Berth Allocation and Quay Crane Scheduling for Jaya Container Terminal - Sri Lanka Ports Authority

A dissertation submitted for the Degree of Master of Information Technology

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2019

UCSC

ABSTRACT

The 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. In view of 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 project models associated with solving resource allocation for incoming vessels in port operations, this report emphasizes the current state in relevant technologies and methods applicable in the industry. Hence, in this project, it is mainly focused on resource allocation problems which related to BAP, QCS in Jaye Container Terminal (JCT) of Sri Lanka Ports Authority (SLPA).

DECLARATION

The thesis is my original work and has not been submitted previously for a degree at this or any other university/institute.

To the best of my knowledge, it does not contain any material published or written by another person, except as acknowledged in the text.

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This is to certify that this thesis is based on the work of Mrs. W.M.D.M. Madhushantha under my supervision. The thesis has been prepared according to the format stipulated and is of acceptable standard.

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ACKNOWLEDGMENTS

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LIST OF ABBREVIATIONS

API   -   Application Program Interface

ATB   -   Actual Time of Berthing

ATC   -   Actual Time of Completion

ATD   -   Actual Time of Departure

BAP   -   Berth Allocation Problem

CICT -   Colombo International Container Terminal

CT   -   Container Terminal

ETA   -   Estimated Time of Arrival

ETB   -   Estimated Time of Berthing

ETC   -   Estimated Time of Completion

ETD   -   Estimated Time of Departure

JCT   -   Jaye Container Terminal

QC   -   Quay Crane

QCS   -   Quay Crane Scheduling

SLPA -   Sri Lanka Ports Authority

SAGT -   South Asia Gateway Terminal

TEUs -   Twenty-foot Equivalent Units

TSAs -   Terminal Services Agreements

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Chapter 1

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

1.1 Introduction

Shipping applications are heterogeneous, distributed, complex, dynamic and large which essentially requires cutting edge technology to yield the efficiencies of port operations [3]. 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 Quay Cranes (QCs) for vessel operation are recognized as the main fundamental issues in the port operation [1][2].

Berth Allocation Problem and Quay Crane Scheduling 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 [1][2]. In view of 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 enhance the tasks of BAP and QCS with quick response.

In view of the global trade, 80 percent of volume and more than 70 percent 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. Marked as the best port in South Asia, SLAP of Colombo is recognized as one of the most economical ports in the region that serves to major shipping lines and feeder services operate 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).

Sri Lanka Ports Authority, Colombo is located in the Indian Ocean by 29 km away from south India and ideally positioned as a transshipment base, capable of serving both the eastside and the west side shipping services. Moreover, Port of Colombo

located in one of the best strategic locations in the main shipping hub 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 harbors in the area. Port of Colombo presently operates with three main born terminals named Colombo International Container Terminal (CICT), South Asia Gateway Terminal (SAGT) and along with one main private state-owned Jaye Container Terminal (JCT). Hence, to sustain in the trade with private terminals operating in Colombo, JCT has to increase its level of services and increase the efficiency and the productivity in terminal operations to accommodate vessel types with a deeper draft currently in service. Hence, to compete with other terminals and to increase the level of services rendered, JCT revising its present port operations by introducing possible tools and applying new methods and models to support its maritime trade between shipping communities.

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.

Therefore, by introducing unique approaches and factors, it can resourcefully be allocating all berths and QCs fully utilized with its maximum capacity to increase its service level further to reduce the berth occupancy ratio of a specific vessel and if properly automated and streamlined, it will hugely contribute towards the total productivity of the terminal.

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

In a Jaya, Container terminals consist of a fixed number of the berth 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.

1.3 Statement of Problem

Berth allocation and quay crane scheduling, Jaya Container Terminals still follow manual procedures. Accordingly, when preparing berthing allocations and quay crane scheduling manually, identified limitations and drawbacks are listed below,

- There are number of factors need to be considered by a human when preparing the berthing schedule manually. Some of the factors are as followers;
    - Vessel length
    - Vessel width
    - Vessel draft
    - Vessel arrival date and time
    - Berthing slot availability
    - Quay cranes availability

    If human kind errors happened, the above described factors can be skipped when preparing the vessel berthing schedule.
- 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 some changes. (Ex. Vessel Agent, Pilots, Documentation centers, 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 the enhancement of day-to-day operational activities by increasing efficiency, accuracy and achieve maximum productivity on its own berths.

In this 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).

1.4 Aim and Objectives

1.4.1 Aim of the Study

The aim of this project is to develop an information system to manage the available resources efficiently and productively to provide services for an incoming vessel to SLPA.

1.4.2 Objectives

One of the most economical container terminals in the Asian region, Jaye Container Terminal 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 high-quality services to decreasing the berth occupancy time of incoming vessels. Therefore, in this study, the following are addressed as specific objectives of the study:

- To provide an up-to-date current status of berths.
- To improve the utilization of berthing resources.
- To increase the efficiency of Vessel operation activities.
- To minimize the Vessel waiting time at Outer harbor and turnaround time (Docking time at Colombo)

- To give facilities to authorized customers to get real-time information of vessels at berth.
- To streamline day-to-day operations and the existing procedures will lead to an increase in staff productivity & satisfaction.
- To maintain security levels by preventing unauthorized access.

1.5 Scope of the Project

According to the requirements of the SLPA, the Berth Allocation System has been identified as one of the important applications in the Jaya Container Terminal and the following functions have been identified as within the scope of the project.

1.5.1 Functions within the scope of the system

- 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 the SLPA website.
- Monthly Vessel arrival forecast schedule for JCT.
- To Automate Quay Crane scheduling.

1.6 Overview of Report

This report illustrate the development of the implementation based project carried on. Chapter 01 includes the introduction and overview of the project which emphasizes the problems that have been solved in berth allocation in a Jaya Container Terminal whereas Chapter 02 discusses the background and the similar systems review done based on this topic. Chapter 03 has summarized the methodology and the technologies which are using and a deep description of the design and analysis of the system and implementation details of the system Chapter 04 evaluates the methods used in the implementation and the results obtained with the proposed system. Finally, Chapter 05 discusses the Conclusion and future developments for the solution.

Background

2.1 Introduction

This chapter illustrates a brief describe business background and overview of the current system and drawbacks. In this review describe the functional and nonfunctional requirement of the proposed system. Also, review an existing system and papers published from early in resolving BAP and QCS in container terminal operations based on the quay area and the previous work is done to explore the distinct factors and approaches of applying different models, techniques and methods affecting port operations in the quay area.

2.2 Business Background

2.2.1 Berth Allocation

Before the arrival of a ship, a berth has to be allocated to the ship. The schedules of large oversea vessels are known about one year in advance. They are transferred from the shipping lines to the terminal operator by means of Electronic Data Integration (EDI) [8]. Berth allocation ideally begins before the arrival of the first containers dedicated to this ship – on average two to three weeks before the ship's arrival. Besides technical data of ships and quay cranes – not all quay cranes can be operated at all ships – other criteria like the ship's length and the length of the crane jib have to be considered. All ships to be moored during the respective time period have to be reflected in berth allocation systems [8]. Several objectives of optimized berth allocation exist. From a practical point of view, the total sum of shore to yard distances for all containers to be loaded and unloaded should be minimized. This corresponds to maximum productivity of ship operation. Automatic and optimized berth allocation is especially important in case of ship delays because then a new berthing place has to be allocated to the ship whereas containers are already stacked in the yard [8].

2.2.2 Crane Scheduling

The next step of ship planning is the allocation of quay cranes to ships and the ships' sections – the crane split (scheduling). Depending on the ship's size commonly three to five cranes operate at one oversea vessel [8]. Feeder ships are operated with one to two cranes. In practice, crane to ship allocation has to reflect several constraints – especially technical data of cranes and ships and the accessibility of cranes at a berth. Because terminals are historically grown, in general, different types of cranes exist at real terminals [8]. The number of cranes operable at one berth, in general, is restricted because not every crane can be driven to every berth [8].

Figure 2-1 - Graphical representation of the crane arrangement

Crane split allocates a respective number of cranes to a ship and its sections (bays) on hold and deck and decides on which schedule the bays have to be operated. It not only reflects one ship but several ships – in neighbored berths and principally all ships moored at a terminal in a given period. There is no unique objective for optimization. Minimization of the sum of the delays of all ships can be an objective while maximization of one ship's performance or a well-balanced or economic utilization of the cranes can be others [8]. In real terminal practice, it depends on the actual terminal situation and the terminal's goal. In addition to the crane split, crane allocation decides on the mode how a ship and the ship's bays are loaded. A bay can be loaded either horizontally or vertically, starting at the quay or at the waterside, resulting in four different modes of loading. There are additional modes but these are the main ones [8]. Stowage plan, crane split, and mode of loading together result in a working instruction which defines the loading sequence for every container of a bay. As

mentioned earlier, the sequence for landside transport has to match this loading sequence [8].

2.3 Overview of the current system and drawbacks

2.3.1 Analyzing the current system

The overall responsibility of the existing manual system handled by the Operations Division of the Sri Lanka Ports Authority. One of the key activities of the division is preparing daily berthing schedules for the vessels waiting in the queue. After analyzing the current system and following functionalities are identified.

Berthing schedule planning commences according to the "monthly schedule of vessels" which is prepared by the operational staff of JCT. Each shipping line has to submit particulars of its vessel arrivals (vessel arrival advice), at least one week before the end of the month.

A three days prior notice (72 hours) is given by agent to confirm their vessel arrivals. They perform their confirmation through fax or by a telephone call. Any change about arrivals would be notified by the agents in every 24 hours before berthing operation commences.

In current operations, shipping Agents would inform the respective port the Expected Time of Arrival (ETA) one month before the arrival of the ship. The Shipping Agent then updates the Port daily about any changes to the original plan of the arrival of the Vessel. Arrival declaration sent by shipping agent to Ports generally contains the Date of arrival, Expected Time of Arrival, Vessel details, Number of Containers to be discharged, Number of Containers to be loaded, any remarks such as Cargo type, Berthing and Sailing draft requirements, etc.

According to the above information, the Berth Operation Management officers assign suitable berths to the vessels manually. The other terminal resources are also assigned at the same time. After preparing the daily berthing schedule, it is published among the relevant parties (Ex: - Vessel Agents, Pilots, Documentation center, Operational staff, etc.). When the schedule is changed, the updated schedule is sent to all relevant parties for their notification.

Berthing Schedule Programmed system of a container terminal is responsible for computing Expected time of Berth (ETB), Expected time of Completion (ETC),

Expected time of departure (ETD), allocation of the berth, etc., by considering resources available in the terminal and the Vessels waiting in the queue.

Some of the other important data for berth allocation are as follows: Vessel sailing and berthing draft; Number of boxes handle in berth; Crane requirement for the vessel; Draft of berth; Length of the berth; Gross-crane productivity of berth; Expected completion time of vessel in the berth; Actual completion time of the vessel in the berth, etc.

Figure 2-2 - Graphical representation of the existing manual system

2.3.2 Constrains considered when allocating berth to a particular vessel

After analysis following constraints were identified,

- 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)

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- 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?

2.3.3 Drawbacks of the current system

- Several factors affect the berthing schedule. It is difficult to trace all factors one by one when the schedule is prepared manually.
- Vessel arrival details can be misplaced or mistakes can occur while reading details. Currently, the vessel agents fax the vessel details.
- It is difficult to change the current berthing schedule when required, as all factors have to be traced one by one manually.
- Difficult to notify all relevant parties when the schedule is changed. (Ex. Vessel Agent, Pilots, Documentation center, Yard, 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.
- After completing the berthing schedule, those details were entered to the www.slpa.lk web site in manually. The manual process can be a delay or an incorrect reading.
- The decision-making process is not an easy task considering manual journals.

2.4 Requirements of the Proposed Solution

2.4.1 Functional requirements

The proposed system is a solution of the identified drawbacks of the current system in above and the following functional requirements describe the required system behaviors and what the system supposed to do. Below illustrated the main functional requirements of the proposed system.

- **User (Internal/External) Management**

System user should be able to view internal or external user details, search and modify own user details according to the corresponding user type.

- **System Administration**

The system should allow the administrator to create a new user, change the privileges of the system users who need to access the system. And also, the system allows modifying the existing reusable component by controlling the log history. The system should allow the administrator to take backups and restore files when needed.

- **Vessel Arrival and Confirmation Analysis**

Shipping agents should be able to add new vessel arrival details, modify information and vessel arrivals are confirmed in 72 hours, 48 hours and 24 hours before the arrival by the shipping line agent respectively.

- **Vessel Arrival Approval**

The system user should be able to approve the vessel arrivals after confirmation before 24 hours.

- **Manage Disable Quay Crane and Quay Crane Schedule**

Duty Manager and the Vessel Planner should be able to notice any delays in vessel operations due to any circumstance of the quay crane and others and the no. of TEU's are allocated to the heavy crane or the long crane to the Berth Planner.

- **Berthing Schedule Automation**

The system automatically shortlisted the vessel arrivals for the next one-month period to be berth at SLPA and the Berthing Manager process the automated vessel berthing schedule for the corresponding date by using the system. After processes were completed, the automated schedule was generated.

- **Reschedule Berthing Schedule**

Berth Planner should be able to amend the automated berthing schedule when notified any delay in the vessel operation regarding the quay crane to disable or any circumstance. According to this amendment, change the estimated time of completion and the time of availability of the particular berth to for the next vessel aligned in the list.

- **Vessel Progress**

The shipping line agent should be able to view his vessel details and progress of vessel operations and also the berthing schedule.

- **Notification**

Shipping agents should be able to display the vessel arrival notification when the port is generated the berthing schedule.

- **Reports**

The system should be able to analysis the previous or history records for forecast decisions.

2.4.2 Non-Functional requirements

Non-functional requirements are the requirements that are not directly affected by the exact basic functions delivered by the system. However, they may affect the whole system. Non-functional requirements affect the quality of the system. The non-functional requirements of the proposed system are listed below.

1. The system should be user-friendly and include a flexible interface.
2. The system should be accurate and consistent when manipulating the fed data in a proper way.
3. As required backups should be taken.
4. Maintain the necessary security measures.
5. The system should be reusable and maintainable.
6. The system should be flexible and portable.

2.5 Review of similar systems

Berth planning problems may be formulated as different optimization problems depending on the specific objectives and restrictions that have to be observed. As an example, berth planning by means of the resource-constrained project scheduling problem. Restrictions may refer to special equipment that is needed for certain operations [8].

Terminal operators today face several challenges. One of the challenges: - among those is achieving higher productivity while reducing costs. As the cost of land and environmental restrictions prohibit the existing terminal growth, the operators must increase their productivity through existing facilities. The following section illustrates a brief review of existing systems.

