling
JCT	-	Jaye Container Terminal
SLPA	-	Sri Lanka Ports Authority
QC	-	Quay Crane
TEUs	-	Twenty-foot Equivalent Units
CICT	-	Colombo International Container Terminal
SAGT	-	South Asia Gateway Terminal
CT	-	Container Terminal
FCFS	-	First Come First Serve
LVF	-	Large Vessel First
TSA	-	Terminal Services Agreements
GP	-	Genetic Programming
GA	-	Genetic Algorithm
MPC	-	Model Predictive Control
BMO	-	Bird Mating Optimizer
ETA	-	Estimated Time of Arrival
ETB	-	Estimated Time of Berthing
ETC	-	Estimated Time of Completion
ETD	-	Estimated Time of Departure
ATB	-	Actual Time of Berthing
ATC	-	Actual Time of Completion
ATD	-	Actual Time of Departure

Appendix A

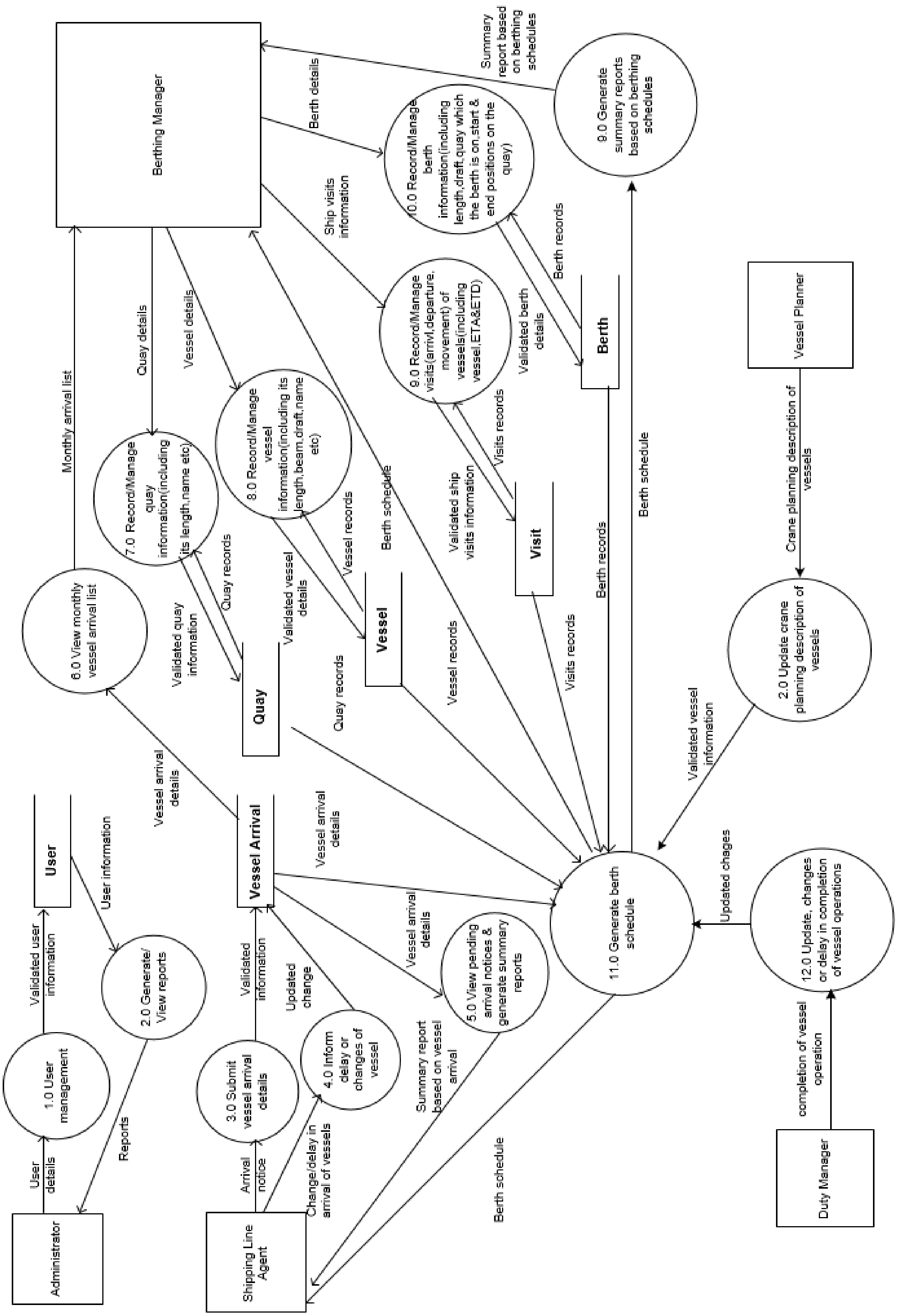
Web Application Development Design

A.1 Data Flow Diagrams