2.5.1 "Navis" system

In Sri Lanka, South Asia Gateway Container Terminal (SAGT) operates with "Navis" SPARCS (Synchronous Planning and Real-time Control System) product. SPARCS provides the all terminal operation facilities including Berthing Scheduling Option and Advanced Berth Scheduling Option.
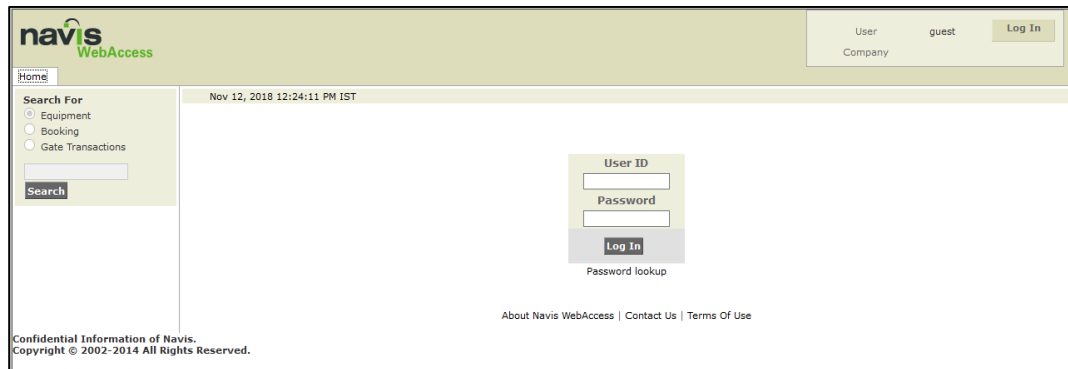
Figure 2-3 - Navis system

Following are the features of the Berth Scheduling Option include,

•   Movable Vessel Block Graphics

In the Berth Schedule, each vessel is represented by a colored block that displays vessel details such as Estimated Time of Arrival (ETA) and Estimated Time of Departure (ETD), vessel class line operator, service and length of the vessel stay, etc. These blocks can be moved around between berths and time periods to reflect the changing schedules demanding at the terminal.

•   Overhead View of Berth Schedules

The overhead view provides a birds-eye perspective of how vessels will have appeared in their assigned berth slots. With this view can see how each vessel will be lined up in relation to the others. This makes it easier to catch conflicts and get an accurate picture of the berth layout.

•   Multiple Time Frames

Display the berth schedules in one of several different timeframes.

(E.g.: Next Week, Next 7 Days, Last Week, All Scheduled)

- Ability to Create and edit ship and berth notes

Can create any number of ship notes that can be saved with the vessel block.

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Advanced Berth Scheduling Option

The Advanced Berth Scheduling option provides long-term/short-term berth planning for all types of the berth operations, including multi-berth and transshipment operations. This option extends the functionality of the Berth Scheduling Option by enabling to:

- Manage quay crane shift assignments.
- Track vessel berth location by back and fore bollard measurements.

The above solution only uses for Colombo International Container Terminal (CICT) or South Asia Gateway Terminal (SAGT) container terminal operations, not for Jaye Container Terminal operations. Because CICT and SAGT terminal has a straight line quay wall, Jaye Container Terminal has a quay wall with a small angle.

The second main drawback of the existing system is the depth of the quay area. Depth of the quay area is uneven one berth slot to other at Jaye Container Terminal. Another considering area is boom lengths. Different boom lengths and sizes of quay cranes are handled by Jaye Container Terminal.

All the function of the "Navis" System has assumed as follows,

- Terminal has a straight-line quay wall.
- Equal depth of the quay area.
- Same size boom length quay cranes.

In that case, the existing system cannot use for Jaye Container Terminal (JCT) container terminal operations. Because Jaye Container Terminal (JCT) has not straight-line quay wall and quay wall with a small angle. Also, it has deferent size boom length quay cranes. Because of these major drawbacks, "Navis" System cannot accommodate the services of JCT. the new system should be implemented for the JCT.

2.5.2 Eco-friendly solution 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 consumption ratios of a particular vessel in connection with the berth allocation window provided by the CT. Since emission reduction and minimizing fuel consumption are directly connected with the world green concept, this can be acknowledged as one of the positive approaches for reducing the global warming situation. However, the heuristic based genetic algorithm developed in this study is not clear enough to get the gravity of the approach used to solve the shipping line scheduling problem describes 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. The 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.

2.5.3   UNCTAD

UNCTAD (1999) categories of port performance indicators: macro performance indicators quantifying aggregate port impacts on economic activity, and micro performance indicators evaluating input/output ratio measurements of port operations (Bichou and Gray, 2004) [9].

Traditionally, the performance of ports has been variously evaluated by calculating cargo-handling productivity at berth (Bendall and Stent, 1987; Tabernacle, b1995; Ashar, 1997), by   measuring a single factor productivity (De Monie, 1987) or by comparing actual with optimum throughput over a specific time period (Talley, 1998) [9]. In recent years, significant progress has been made concerning the measurement of efficiency in relation to productive activities [9]. In this vein, two more complexes, yet holistic approaches, named   Data   Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA), have been increasingly utilized to analyze port production and performance (Cullinane at all, 2004, Sanches at all, 2002) [9].

The complexity of the different seaport operations often results in difficulties in using analytical tools as a method of investigation. In such a situation, computer simulation provides a powerful tool to analyze the port performance (Tahar and Hussain, 2000). Simulation has been widely used and applied for the planning and management of the port system (Borovits and Ein-Dor, 1990; Hassan, 1993; Collier, 1980; Merkuryev et al., 1998; Geert and Janssens, 1998; Gambardella et al., 1998) [9]. Tongzon (1995) suggested that attention should be paid to this information when developing a port reform aimed at improving port performance methods as this provides a clear distinction between port efficiency and effectiveness. Consequently, port performance indicators have been classified into two broad categories, financial and operational [9].

2.6 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, there is still a 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.

Figure 2-4 - JCT Quay wall

- Since the quay wall is not in a straight line, these approaches are not applicable.
- The 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 that 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.

2.7 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, formulation methods 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.

Methodology

3.1 Introduction

This chapter illustrates the design of the proposed system and describes methodologies and techniques which have been used to develop the system. Considering the complexity of the 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 application development architecture are described in this section.

3.2 Implementation Environment

The 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 centralized 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 Technology and Development tools used for the solution

To develop a web-based solution for the BAP and QCS following technologies and the tools were used.

3.3.1 Technologies

- **PHP Language:**

Hypertext Pre-processor (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 the development of 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, the Joomla framework has been utilized for session handling and log file maintenance.

3.3.2 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 programs 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 fast, reliable and secure. It can be highly customized to meet the needs of many different environments by using extensions and modules [13].

Apache is also called as a web server and it is not only a physical sever but rather a software that runs on a server. Its job is to establish a connection between a server and the browsers of website visitors (Firefox, Google Chrome, Safari, etc.) [14].

- **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 [15].

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 [15].

- **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.
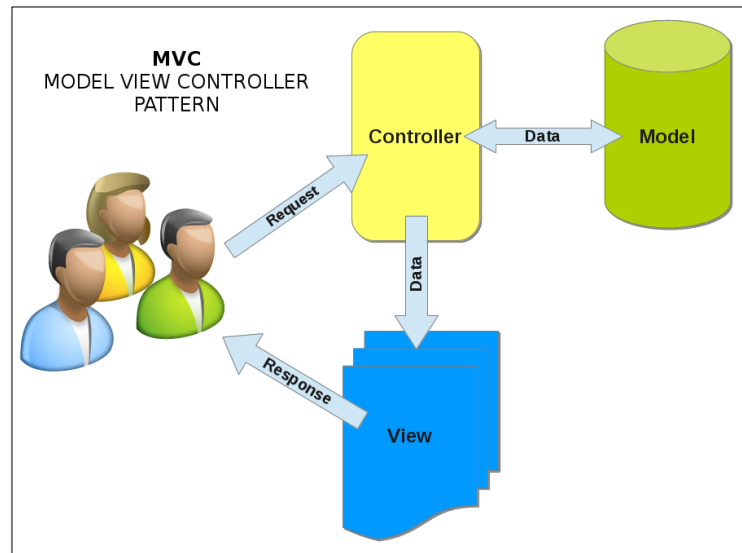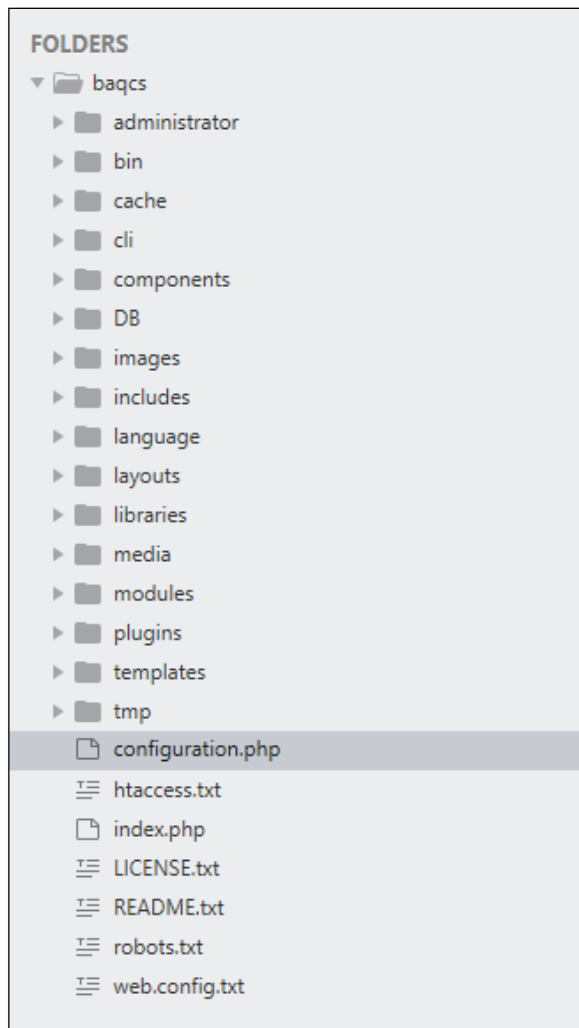

Figure 3-1 - MVC Architecture

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 [7].

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 [7].

View: It means the 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 [7].

Following figure 3.2 shows the design architecture for the development and figure 3.3 shows MVC architecture implement inside the system.

Figure 3-2 -The application development architecture of the system
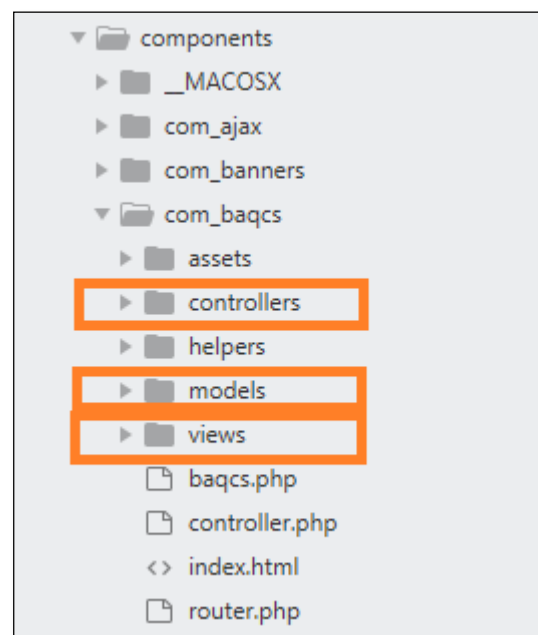
Figure 3-3 - The MVC structure of the system

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3.5 Design Technique

There are different types of design techniques such as Rapid application development, object-oriented design, and prototyping, etc. and object-oriented design technique was chosen out of them. Because of code reusable and recursive facility, design benefits and maintainable facilities with objects and classes.

Unified Modeling Language (UML), which has become a standard modeling language for object-oriented modeling. Programmers can easily understand models of objects in UML and the programmers can easily write software. Few of structural and behavioral UML diagrams use for design proposes systems are mentioned below [10],

- Use-Case diagrams – shows what the system needs to do.

- Class diagrams – shows the needed objects and relationships between them.

- Sequence diagrams – shows how the objects interact over time.

3.6 Proposed System Design

3.6.1   Phases of the system

The solution is designed in two separate phases and integrate at the implementation. The two phases are,

1. Allocate a suitable berth for incoming vessel call at SLPA
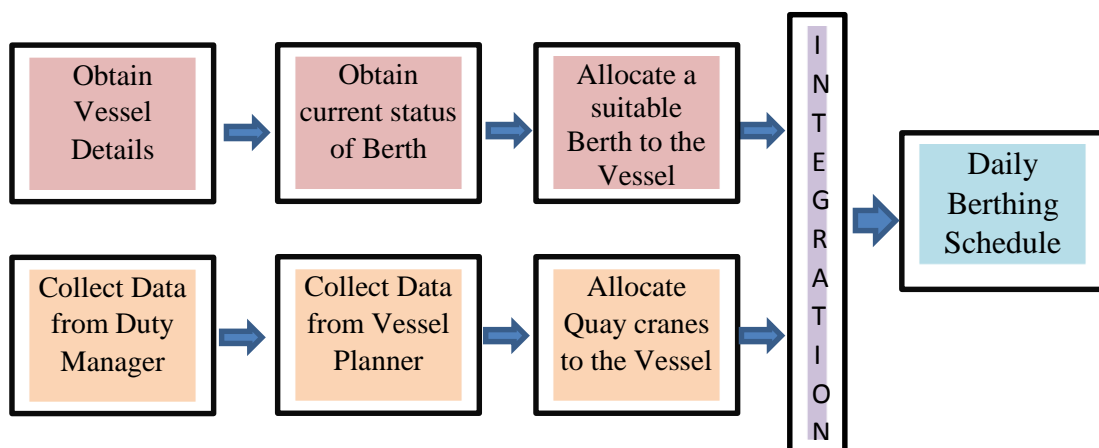2. Allocate quay cranes to perform quayside operation

Figure 3-4 - High-Level Design of the Solution

The proposed system has five main actors and one cooperating system. Shipping line agents are the external users and external users can access the system through the vessel arrival submission form. Other actors such as administrator, berthing manager, duty manager, and vessel planner communicate with the system as internal users.

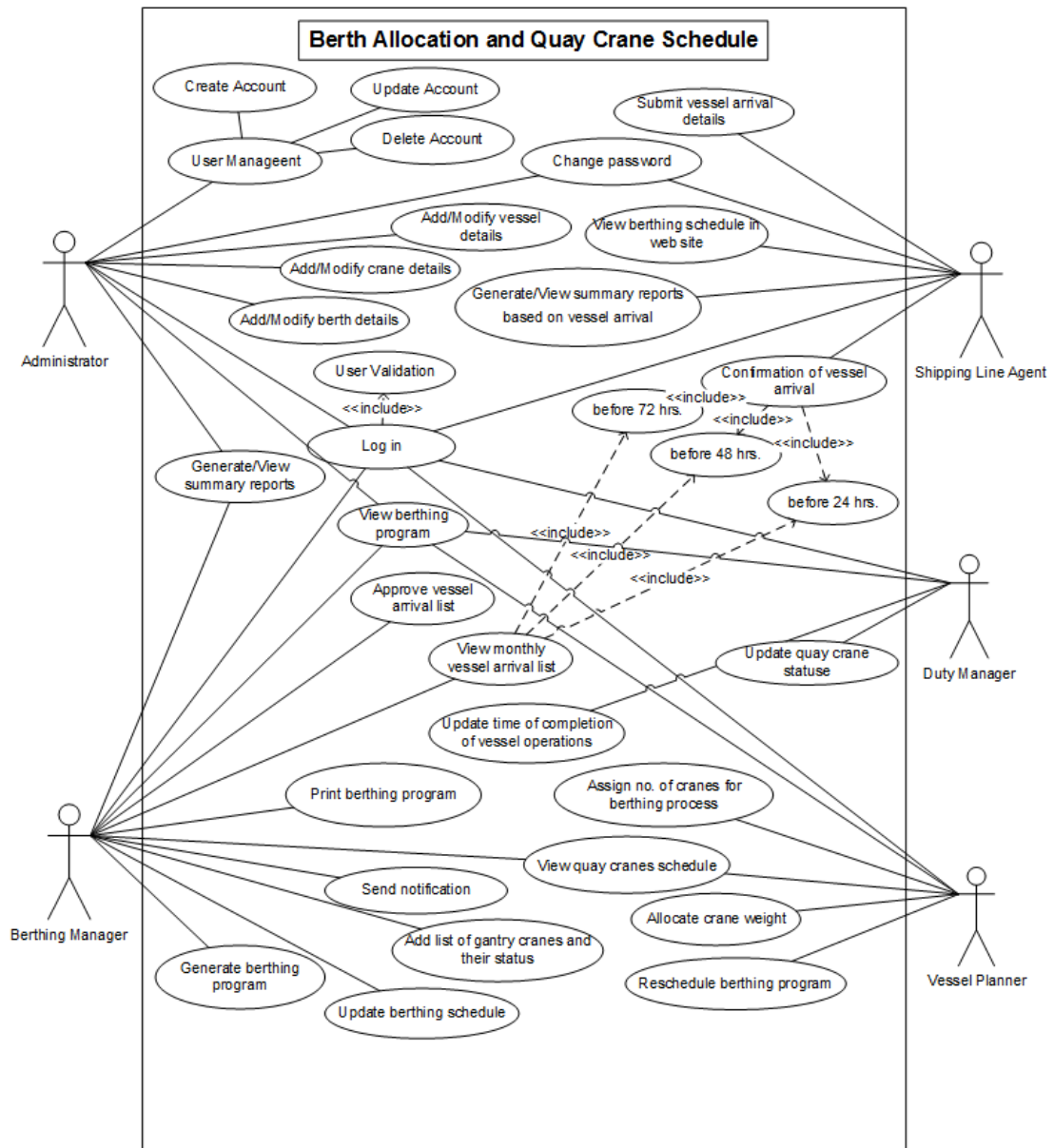A graphical representation of the main actors is shown below,

Figure 3-5 - Use Case of Proposed System

The system collaborates with five active actors in one cooperate system. Following user 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
- Manage vessel, berth and quay information (including its length, name, etc.)
- Create a New password
- Report handling

Berthing Manager:

- Secure login to the system
- Generate berthing program
- View/Generate a summary report
- View monthly vessel arrival list
- Approve vessel arrival
- View berthing schedule
- View quay cranes schedule
- Print berthing program
- Send notifications to the shipping agents

Shipping line agent:

- Secure login to the system
- Submit vessel arrival details
- View berthing schedule on the web site
- Modify delay or changes of vessel arrivals

- View summary reports based on vessel arrival
- View berthing schedule on the web site
- View notifications

Duty manager:

- Secure login to the system
- View berthing schedule
- Update, changes or delay in completion of vessel operations
- The update time of completion of vessel operations
- Update gantry cranes status

Vessel planner:

- Secure login to the system
- View quay cranes schedule
- View berthing schedule
- Allocate crane weight
- Record quay cranes information
- Update crane planning description of vessels
- Reschedule berthing program

As depicted in Figure 3.5 – Use Case of Proposed System will show the users to bring out their responsibilities effectively and efficiently by reducing the manual human effort. The proposed solution has been divided into a few modules in order to make the development and maintenance easier. The modules are as follows,

1. User (Internal/External) management
2. System administration
3. Vessel arrival and confirmation analysis
4. Vessel arrival approval
5. Manage disable quay crane and quay crane scheduling
6. Berth schedule automation
7. Reschedule berthing schedule
8. Vessel progress
9. Notification
10. Report

3.7   Implementation of modules

All the modules are divided into five main modules and those 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.

3.7.1   Implementation of Administrator module

The administrator module controls all the login parties and controls the privileges of them. The administrator module provides a facility that maintains vessels, berth, and quay cranes.

- Login

  In this use-case, administrators can log in to the system.

- Logout

  In this use-case, the administrator can log out of the system.

- User Management

  The administrator can add new users and change user details.

- Manage reference data

  The administrator can manage the reference data of the systems.

- Report handling

  The administrator can generate reports according to the different criteria.

- View notification

  The administrator can view all notifications.

- View berthing program

  Berth planner can view the berth allocation details.

- Register

  Shipping line agents can register to the system.

3.7.2 Implementation of Berth planner module

The main functionalities of the Berth Planner module are as follows.

- Login

  In this use case, Berth Planner can log in to the system.

- Logout

  In this use case, Berth Planner can log out from the system.

- Review Vessel Arrivals and Approve

  When the shipping line agent adds a vessel arrival, the berth planner must review the vessel arrivals and approved it.

- 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 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 berthing program

  Berth planner 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 can print the berthing schedule.

- Change profile details

  In the system, they can change their password and user details except for their user name.

- View current berthing schedule

Generate notifications and send to the shipping agents

- View current berthing schedule

Berth planner can view the berth allocation details.

3.7.3 Implementation of Shipping Line agent module

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

- Login

In this use case, the shipping line agent can log in to the system.

- Logout

In this use case, Berth Planner can log out from the system.

- Submit vessel arrival details

Shipping line agents can submit vessel arrival details to the server.

- Edit vessel arrival details

The shipping line agent can edit vessel arrival 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

The shipping agent can view the berthing program 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

Shipping line agents can change their password.

- View notifications

Shipping line agents can view all notification when login to their own account.

- Print berth schedule

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

3.7.4 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. The functionalities of this module are implemented as follows.

- Login

  In this use case, the Vessel Planner and Duty Manager can log in to the system.

- Logout

  In this use case, the Vessel Planner and Duty Manager can log out from the system

- View current berth schedule

  Vessel planner and Duty manager can view the berthing schedule details.

- Notify berth planner

  The duty Manager can notify the vessel 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 corresponding vessel operation along with the crane which allocated the most number of work to be done (Long Crane or Heavy Crane) and reschedule the berthing program.

3.8 Data Flow architecture of the proposed solution

Data Flow structure of the proposed system;
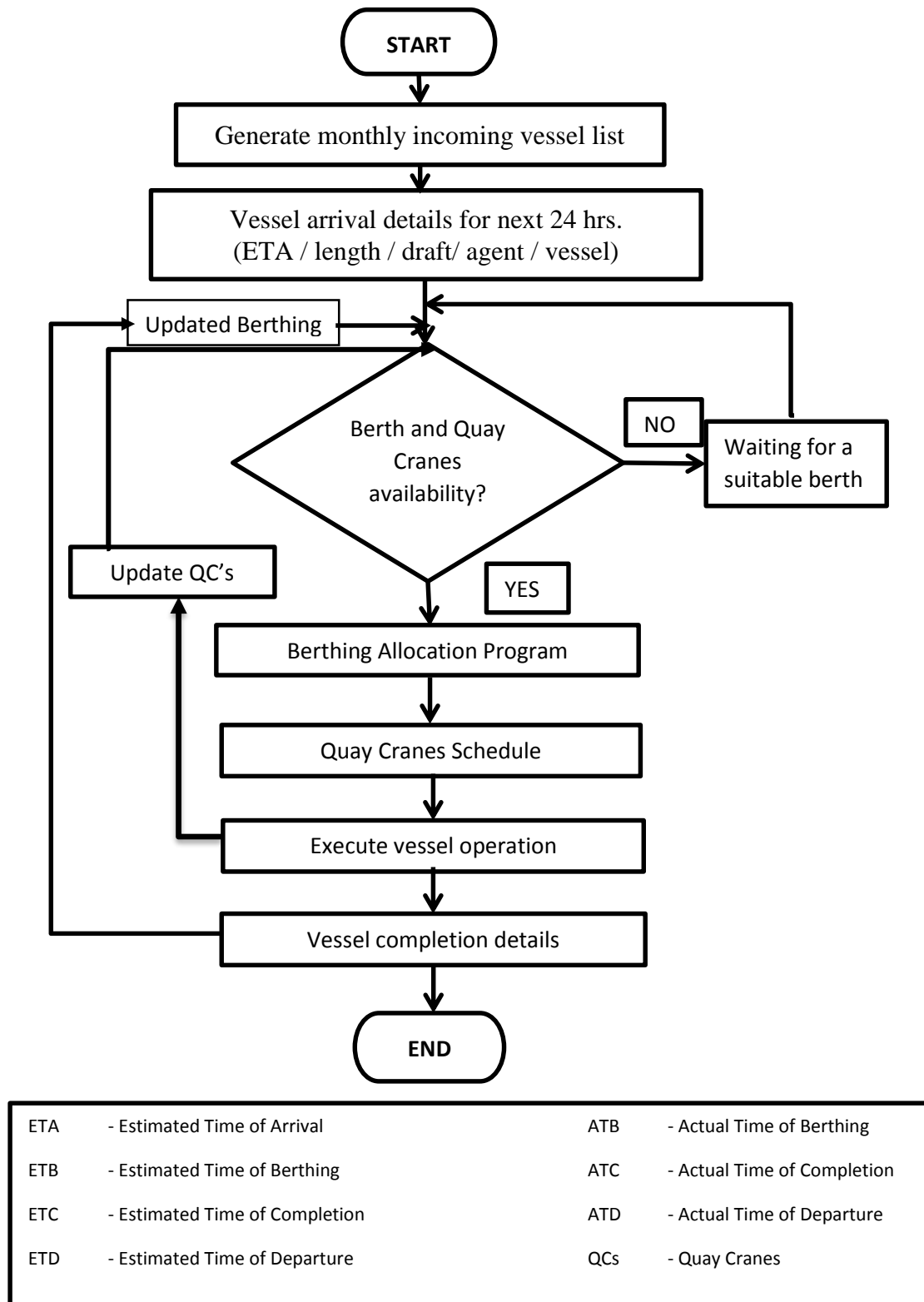
Figure 3-6 - Data Flow Diagram of the Main System

3.9 Database Design

Database design is the organization of data according to a database model. The designer determines what data must be stored and how the data elements interrelate. Database design is used to specify the structure of business objects used in the client/server system. Database design involves classifying data and identifying interrelationships [10]. The following Entity-Relationship diagram in Figure 3.7 describes the structure of the relational database model.
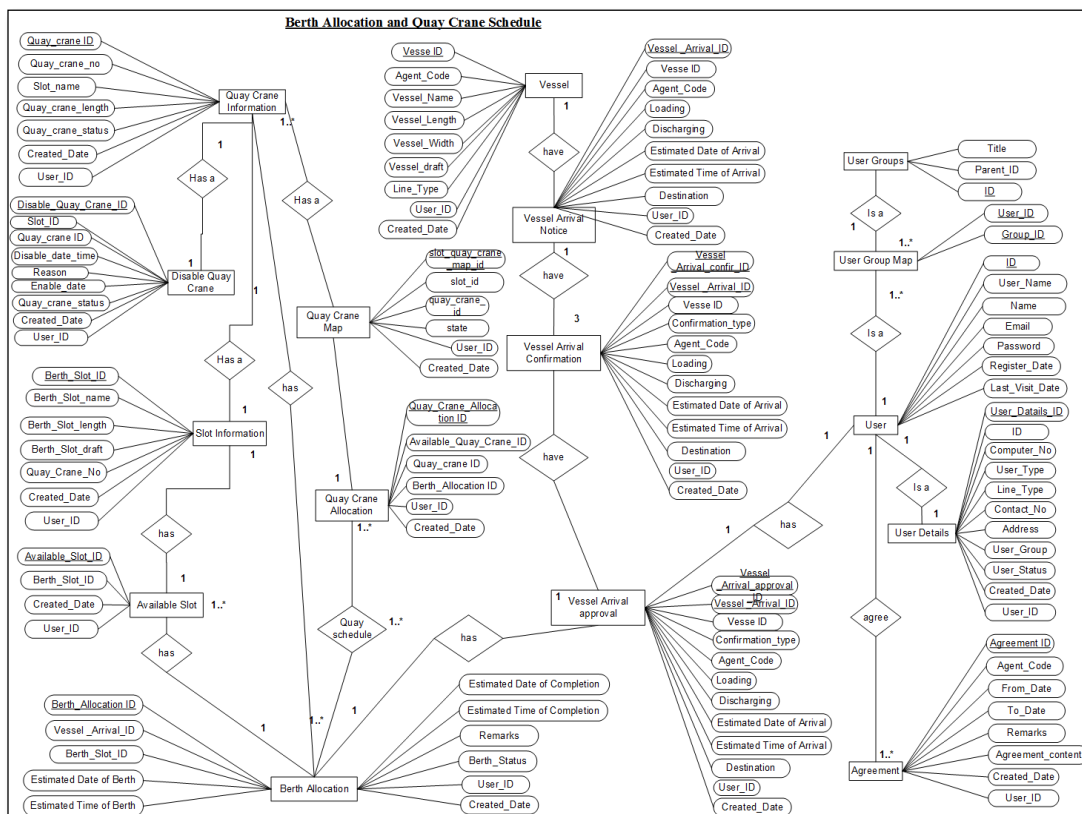
Figure 3-7 - ER Diagram

The current version of the ER diagram describes the number of attributes that are grouped with twelve elements. This includes managing quay crane information, check available quay cranes, check slot information or berth allocations, manage users and user groups, managing vessel details and their arrival details, etc. most of the elements have one to one or one to many cardinalities of the relationship.