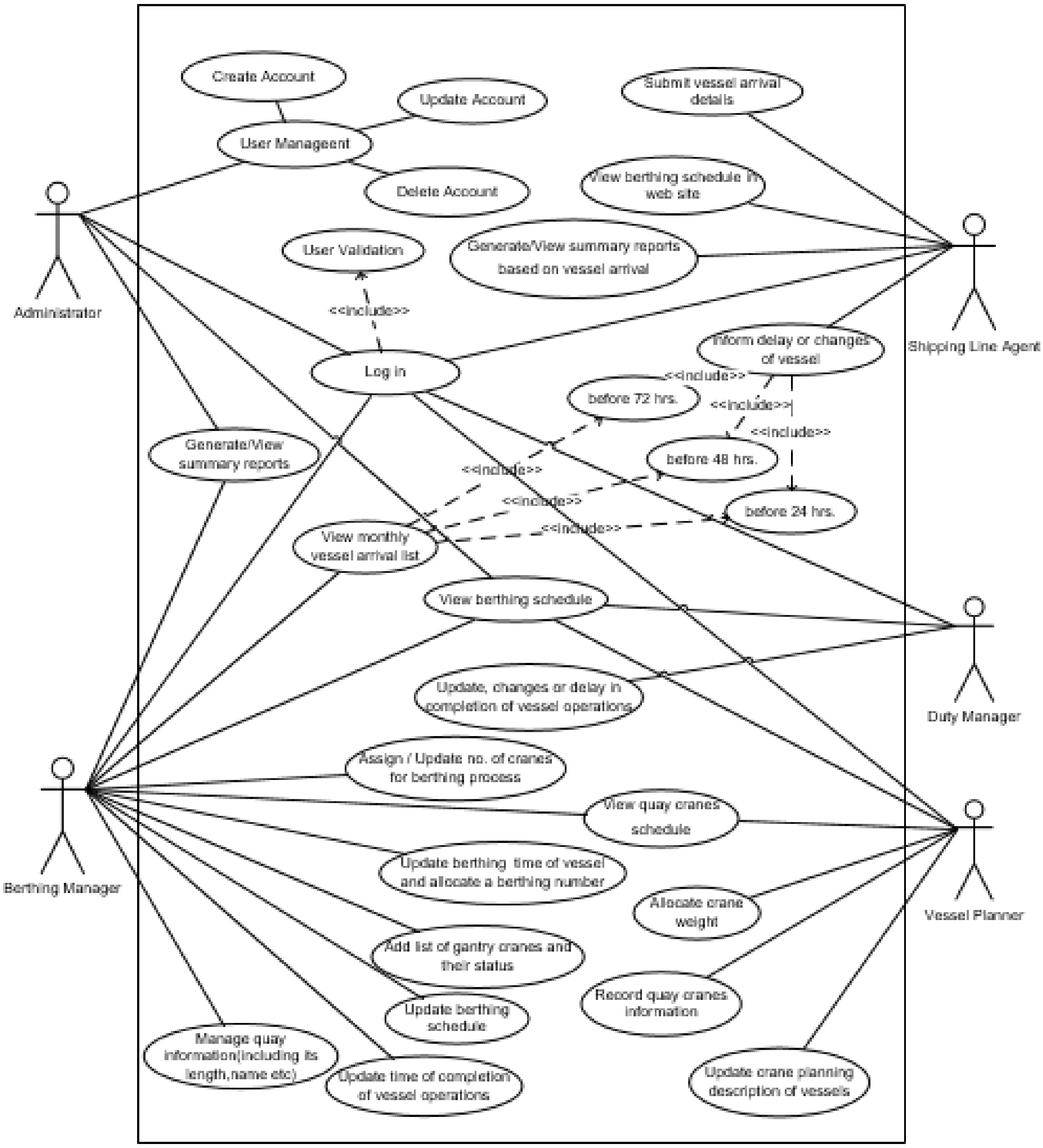
A.1.1 Context Diagram



A.1.2 Level – 0 Diagram

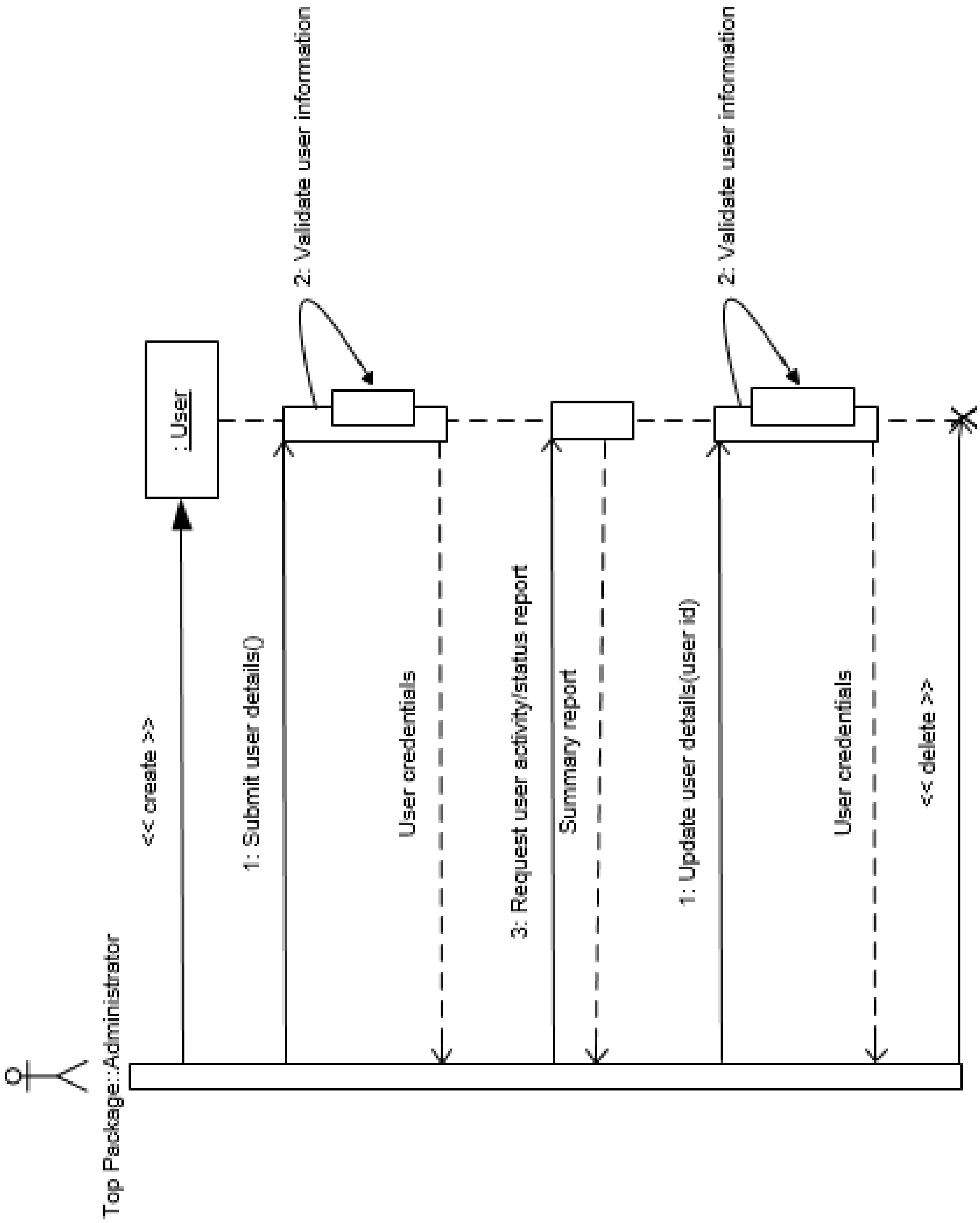


A.2 Use Case Diagram

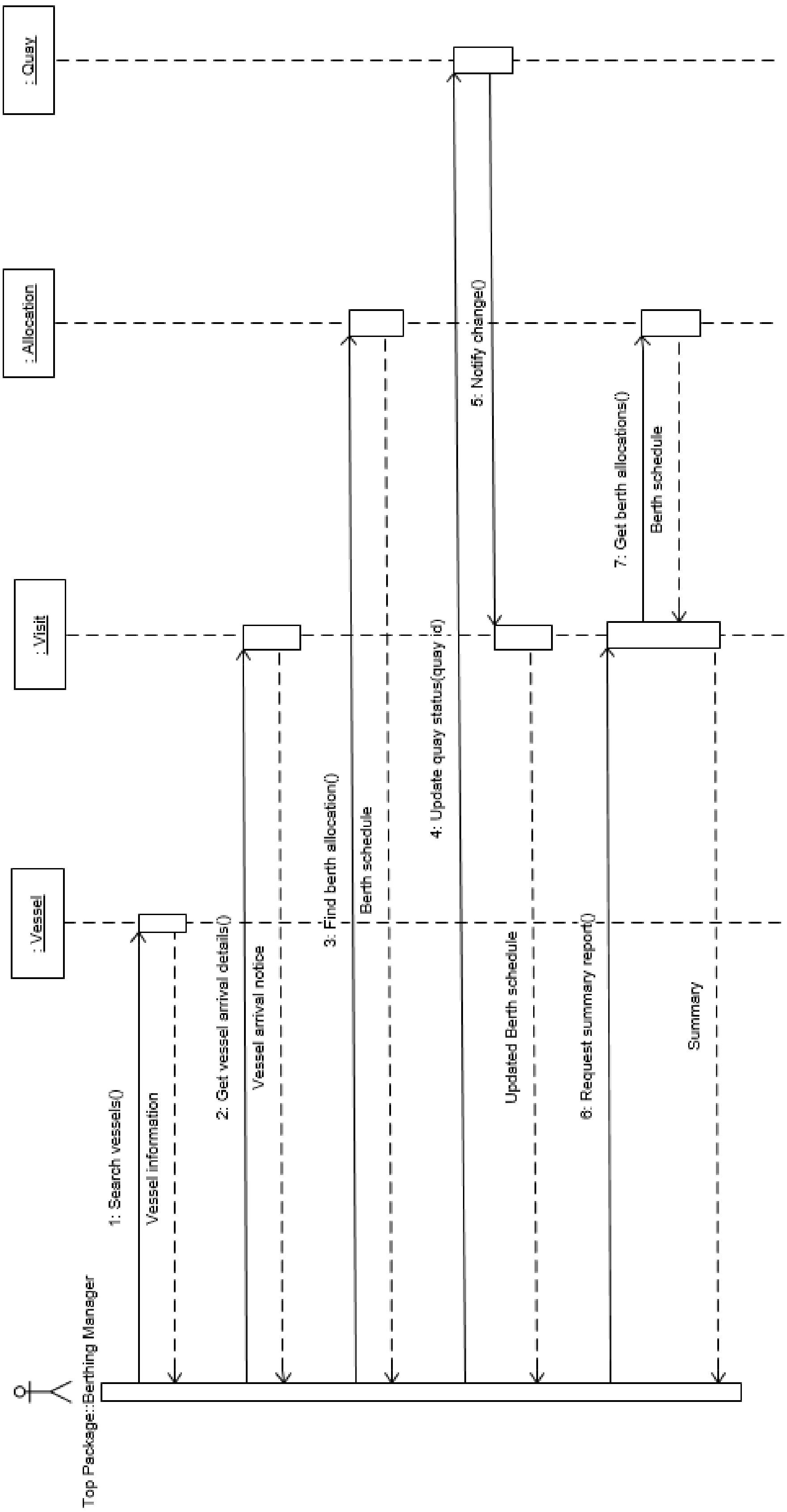


A.3 Sequence Diagrams

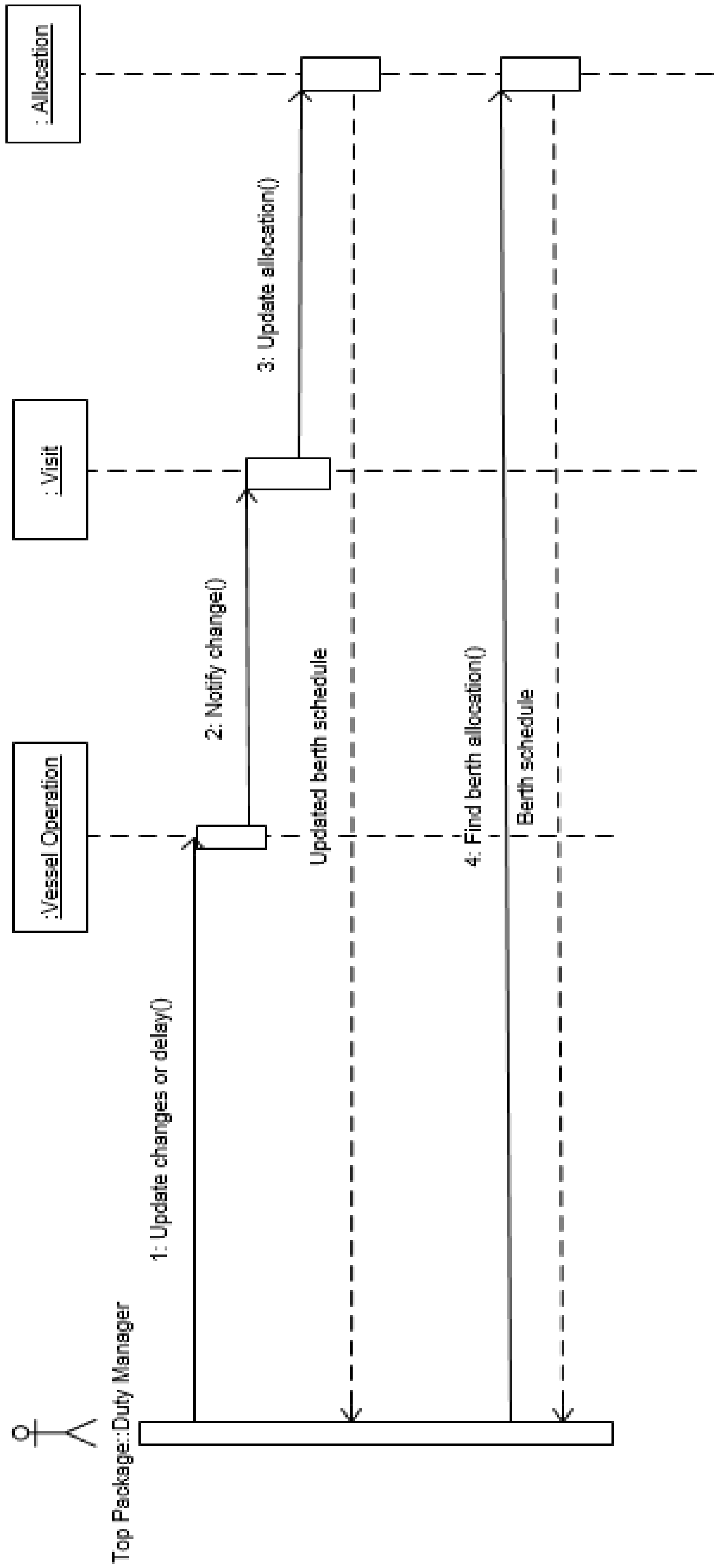
A.3.1 Sequence Diagram – Administrator



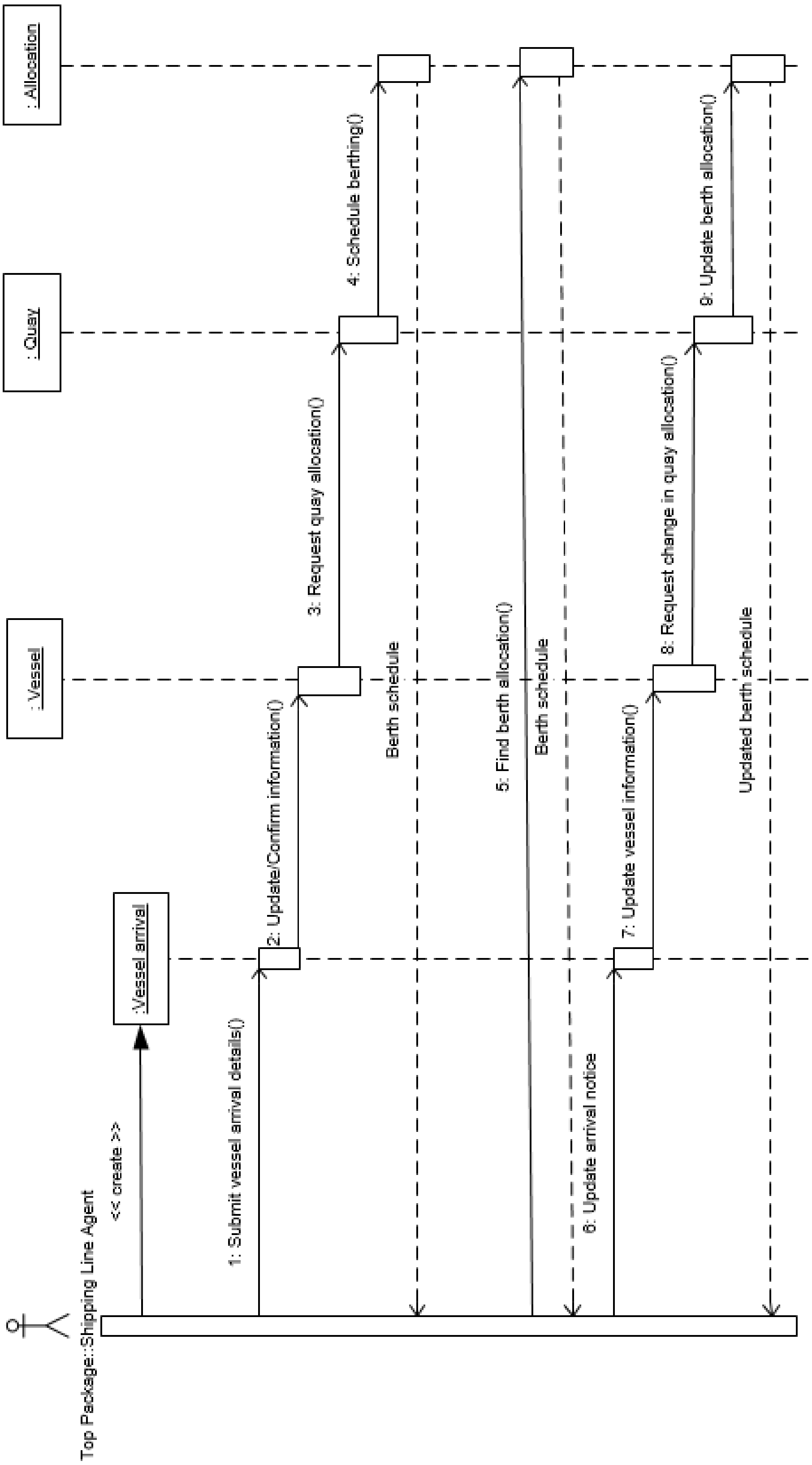
A.3.2 Sequence Diagram – Berthing Manager