3.10 Class diagram of the system

A class diagram in the Unified Modeling Language (UML) is a type of static structure diagram that describes the structure of a system by showing the system's classes, their attributes, operations (or methods), and the relationships among objects [11]. The following class diagram in Figure 3.8 depicts the overall class system of the system.
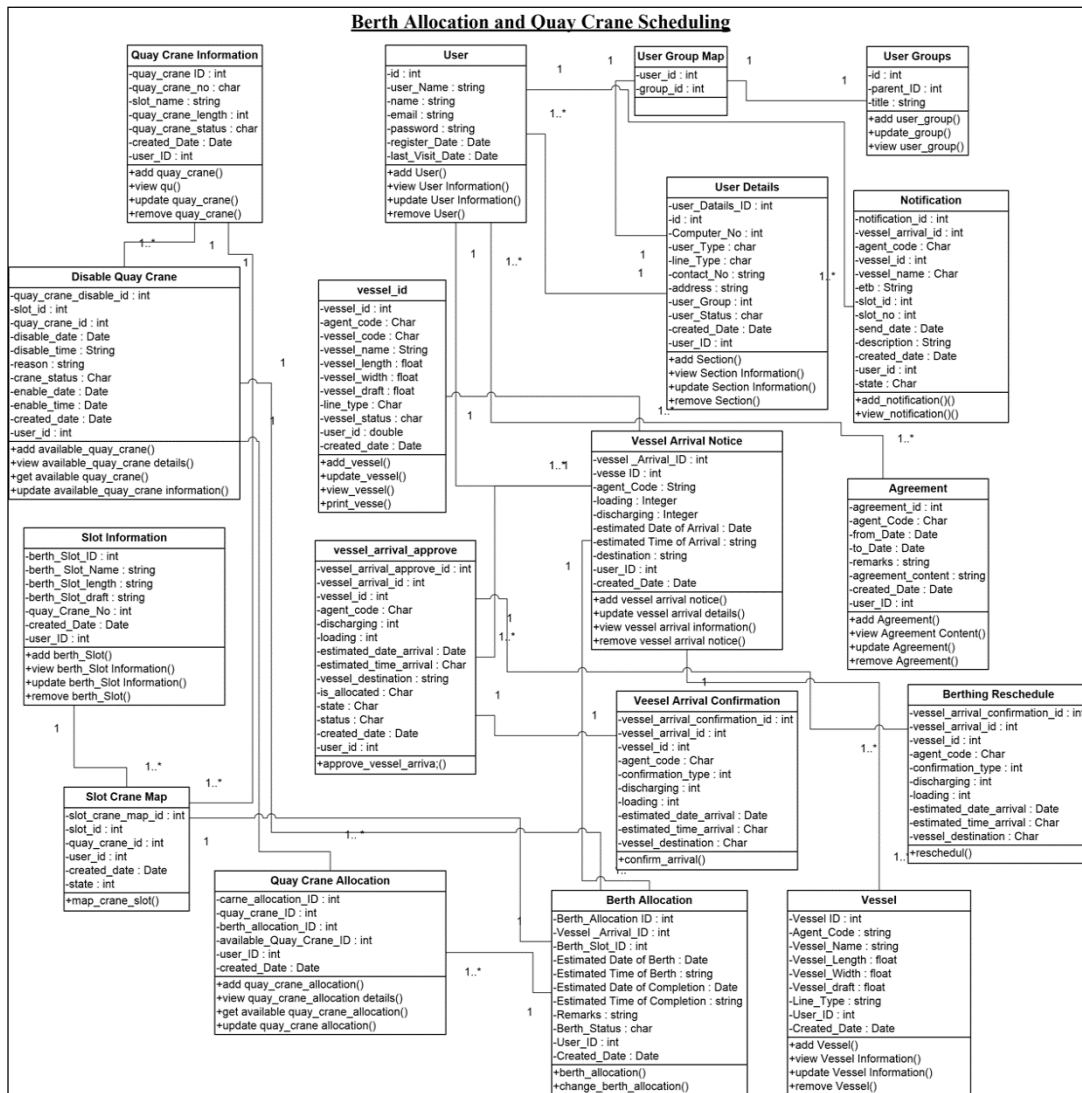
Figure 3-8 - Class Diagram

3.11 Sequence diagram of the system

The following tasks can be handled by a user role called Berthing Manager.

- View vessels arrival details
- Approve vessel arrival details
- Generate berth schedule
- View report

The below figures 3.9 display a sequence diagram of Berthing Manager.
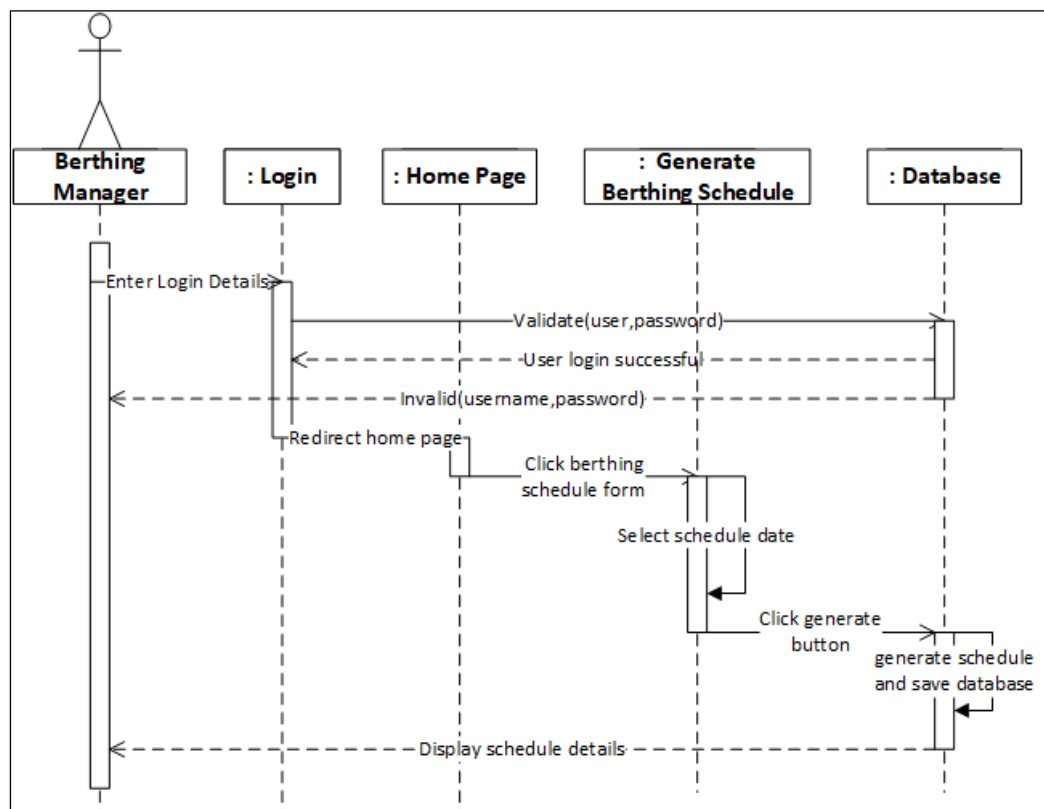
Figure 3-9 - Sequence Diagram: Generate Berthing Schedule

The above figure 3.9 describes the flow of generating berthing schedule.

The shipping line agent can handle the following task.

- Submit vessel arrival details
- Modify/Confirm vessel arrival
- View berthing schedule
- View notification
- View vessel progress

Figure 3.10 shows add new vessel arrival and confirmation flow.
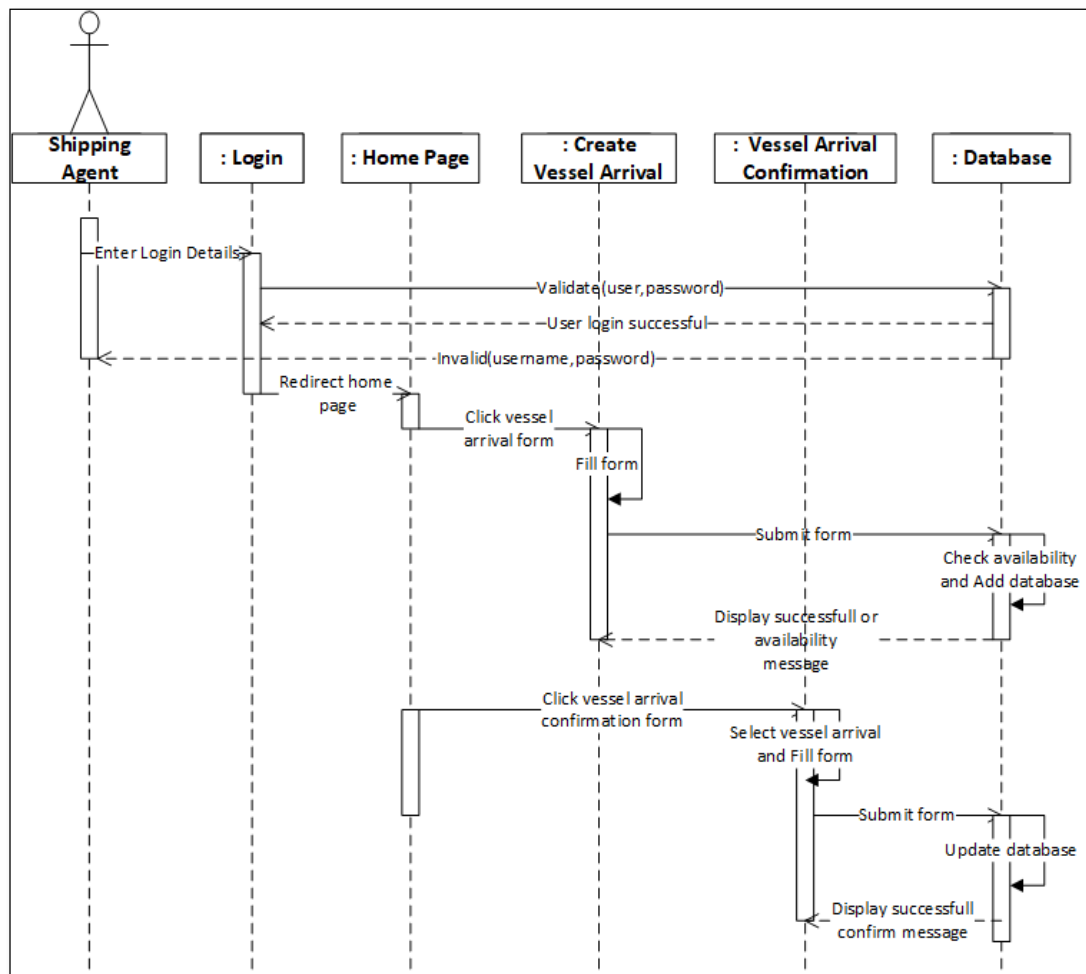
Figure 3-10 - Sequence Diagram: Vessel Arrival

The rest of the sequence is referring in Appendix B.

3.12 Main User Interfaces

This section disputes a few main user interfaces to show the system interface structure. The rest of the interfaces are referring to in Appendix C.

Login Page

Figure 3.11 allows the user to login to the system correct user name and password. Both internal and external user's same login interface as a login page.

Berth Allocation and Quay Crane Scheduling

SIGN IN

USERNAME

Username

PASSWORD

Password

Log in

Figure 3-11 - Login page

Home Page

The homepage provides the links and the menu bar to let the user navigate easily through the system. This page display according to user privileges. Figure 3.11 shows the home page of the Internal (Supper user, Administrator, Berthing Planner, Duty Manager, and Vessel Planer) level user.
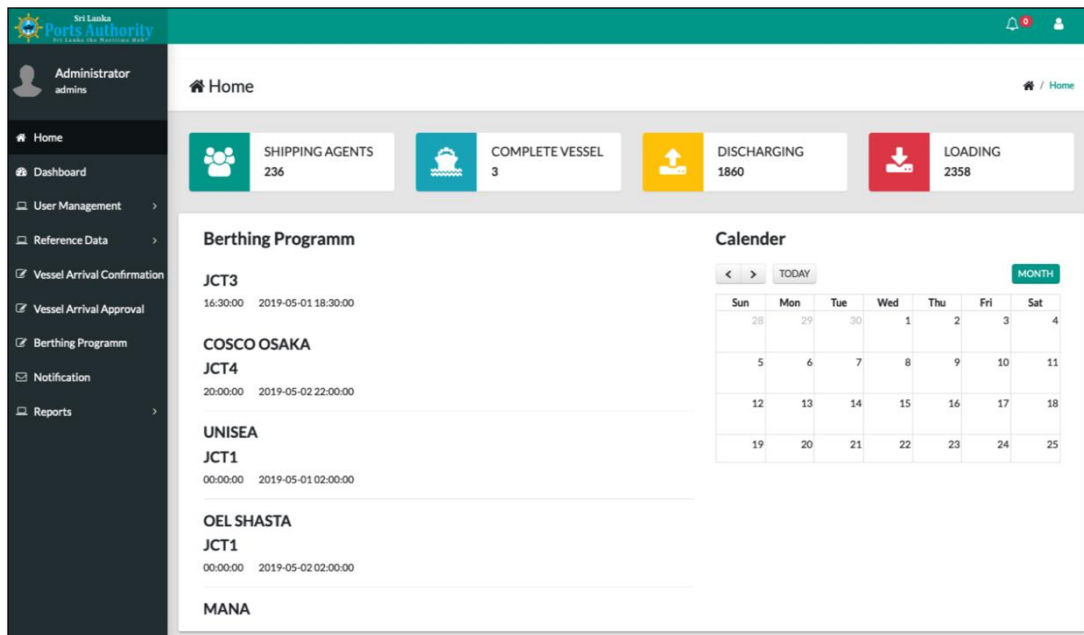
Figure 3-12 - Home page

Data Entry Form

The system uses some forms to manage reference data. Such reference modules are the Vessel module, Berth module, and Quay crane module. Using these forms each module can add new records and modify existing data. The system uses both client and server side validation before fed data to the database.

- Vessel module: Add and Modify vessel details
- Berth module: Add and Modify berth details
- Quay crane module: Add and Modify crane details

User Management another module, which use to manage user details, user privileges, and user login. All system users are divided into two categories such as internal and external. The system proved two types of forms to register new users. Figure 3.12 shows the internal user creation form and Figure 3.13 shows validations of the internal user creation form.

CREATE INTERNAL USER
User Type - I

ADD   MODIFY   VIEW

Register

Computer No

Name   M. V. Perera

Address

Contact No   xxxxxxxxxx

Email

User Name

Password

Re-Password

User Group   --SELECT USER GROUP--

User Status   --SELECT USER STATUS--

← Back   ✔ Register   ✕ Cancel

Figure 3-13 - Add New User Form

CREATE INTERNAL USER
User Type - I

👥 ADD	✎ MODIFY	☰ VIEW

Register

Computer No

❌ This field is required.

Name

M. V. Perera

❌ This field is required.

Address

❌ This field is required.

Contact No

xxxxxxxxxx

❌ This field is required.

Email

❌ This field is required.

User Name

❌ This field is required.

Password

❌ This field is required.

Re-Password

❌ This field is required.

User Group

--SELECT USER GROUP--

❌ This field is required.

User Status

--SELECT USER STATUS--

❌ This field is required.

← Back   ✓ Register   ✗ Cancel

Figure 3-14 - Validate Add New User Form

Berthing Program

Figure 3-16 - Berthing Program Schedule Form

Berthing Schedule

Show 10 entries   Search: [   ]

#	Date	ETA	ETB	B/No	ETC	NO OF CRANES	Vessel	DIS	LOAD	Total
1	2019-05-03	01:00:00	2019-05-03 03:00:00	JCT1	2019-05-03 12:30:00	3	GANTA BHUM	400	455	855
2	2019-05-02	05:00:00	2019-05-02 07:00:00	JCT2	2019-05-03 16:00:00	3	MSC ANCHROGE	1690	600	2290
3	2019-05-02	00:00:00	2019-05-02 02:00:00	JCT1	2019-05-02 06:27:00	3	OEL SHASTA	0	400	400
4	2019-05-02	20:00:00	2019-05-02 22:00:00	JCT4	2019-05-02 23:22:00	4	COSCO OSAKA	79	85	164
5	2019-05-02	07:00:00	2019-05-02 09:00:00	JCT1	2019-05-02 09:01:00	3	MANA	1	0	1
6	2019-05-02	00:00:00	2019-05-02 11:01:00	JCT1	2019-05-02 18:14:00	3	SMILEY LADY	0	650	650
7	2019-05-01	00:00:00	2019-05-01 02:00:00	JCT1	2019-05-01 04:42:00	3	UNISEA	0	243	243
8	2019-05-01	16:30:00	2019-05-01 18:30:00	JCT3	2019-05-03 05:50:00	3	MSC PARIS	1650	1530	3180
9	2019-04-29	18:00:00	2019-04-29 20:00:00	JCT1	2019-04-30 04:50:00	3	RT ODIN	210	585	795

Showing 1 to 9 of 9 entries   Previous 1 Next

Figure 3-15 - Berthing Program

Report and Chart

Figure 3-17 - Report List Form
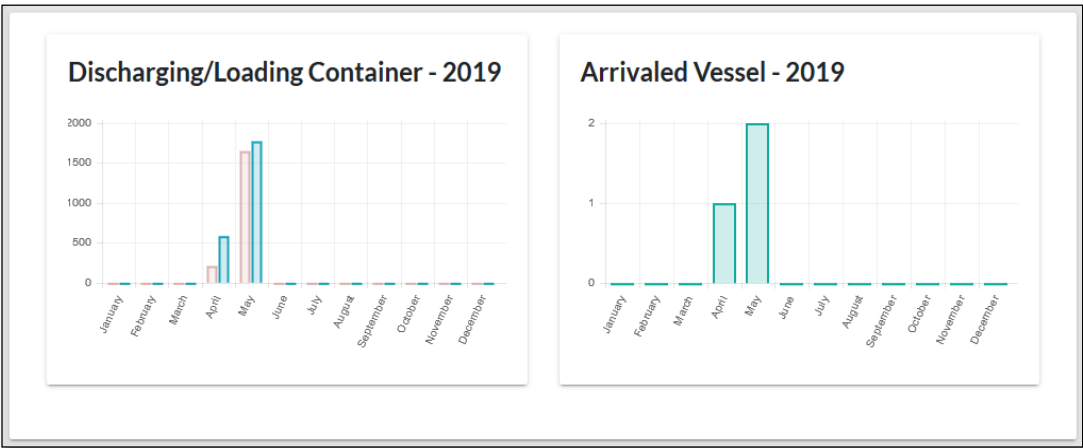
Figure 3-18 – Charts

3.13 Summary

This chapter illustrated the hardware and software infrastructure, technologies and tools used in an implementation environment to solve the BAP and QCS of the SLPA. This chapter also shows the design part of the application. After analysis, the requirement the proposed system mainly divided into five modules according to the user privileges. This approach is mainly based on the web-based application and it gives the opportunity to both internal and external users to access the system according to the corresponding user privileges.

Evaluation

4.1 Introduction

Software testing is a part of the software quality assurance that represents the different analyses of specification, design and code generation of the software product. Validation and verification are two basic methods of software testing and 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. The basic goal of the test evaluation is determined whether the system and the users are met the system requirements.

4.2 Test Plane

Testing begins with the implementation stage and code testing is started in the development stage. Before the system implementation, the test plane was designed. A test plan is a detailed document that outlines the test strategy, testing objectives, resources (manpower, software, and hardware) required for testing, test schedule, Test Estimation, and test deliverables [12].

Test cases were created according to the designed test plan. To reduce the complexity of the testing process test cases were designed for each module independently. The following tables specify some test cases.

Manual testing methods and procedures used for testing rather than automation tools and technologies.
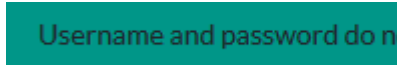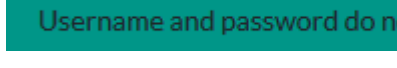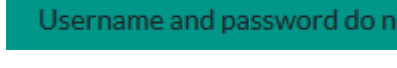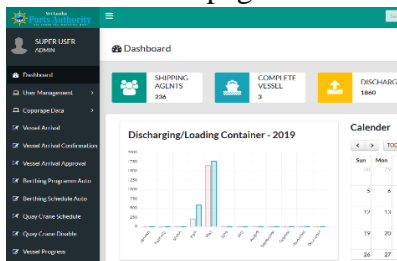
4.3 Testing Cases

Test case Id	01		
Tested component	Login		
Module name	Login		
Test case	Login		
Expected output	Satisfy the system login functions to run the system accurately		
Test case description			
No	**Test case**	**Actual output**	**Status**
01	Not entered the relevant password and click 'Login' button	Notify Username or password entered is wrong Username and password do n	pass
02	Not entered relevant username and click the 'Login' button	Notify Username or password entered is wrong Username and password do n	pass
03	Enter incorrect username and password and click 'Login' button	Notify Username or password entered is wrong Username and password do n	pass
04	Enter the correct username and password and click 'Login' button	Direct to home page 	pass

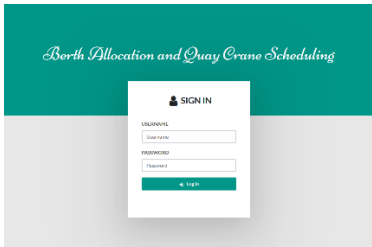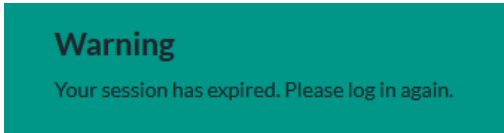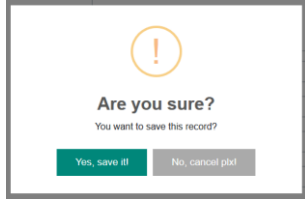**Table 4-1 - Login form test of web application**
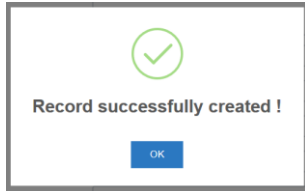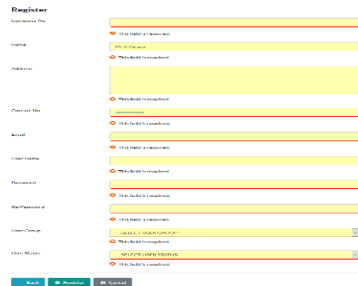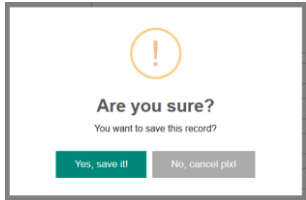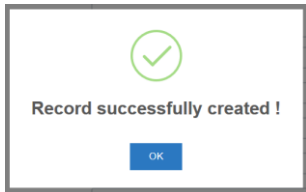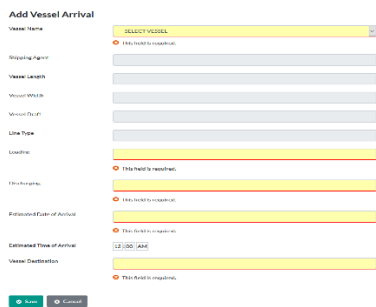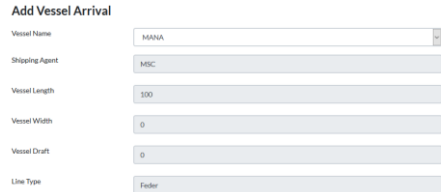
Test case Id	02		
Tested component	Common		
Module name	Common		
Test case	Common		
Expected output	Satisfy common system functions to run the system smoothly.		
Test case description			
No	Test case	Actual output	Status
01	Click the 'Logout' button	Logout the user and redirect to the login page. 	pass
02	Test with different browses	Load the system in different browsers (Firefox, Chrome).	pass
03	Incorrect DB connection	Display database error message Error: Failed to start application: Failed to start the session	pass
04	Login time out.	Idle for 15 minutes log out automatically. **Warning** Your session has expired. Please log in again.	pass
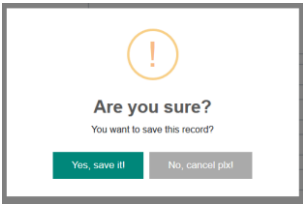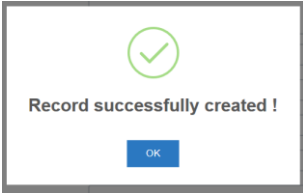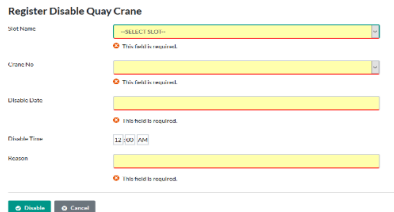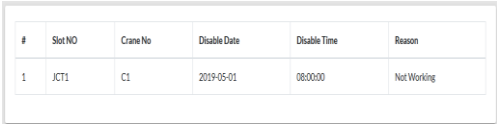
Table 4-2 - Common criteria test of web application

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Test case Id	03
Tested component	User Registration
Module name	User Management
Test case	User Registration
Expected output	Successfully save data and error messages display when wrong data enter.
Test case description	

No	Test case	Actual output	Status
01	Fill the registration form and click 'Register' button	Confirmation alert is display	pass
02	Click the 'Yes' button in the Confirmation alert	The successful alert is display	pass
03	Incomplete registration form filling	Notify the field required	pass
04	Type the different password and confirm password into the registration form	Notify password and confirm password is a mismatch	pass

Table 4-3 - User Registration test of web application

Test case Id	04		
Tested component	Vessel Arrival		
Module name	Vessel Arrival		
Test case	Vessel Arrival Create		
Expected output	Successfully save data and error messages display when wrong data enter.		
Test case description			

No	Test case	Actual output	Status
01	Fill the add vessel form and click the 'Save' button	Confirmation alert is display 	pass
02	Click the 'Yes' button in the Confirmation alert	The successful alert is display 	pass
03	Incomplete form filling	Notify the field required 	pass
04	Select the vessel name in the drop-down list	Fill the relevant details regarding the corresponding vessel 	pass

Table 4-4 - Vessel Arrival test of web application

Test case Id	05			
Tested component	Disable Quay Crane			
Module name	Disable Quay Crane			
Test case	Disable and Enable Quay Crane			
Expected output	Successfully save data and error messages display when wrong data enter.			
Test case description				
No	**Test case**	**Actual output**		**Status**
01	Fill the disable quay crane form and click the 'Save' button	Confirmation alert is display 		pass
02	Click the 'Yes' button in the Confirmation alert	The successful alert is display 		pass
03	Incomplete form filling	Notify the field required 		pass
04	Click the 'Enable' icon	Fill Display all the disable crane details in the grid 		pass

Table 4-5 - Disable quay crane test of web application

Please Refer to Appendix-C for the rest of the test cases.

4.4 Evaluation of the System

	User Evaluation Form Berth Allocation and Quay Crane Scheduling for Jaya Container Terminal Sri Lanka Ports Authority					
Date:	Role:					
* Please fill short answers to the below questions. Put "X" to the appropriate column						
No	Question	Strongly Agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly Disagree(1)
01.	Do you think the web-based system is better than the traditional system?					
02.	This web-based system is essential for an organization?					
03.	Does the web-based system provide a good interaction mechanism between the system and user?					
04.	Through the web-based system, the log-in and operation interfaces are clear and easy?					
05.	I am satisfied with the content of the web-based system?					
06.	The web-based system provides better information for the decision-making process					
07.	Web-based system content is understandable?					
08.	Is the language used in the web-based system is simple?					
09.	Is this web-based system helps my job?					
10.	I'm confident with my job after using the web-based system					

Table 4-6 - Acceptancy test of web application

The overall feedback of the proposed solution given by each user was collected and converted into a graphical evaluation chart. The following Figure 4.1 display the summary of the feedback.
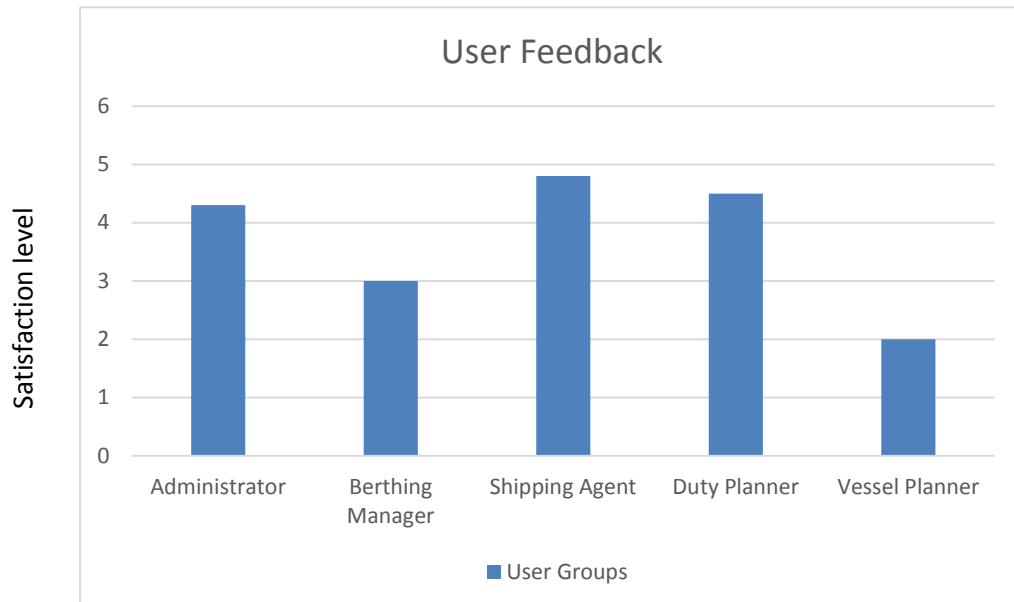

Figure 4-1 - Overall Feedback

4.5   Evaluation of the Berthing Schedule

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 highest percentage accuracy over the Berthing Schedule Program prepared by the Berthing Manager by using his expert knowledge of the problem domain.

4.6 Summary

After completing the user testing and when considering the user acceptance test results, in the evaluation process can identify all the functional requirements given by the client were fulfilled or the user can carry out their tasks effectively and productively through the new system. Berthing program generated by the new system was compared and it is identified that the results are having highest percentage accurate with berthing schedule prepared by manually 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 detail are included in the last chapter.

There are some limitations of the system are identified. Such as The System does not have API services to share the functionality with other system, some of the steps in the system depended with the record manually entered by user groups.

Conclusion & Future Developments

5.1 Introduction

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

5.2 Conclusion

Considering the standard steel container boxes for global freight transport, container loading and discharging has been in a continuous increase 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 more than thousands of load and discharge 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 neighboring ports in the region. This competitive advantage would help the terminal increase its customers and its profit.

In the competitive international shipping industry environment, the essential 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 berth and resources available in a container terminal to be assigned for a number of vessels waiting in a queue.

To accomplish the required efficiency and quality, the system was developed to overcome the Berth Allocation Problem and maximize Quay Crane Scheduling in JCT. Since JCT is the only state-owned terminal in Sri Lanka Ports Authority, Colombo and JCT have to be substituted with the modern technological approaches to compare 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.

After 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 practiced 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 have arrived 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.

5.3 Further work

Although the system does not send notifications to the Shipping Line Agents reminding them to confirm the vessel arrivals, 72 hours, 48 hours and 24 hours before the vessel arrives. 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. Also, agreement vessels are not considered to the automated berthing program. This is also expected to be implemented as a further work of this project.

In today context, the mobile platform is a very important area in IT solutions. Because of the mobility feature. Most of the time, shipping agents are traveling. So, shipping agents are requested to the mobile interface to log in to the system. The mobile platform is expected to be implemented as further work of the project.