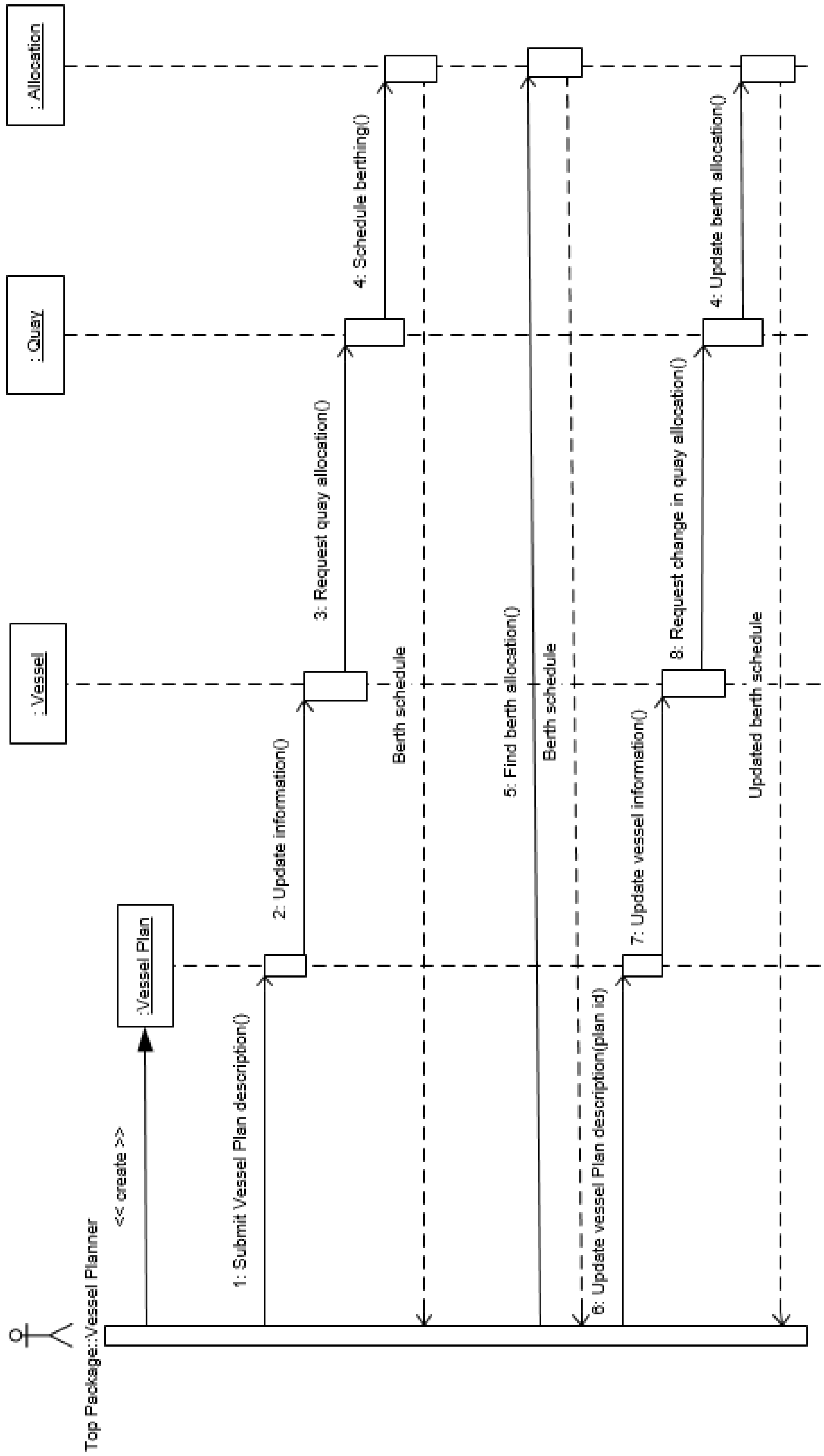
A.3.3 Sequence Diagram – Duty Manager



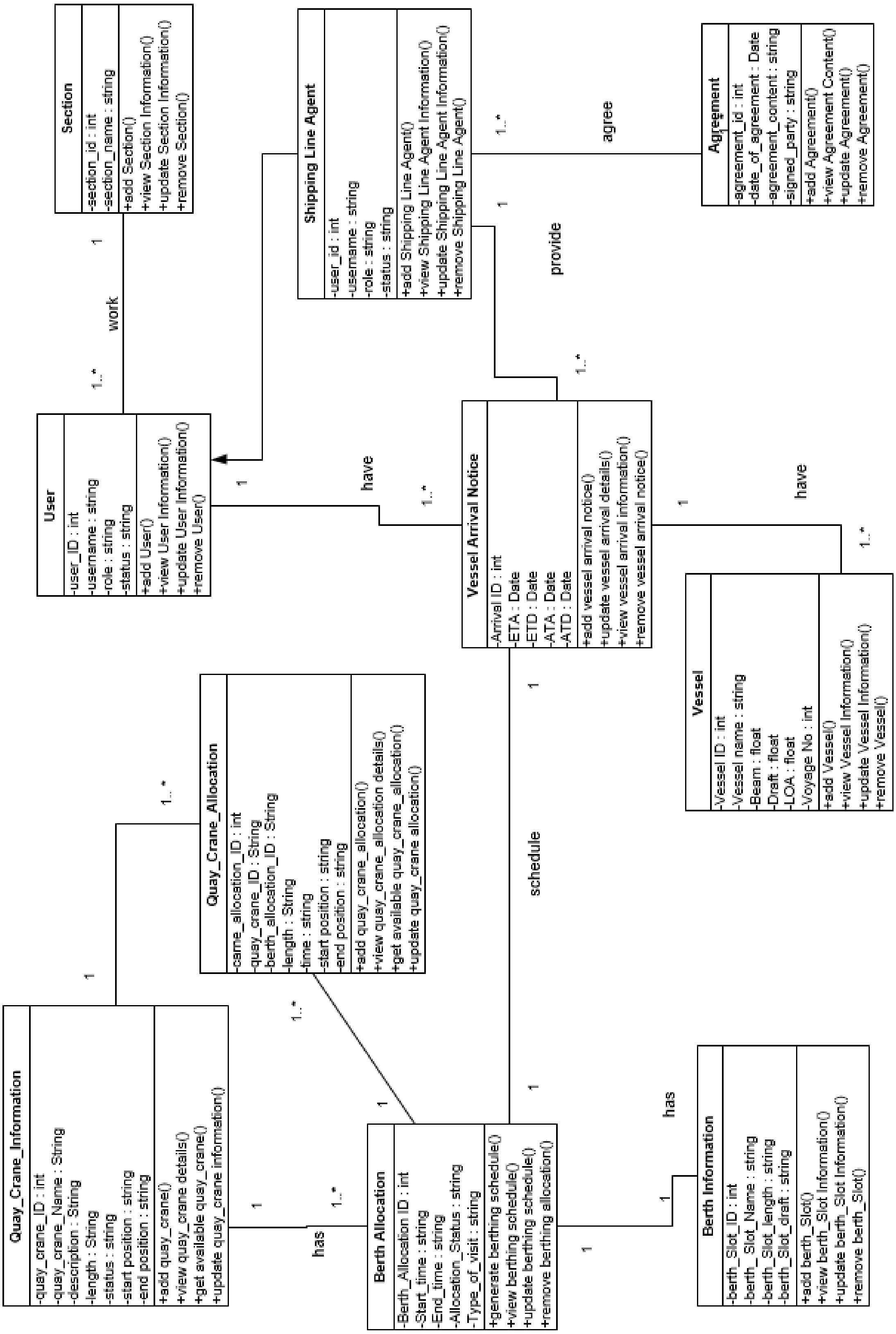
A.3.4 Sequence Diagram – Shipping Line Agent



A.3.5 Sequence Diagram – Vessel Planner



A.4 Class Diagram



A.5 ER Diagram