5.4 Summary

In conclusion chapter, the developed web application is complete and the acceptable solution for BAP and QCS in JCT. A real-time notification system and full automation of the berth allocation process using the mobile platform 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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Web Application Design Documentation

A.1 Use case Description

A.1.1 Use-Case Description for Vessel Arrival Module

Use-Case	**Submit vessel arrival details**
Actors	Shipping Line Agent
Overview	
Shipping Line Agent accesses the vessel arrival submission form through the system, fill the arrival details and send the form.	
Pre-conditions	
The agent has a login account and the vessel is already registered.	
Flow of events	
- Log in to the system by entering the user name and password. - Go to the vessel arrival form. - Fill the form - Click the save button.	
Post conditions: n/a	

Table A-1 -Use-Case Description for Vessel Arrival Module

A.1.2 Use-Case Description for Vessel Confirmation Module

Use-Case	**Changes vessel details and confirm vessel arrival**
Actors	Shipping Line Agent
Overview	
The Shipping Line Agent accesses the online vessel details confirmation form, fill the modification details and submit the form	
Pre-conditions	
Vessel arrival is already submitted.	
Flow of events	
- Log in to the system by entering the user name and password. - Go to a vessel confirmation form. - Click the confirmation button. - Change vessel arrival details - Click the save button.	
Post conditions: n/a	

Table A-2 - Use-Case Description for Vessel Confirmation Module

A.1.3 Use-Case Description for View Berthing Program Module

Use-Case	View berthing schedule on the web site
Actors	Shipping Line Agent
Overview	
Accesses web site.	
Pre-conditions	
Log in to the system.	
Flow of events	
Log in to the system and go to the dashboard.	
Post-conditions: n/a	

Table A-3 - Use-Case Description for View Berthing Program Module

A.1.4 Use-Case Description for Arrival List Approve Module

Use-Case	View the monthly arrival list and approve
Actors	Berthing Manager
Overview	
Accesses the vessel arrival approve the form and approved vessel confirmations.	
Pre-conditions	
Already confirm the vessel arrivals.	
Flow of events	
• Log in to the system by entering the user name and password. • Go to the vessel approval form. • Click the approve button.	
Post conditions: n/a	

Table A-4 - Use-Case Description for Arrival List Approve Module

A.1.5 Use-Case Description for Generate Berthing Program Module

Use-Case	Generate berthing program
Actors	Berthing Manager
Overview	
Access the berthing schedule form and generate the berthing program of the corresponding arrival date.	
Pre-conditions	
All the vessel arrival must be approved before generating the schedule.	

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Flow of events
- Log in to the system by entering the user name and password.   - Go to the berthing schedule form.   - Select the corresponding date.   - Click the Generate Schedule button.
Post-conditions: Quay crane schedule and completion time are automatically generated.

Table A-5 - Use-Case Description for Generate Berthing Program Module

A.1.6 Use-Case Description for View Berthing Program Module

Use-Case	**View berthing program**
Actors	Berthing Manager
Overview	
Access the berthing program form.	
Pre-conditions	
The berthing program must be generated to the corresponding date.	
Flow of events	
- Log in to the system by entering the user name and password. - Go to the berthing program form. - Select the corresponding date and view.	
Post-conditions: n/a	

Table A-6 - Use-Case Description for View Berthing Program Module

A.1.7 Use-Case Description for View Quay Crane Schedule Module

Use-Case	**View quay crane schedule**
Actors	Berthing Manager
Overview	
Access the berthing program form.	
Pre-conditions	
The berthing program must be generated to the corresponding date.	
Flow of events	
- Log in to the system by entering the user name and password. - Go to the berthing program form. - Click the corresponding berthing program and view.	
Post conditions: n/a	

Table A-7 - Use-Case Description for View Quay Crane Schedule Module

A.1.8 Use-Case Description for Define Heavy Crane and Reschedule Module

Use-Case	**Define heavy crane and reschedule**
Actors	Vessel Planer
Overview	
Access the quay crane schedule form.	
Pre-conditions	
The berthing program must be generated to the corresponding date.	
Flow of events	
- Log in to the system by entering the user name and password. - Go to the quay crane schedule form. - Click the corresponding berthing vessel. - Go to the quay crane scheduling. - Assign the heavy crane. - Click the reschedule button.	
Post-conditions: The Berthing program is rescheduled according to the crane allocation.	

Table A-8 - Use-Case Description for Define Heavy Crane and Reschedule Module

A.1.9 Use-Case Description for Define Disable Crane Module

Use-Case	**Define disable crane**
Actors	Duty Planer
Overview	
Access the quay crane disable form and update the crane status.	
Pre-conditions	
Berth and the crane details are added to the system.	
Flow of events	
- Log in to the system by entering the user name and password. - Go to quay crane disable the form. - Click the corresponding berth and the crane. - Update the crane status - Click the save button.	
Post conditions: n/a.	

Table A-9 - Use-Case Description for Define Disable Crane Module

A.1.10 Use-Case Description for User Management Module

Use-Case	User Management
Actors	Administrator
Overview	
Access the user creation form, and create new users and update users.	
Pre-conditions	
n/a.	
Flow of events	
- Log in to the system by entering the user name and password. - Go to the user creation form. - Fill the form. - Click the save button.	
Post conditions: n/a.	

Table A-10 - Use-Case Description for User Management Module

Web Application Development Design

B.1 Diagrams

B.1.1 Context Diagram
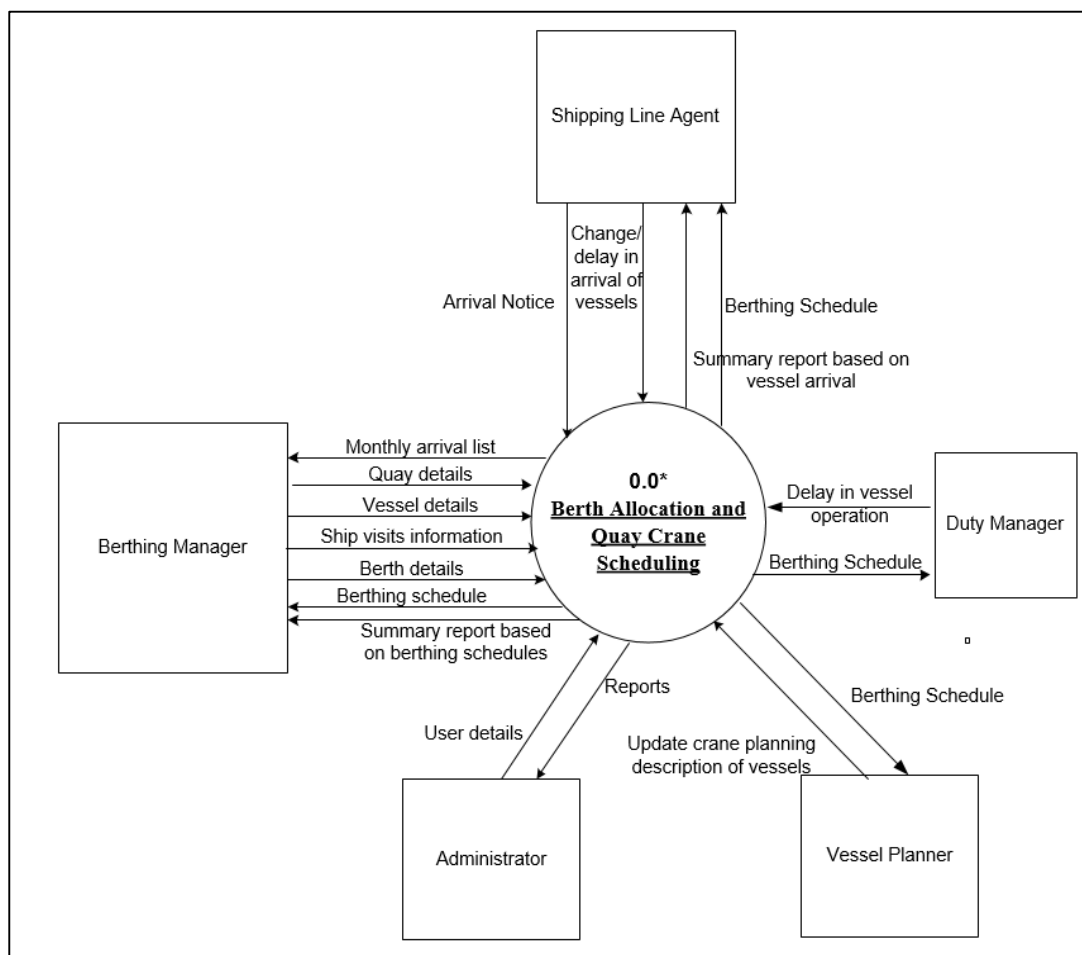
Figure B-1 - Data Flow Diagram

B.1.2 Sequence Diagram
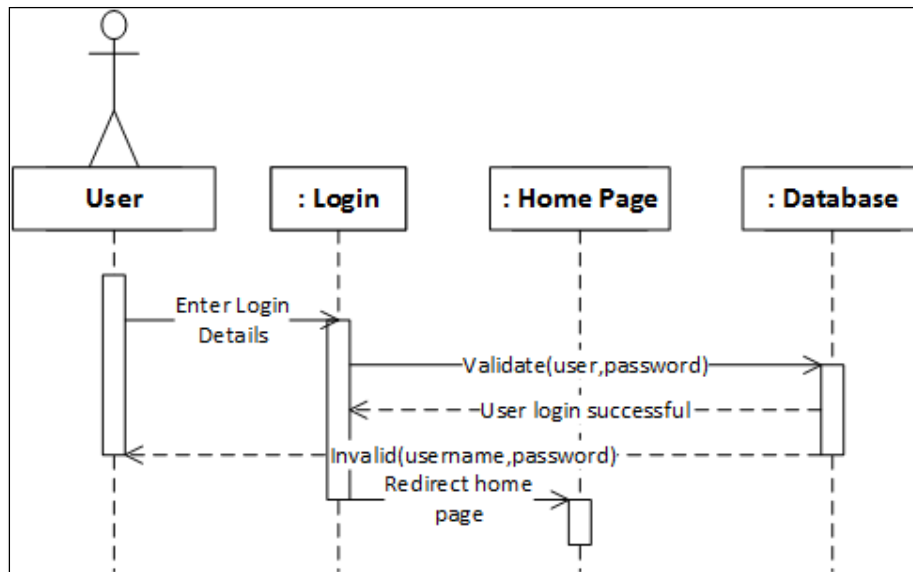
Figure B-2 - Sequence Diagram: Login

Figure B.3 shows the object interaction arrangement of the login function and how the flow is arranged. Both internal and external user logins are working in this way.
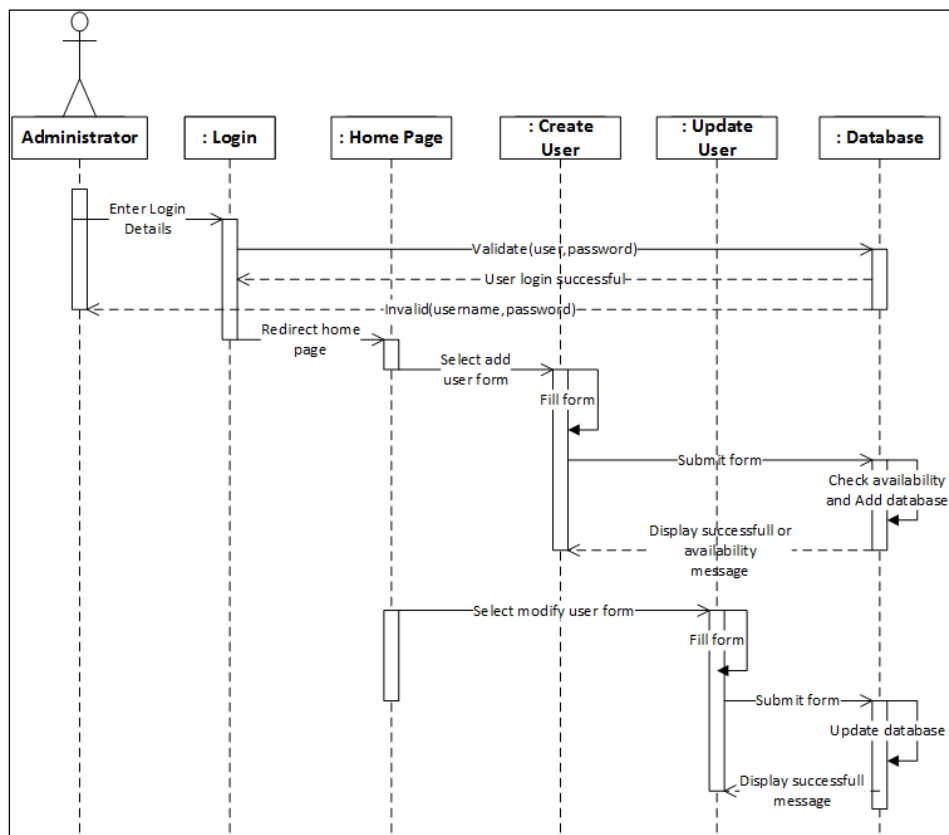
Figure B-3 - Sequence Diagram: User Management

Below figures show how vessel and crane creation and updating process is work.
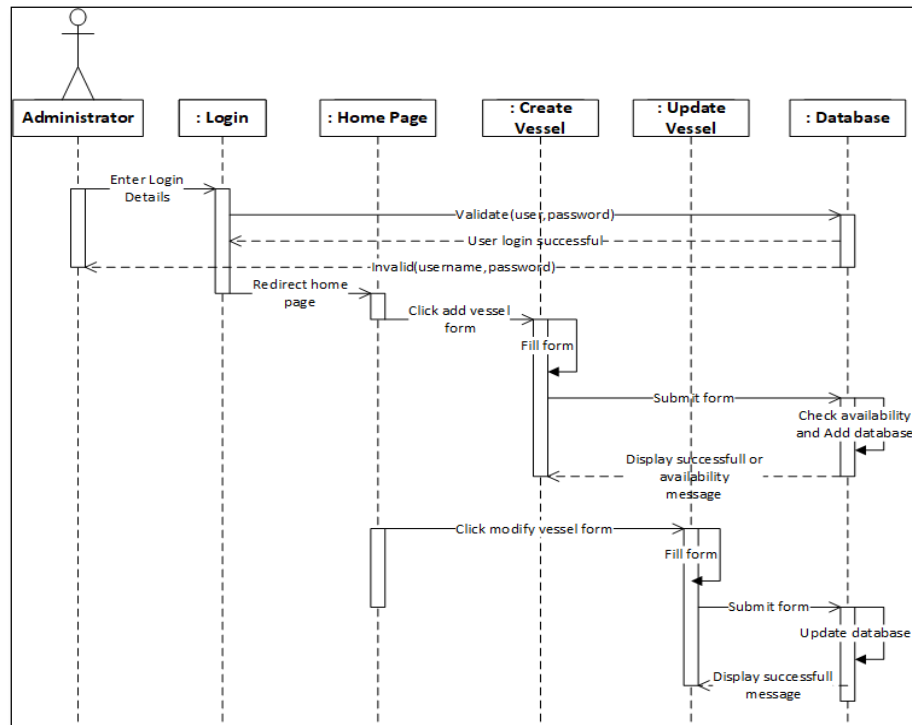
Figure B-4 - Sequence Diagram: Vessel Management
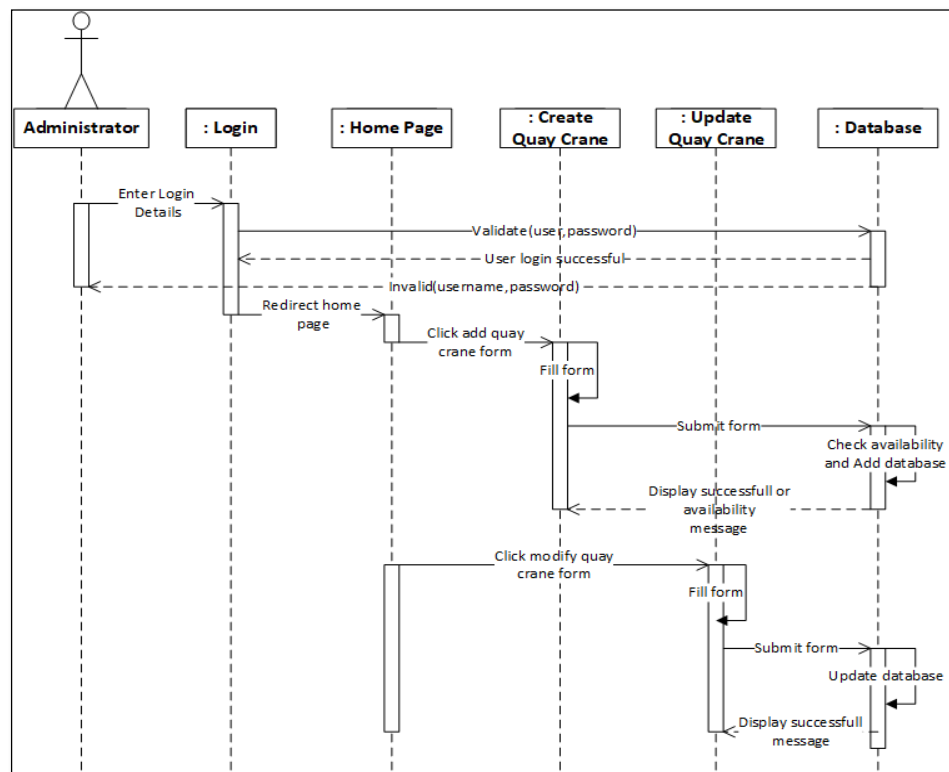
Figure B-5 - Sequence Diagram: Crane Management

Figure B.6 shows how crane enable and disable process is work.
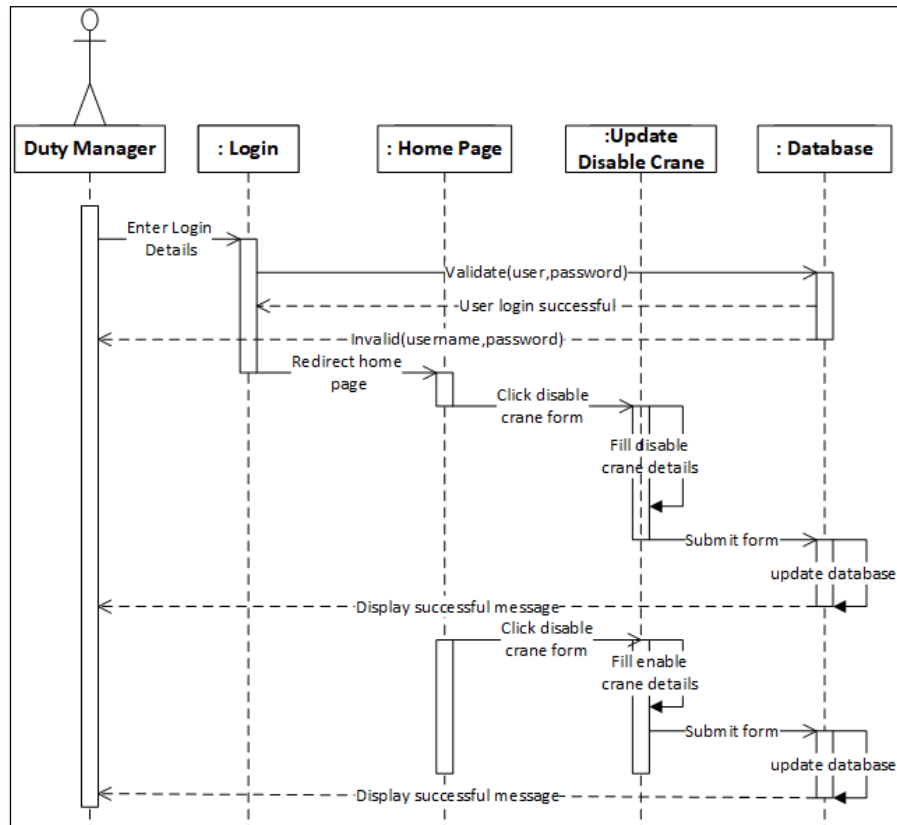
Figure B-6 - Sequence Diagram: Enable/Disable crane
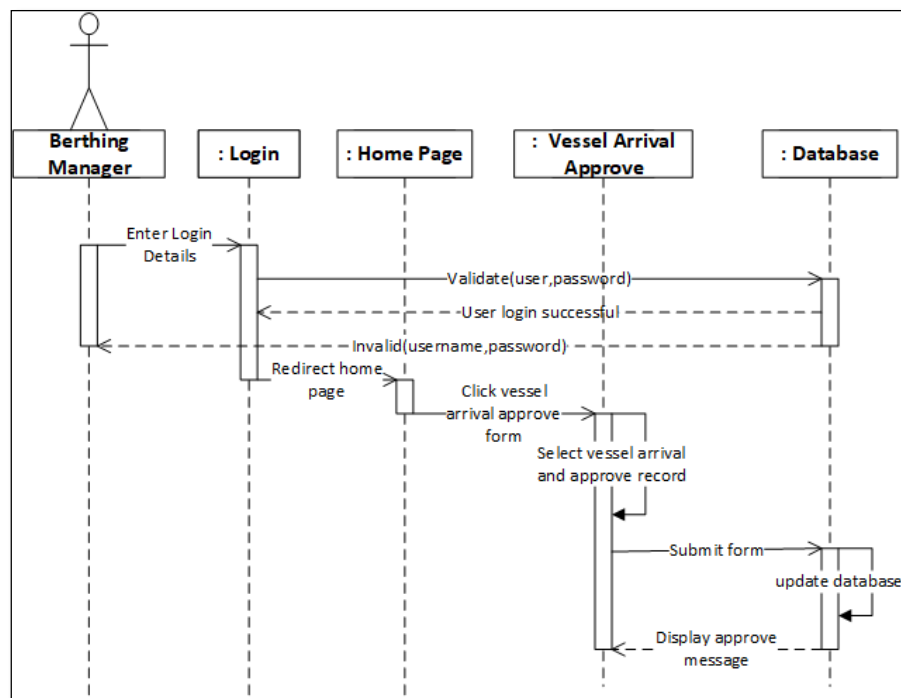
Figure B-7 - Sequence Diagram: Vessel Approval

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Above Figure B.7 shows how the vessel arrival approval process is work and Figure B.8 shows how to reschedule the berthing program process is work.
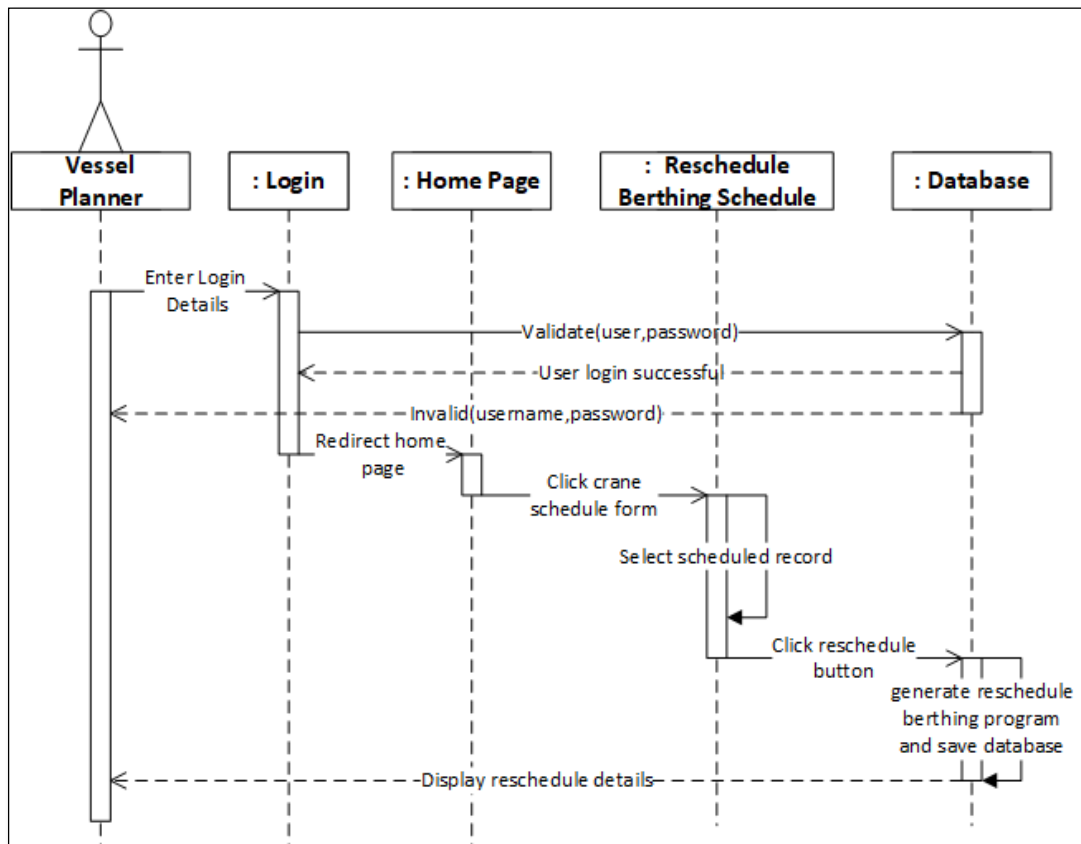
Figure B-8 - Sequence Diagram: Reschedule Berthing Program

Web Application Development Testing

C.1 Test Case

C.1.1 Notification test of web application

Test case Id	06
Tested component	Notification
Module name	Notification
Test case	Notification
Expected output	Display the unread notification count
Test case description	

No	Test case	Actual output	Status
01	When the agent is logged into the system, no of unread notification is display	Display the no. of unread notification count.	pass

Table C-1 - Notification test of web application

C.1.2 Select Approved Vessel Arrival List for the test of web application

Test case Id	07
Tested component	Select Vessel Arrival List for generating berthing program
Module name	Berthing Program
Test case	Generate Vessel Arrival List for generating berthing program
Expected output	Successfully Select data to complete the approved date list.
Test case description	

No	Test case	Actual output	Status
01	If vessel arrival is not yet confirmed (before 72 hours) and the remaining time is already less than 72 hours for the vessel arrival.	This arrival is not select to the berthing schedule list.	pass
03	If vessel arrival is not yet confirmed (before 48 hours) and the remaining time is already less than 48 hours for the vessel arrival.	This arrival is not select to the berthing schedule list.	pass
05	If vessel arrival is not yet confirmed (before 24 hours) and the remaining time is already less than 24 hours for the vessel arrival.	This arrival is not select to the berthing schedule list.	pass

Table C-2 - Select Approved Vessel Arrival List for the test of web application

C.1.3   Quay Crane Schedule test of web application

Test case Id	08		
Tested component	Quay Crane Schedule		
Module name	Quay Crane Schedule		
Test case	Quay Crane Schedule		
Expected output	Successfully save data and error messages display when wrong data enter.		
Test case description			
No	**Test case**	**Actual output**	**Status**
01	Click 'On' or 'Off' button to allocate or not the crane into the corresponding vessel	Click 'Off' crane is disabled. Click 'On' crane is enabled.	pass
02	When added exceeded amount offloading and discharging	The display error message	pass
03	Click 'View crane' button	Display crane schedule	pass
04	Click the 'Reschedule' button	The schedule is changed according to the changes in loading and discharging	pass

Table C-3 - Quay Crane Schedule test of web application

C.1.4 Berthing Schedule test of web application
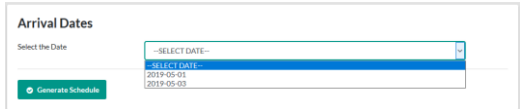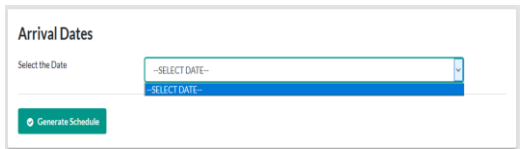
Test case Id	09			
Tested component	Berthing Schedule			
Module name	Berthing Schedule			
Test case	Berthing Schedule			
Expected output	Select all the approved vessel arrivals to the schedule date list			
Test case description				
No	**Test case**	**Actual output**		**Status**
01	Click the berthing schedule tab	Display all the approved arrival date list		pass
02	When arrivals not approved	Arrival dates not display		pass

Table C-4 - Berthing Schedule test of web application

Web Application Development – User Documentation
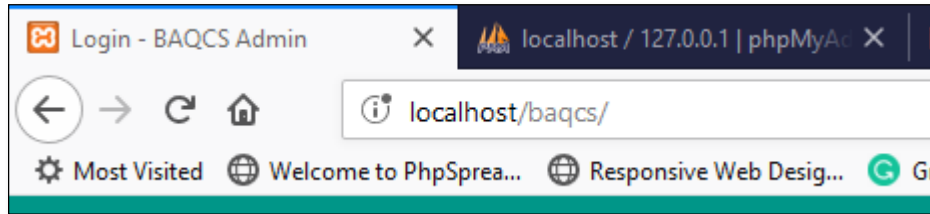
D.1 User Interfaces
D.1.1 URL of the system

Figure D-1- URL of the system

D.1.2 Login page

When the user provides the correct user name and password to access the system. User can log in to the system after giving correct user name and password. Home page view display after initial login. The left side of the home page displays the navigation bar with all modules which the user can access.
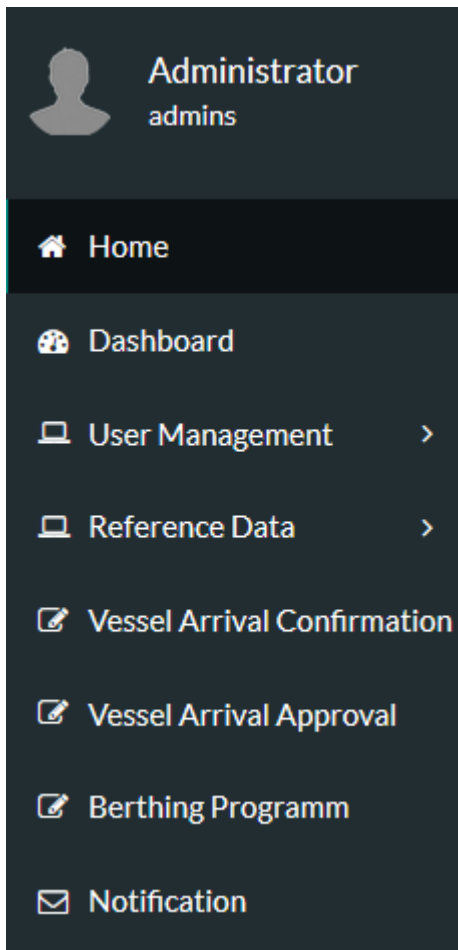

Figure D-2 - Login page

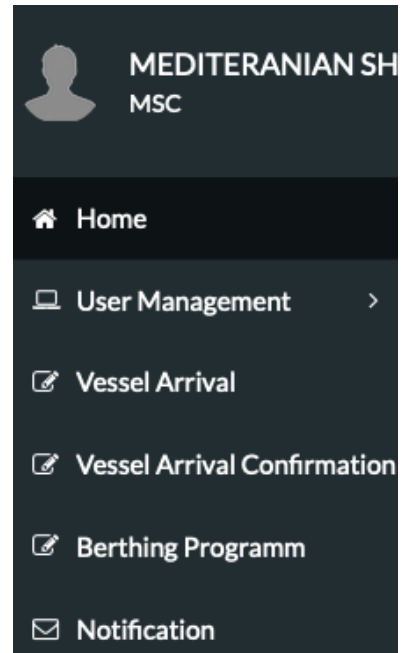**Figure D-3 - Navigation bar of the administrator**

Figure D-4 - Navigation bar of the agent

Figure D.3 shows the Administrator navigation bar and administrator can access only Dashboard, User Management, Reference Data, Vessel Arrival confirmation, Vessel Arrival Approval, Berthing Program, and Notification panels according to the administrator privileges.

The below section gives brief descriptions of the "User Management" module and features. The data add, modify and view functions are allowed in these modules. The User Management module divided into subcategories called User and New Password. The special features of these panels are explained below.

User module

This module uses to create new users. Admin creates users and when the user log login user can edit his/him passwords. According to the system requirement, users are categorized into two types called internal and external users. Figure D.5 shows below.

Figure D-5 - User Type

The internal panel is shown in Figure 3.11 and the external panel is shown below.

Figure D-6 - Add External User

Figure D-7 - Modify External User

INQUIRY EXTERNAL USER
User Type - E

👥 ADD	✎ MODIFY	☰ VIEW

USER TABLE

| Copy | Excel | Print | | Search: |

# ↑↓	AGENT CODE ↑↓	NAME ↑↓	ADDRESS ↑↓	EMAIL ↑↓	CONTACT NO ↑↓	USER NAME ↑↓	USER GROUP ↑↓	USER STATUS ↑↓
1	UAS	UNITED ARAB SHIPPING LINE		test@gmail.com		UAS	4	A
2	CHS	CHINA SHIPPING CONTAINER LINES CO L		test@gmail.com		CHS	4	A
3	ERL	EMIRATES SHIPPING LINE		test@gmail.com		ERL	4	A
4	PL	PRO LINE		test@gmail.com		PL	4	A
5	APL	AMERICAN PRE. LINE		test@gmail.com		APL	4	A
6	OCL	ORIENT SHIPPING CONTAINER LINE		test@gmail.com		OCL	4	A
7	PIL	PACIFIC INTERNATIONAL Line		test@gmail.com		PIL	4	A
8	OOL	Orient Overseas Line		test@gmail.com		OOL	4	A
9	ZIM	ZIM LINE		test@gmail.com		ZIM	4	A
10	MOL	MITSUI OSK LINE		test@gmail.com		MOL	4	A

Showing 1 to 10 of 236 entries

Previous 1 2 3 4 5 ... 24 Next

Figure D-8 - View External User

Figure D.4 shows the Agent navigation bar and agent can access only User Management, Vessel Arrival, Vessel Arrival confirmation, Berthing Program, and Notification panels according to the agent privileges.

When shipping agent login to the system, in the right side top corner display the count of unread notifications and the agent can view this notification after clicking on the message.
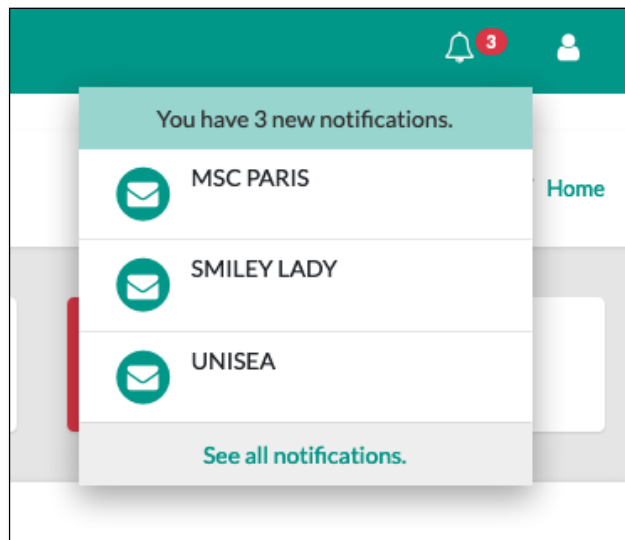
Figure D-9 - Notification list
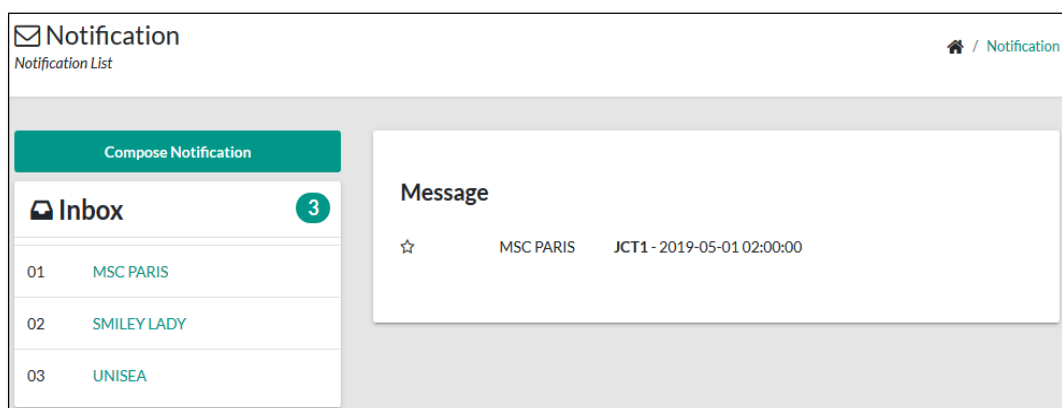
Figure D-10 - Notification Message

The below section gives brief descriptions of the "Vessel Arrival" module and features. The data add, modify and view functions are allowed in these modules. Vessel arrivals request only submit by vessel agent and the confirmations of the vessel arrivals also submitted by the vessel agent. In the Add, the new vessel form is listed all the vessels which already registered in the system. When the agent needs to register the new vessel into the system, the agent has to submit the required documentation to the administrator of the operation division in SLPA and the registration of the new vessel is done by the administrator. After filling the form and press the save button, then arrival request is generated. This arrival request is displayed in the arrival confirmation panel. When clicking confirmation button arrival is confirmed (figure D.13).

Figure D-11 - Add Vessel Arrival

Figure D-12 - Vessel Arrival Confirmation list

Figure D-13 - Vessel Arrival Confirmation Form

Reports

The system allows the administrators and managers can access reports and dashboard panels and to generate well-documented reports with a filtering Yearly, Monthly, Daily, Date range reports. The report helps the management to get an idea about vessel arrivals and forecasting of annual loading and discharging count of the JCT terminal. These reports are given in a clear format which helps the administrator to easily browse, view and print the report. Figure D.14 shows the report panel and list all the report which can view and print.

Figure D-14 - Vessel Arrival Confirmation Form

Below figure D.15 shown the Vessel List excel report. This report can also download a pdf format and can print.

#	AGENT CODE	VESSEL NAME	VESSEL LENGTH	VESSEL WIDTH	VESSEL DRAFT	LINE TYPE
			Vessel Details			
1	COC	COSCO OSAKA	260	0	0	M
2	COS	XIN SHANGHAI	337	0	0	M
3	EMC	EVER CONQUEST	334	0	0	M
4	FAR	TR ARAMIS	186	0	0	F
5	LIL	NICKIE B	162	0	0	F
6	LIL	RT ODIN	170	0	0	F
7	MSC	MANA	100	0	0	F
8	MSC	MSC SINDY	337	0	0	M
9	MSC	MSC MARIA LAURA	228	0	0	M
10	MSC	MSC ANCHROGE	299	0	0	M
11	MSC	MSC PARIS	335	0	0	M
12	OEL	UNISEA	155	0	0	F
13	OEL	OEL INDIA	150	0	0	F
14	OLS	MCP LONDON	117	0	0	F
15	ORD	RDO CONCERT	304	0	0	M
16	RCL	GANTA BHUM	152	0	0	F
17	SIM	HAPPY BEE	172	0	0	M
18	SIM	MP THE BELICHICK	295	0	0	M
19	TWF	OEL SHASTA	179	0	0	F
20	XCL	ASIATIC JADE	149	0	0	F
21	XCL	SMILEY LADY	184	0	0	F
22	XCL	CORHELIA1	294	0	0	M

Figure D-15 – Vessel List report

Web Application Development – Code Listing

E.1 Introduction

This section illustrates the fundamental area of the code structure of the system. The developed system has used the MVC design pattern. Codes related to each function includes a separate Model, View, and Controller. Some main code segments are described below.

The codes are very lengthy and only important code snippets are represented in this below.

E.1.1　Model

```php
class BaqcsModelUser extends JModelItem
{
    public static function getInternalUserDetails() {
        $app = JFactory::getApplication();
        $db = &JFactory::getDbo();
        $query = $db->getQuery(true);
        $query->select(array('a.*','b.*'))
            ->from($db->quoteName('#__users', 'a'))
            ->join('INNER', $db->quoteName('#__slpa_user_details', 'b') . ' ON (' . $db->quoteName('a.id') . ' =
                ' . $db->quoteName('b.id') . ')')
            ->where($db->quoteName('b.user_type') . '=' . $db->quote('I'));
        $db->setQuery($query);
        //echo $query;
        $results = $db->loadObjectList();
        return $results;
        $app->close();
    }

    public static function getExternalUserDetails() {
        $app = JFactory::getApplication();
        $db = &JFactory::getDbo();
        $query = $db->getQuery(true);
        $query->select(array('a.*','b.*'))
            ->from($db->quoteName('#__users', 'a'))
            ->join('INNER', $db->quoteName('#__slpa_user_details', 'b') . ' ON (' . $db->quoteName('a.id') . ' =
                ' . $db->quoteName('b.id') . ')')
            ->where($db->quoteName('b.user_type') . '=' . $db->quote('E'));
        $db->setQuery($query);
        //echo $query;
        $results = $db->loadObjectList();
        //var_dump($results);die();
        return $results;
        $app->close();
    }
```

Figure E-1 - Code snippet of model

E.1.2 View

```html
<main class="app-content">
  <div class="app-title">
    <div>
      <h1><i class="fa fa-edit"></i> USER </h1>
      <p>Manger Users Type</p>
    </div>
    <ul class="app-breadcrumb breadcrumb">
      <li class="breadcrumb-item"><i class="fa fa-home fa-lg"></i></li>
      <li class="breadcrumb-item">Users Management</li>
      <li class="breadcrumb-item"><a href="#">Users Type</a></li>
    </ul>
  </div>
  <div class="row">
    <div class="col-md-12">
      <div class="tile">
        <h3 class="tile-title">Register</h3>
        <form class="form-horizontal" id="userTypeForm" name="userTypeForm" action="
        index.php?option=com_baqcs&task=user.selectUserType" method="post">
        <div class="tile-body">
          <div class="form-group row">
            <label class="control-label col-md-3">User Type</label>
            <div class="col-md-9">
              <div class="form-check">
                <label class="form-check-label">
                  <input class="form-check-input" type="radio" name="user_type" id="internal" checked=""
                  value="I">Internal
                </label>
              </div>
              <div class="form-check">
                <label class="form-check-label">
                  <input class="form-check-input" type="radio" name="user_type" id="external" value="E">
                  External
                </label>
              </div>
            </div>
          </div>
        </div>
        <div class="tile-footer">
          <div class="row">
            <div class="col-md-8 col-md-offset-3">
              <button class="btn btn-primary" type="submit" id="subBut" name="subBut"><i class="fa fa-fw
              fa-lg fa-check-circle"></i>Procced</button>   <a class="btn btn-secondary"><i
              class="fa fa-fw fa-lg fa-times-circle"></i>Cancel</a>
            </div>
          </div>
        </div>
        </form>
      </div>
    </div>
  </div>
</main>
```

Figure E-2 - Code snippet of the view

E.1.3 Control

```
class BaqcsControllerActualberthingschedule extends JControllerLegacy
{
    public function actualVesselCompletion(){
        $app = JFactory::getApplication();
        $user = JFactory::getUser();
        $userId = $user->get('id');
        $now = date('Y-m-d h:i:s');
        $stateUpdated            = false;
        $stateNotFoundRecord     = false;
        $userlogin               = true;

        $atc = $_POST['atc'];
        $adc = $_POST['adc'];
        $atb = $_POST['atb'];
        $adb = $_POST['adb'];
        $reference_no = $_POST['reference_no'];
        $remarks = $_POST['remarks'];
        $schedule_automaic_id = $_POST['schedule_automaic_id'];

        if($userId == '0'){
            $userlogin = false;
        }
        if($userlogin == true){
            $dbe = &JFactory::getDbo();
            $querye = $dbe->getQuery(true);
            $querye->select(array('a.*'))
                ->from($dbe->quoteName('#__slpa_schedule_automatic') . 'AS a')
                ->where($dbe->quoteName("a.schedule_automaic_id") . '=' . $dbe->quote($schedule_automaic_id));
                //->order('A.agent_code ASC');
            $dbe->setQuery($querye);
            $resultse = $dbe->loadObjectList();
            if($resultse){
                $db = &JFactory::getDbo();
                $query = $db->getQuery(true);
                $query->update($db->quoteName('#__slpa_schedule_automatic'));
                $query->set("adb " . '=' . $db->quote($adb));
                $query->set("atb " . '=' . $db->quote($atb));
                $query->set("adc" . '=' . $db->quote($adc));
                $query->set("atc" . '=' . $db->quote($atc));
                $query->set("complete_status" . '=' . $db->quote('C'));
                $query->set("ref_no" . '=' . $db->quote($reference_no));
                $query->set("remarks " . '=' . $db->quote($remarks));
                $query->where('schedule_automaic_id' . '=' . $db->quote($resultse[0]->schedule_automaic_id));
                $db->setQuery($query);
                $result = $db->execute();
                $stateUpdated =true;

            }else{
                $stateNotFoundRecord = true;
            }
```

Figure E-3 - Code snippet of control

E.1.4 Reusable component

Common date picker and time picker use for all PHP pages within the javaScript tag which use to display calendar date selection functions and time selection functions.

```
<script type="text/javascript">
  $('#disable_date').datepicker({
    format: "yyyy/mm/dd",
    autoclose: true,
    todayHighlight: true
  });

  $('#disable_time').timepicker();
```

Figure E-4 - Code snippet of date and time picker

Following Common "DataTable" library files used to export "Excel Report", "PDF Report" and copy to "DataTable" records. These library files used to all the reports generated by the system.

```
<link href="https://cdn.datatables.net/buttons/1.5.6/css/buttons.dataTables.min.css" rel="stylesheet">
<script type="text/javascript" src="https://cdn.datatables.net/buttons/1.5.6/js/dataTables.buttons.min.js"></
script>
<script type="text/javascript" src="https://cdnjs.cloudflare.com/ajax/libs/jszip/3.1.3/jszip.min.js"></script>
<script type="text/javascript" src="https://cdnjs.cloudflare.com/ajax/libs/pdfmake/0.1.53/pdfmake.min.js"></
script>
<script type="text/javascript" src="https://cdnjs.cloudflare.com/ajax/libs/pdfmake/0.1.53/vfs_fonts.js"></script
>
<script type="text/javascript" src="https://cdn.datatables.net/buttons/1.5.6/js/buttons.html5.min.js"></script>
<script type="text/javascript" src="https://cdn.datatables.net/buttons/1.5.6/js/buttons.print.min.js"></script>
```

Figure E-5 - Code snippet of DataTable Libraries