MATHEMATICAL MODELLING OF BERTH UTILISATION RATE FOR MULTIPURPOSE PORT OPERATIONS

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ABSTRACT

Productivity is an essential element which shows the effectiveness of a port and its operations. Berth utilisation rate is the key indicator determining ship turnaround time. To date, there is no clear guidance for port operators on getting a precise data in the terms of berth utilisation rate. Thus, this study was conducted to determine berth utilisation rate for a port using derived mathematical model. Derived model incorporated eight parameters in the equation, each of the elements being independent but inter-related to one another. Parameters involved in the development of the mathematical model are, ship length, port stay, berthable length, utilisable hours per day, number of days in a month, total capacity, immobilised capacity and final capacity. The model was validated by using 36 months data, from January 2012 to December 2014, based on data collected from Jurong Port Pte.Ltd., being port of understudy. Comparative analysis was used to analyse the precision between the existing berth occupancy model and the newly developed berth utilisation model, in comparison to the real time berth productivity rate of the port under study. Data obtained from the newly developed berth utilisation model significantly showed that on average the utilisation percentage deviates by 5 to 20 percentages, compared to the existing berth occupancy model, depending on the berth terminals. The utilisation rate of bulk cargo berths showed less deviation (5 to 10 percentages) while general cargo berths show higher deviation (15 to 20 percentages) and the containerised cargo berths (10 to 20 percentages). This study can be applied in actual shipping industry to reduce ship turn-around time by providing efficient and effective services and high port productivity, with the aim to achieve optimum port performance.

ABSTRAK

Produktiviti merupakan elemen penting yang menyumbang kepada keberkesanan operasi dalam pelabuhan. Kecekapan dalam kadar penggunaan kawasan dermaga menjadi petunjuk utama dalam penentuan masa untuk memberikan khidmat perkapalan kepada kapal-kapal yang menunggu. Sehingga kini, masih belum terdapat panduan untuk menentukan kadar kepenggunaan dermaga yang efisen dan tepat. Oleh itu, kajian ini dijalankan untuk menentukan kadar penggunaan dermaga bagi operasi sesebuah pelabuhan dengan menggunakan kaedah pemodelan matematik. Model tersebut dihasilkan dengan menggunakan lapan elemen yang mempunyai parameter berlainan tetapi saling berkaitan antara satu dan lain. Parameter yang terlibat dalam pembangunan model matematik adalah, panjang kapal, tempoh penginapan kapal, ukuran panjang boleh guna, kebolehpenggunaan masa dalam sehari, bilangan hari dalam sebulan, jumlah kapasiti, keupayaan yang dibekukan dan keupayaan muktamad. Model tersebut telah disahkan dengan menggunakan data 36 bulan berdasarkan data sebenar daripada pihak pelabuhan. Data yang diperolehi daripada model penggunaan dermaga yang baru dibangunkan dengan ketara menunjukkan bahawa peratusan penggunaan itu puratanya menyimpang dari 5 hingga 20 peratus, berbanding model penghunian dermaga yang sedia ada, bergantung kepada jenis terminal dermaga. Kadar penggunaan dermaga kargo pukal menunjukkan sisihan kurang (5 hingga 10 peratus) manakala dermaga kargo am menunjukkan sisihan yang lebih tinggi (15 hingga 20 peratus) dan dermaga kargo kontena (10 hingga 20 peratus). Kajian ini boleh digunakan dalam industri perkapalan untuk mengurangkan kadar masa kapal-kapal menunggu dengan menyediakan perkhidmatan yang berkesan, dengan matlamat untuk mencapai prestasi pelabuhan yang optimum.

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LIST OF ABBREVIATIONS

ATB	Actual Time of Berthing
ATU	Actual Time of Unberthing
BAQ	Berth Application Query
BμR	Berth utilisation rate
Bʆ	Berthable length
Hℓ	Utilisable hours per day
FTZ	Free Trade Zone
Ic	Immobilised capacity
IMO	International Maritime Organisation
Md	Number of days in a month
MPA	Marine and Port Authority of Singapore
n	Number of ships alongside
PSA	Port of Singapore Authority
Pƪ	Port stay
Ro-Ro	Roll on and Roll off cargoes
Sʆ	Length Overall (LOA) of ship
Tc	Total capacity
TEU	Twenty foot Equivalent Unit
UNCTAD	United Nations Conference on Trade And Development
VAT	Vessel Allocated Time

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CHAPTER 1

INTRODUCTION

1.1 Introduction

In general terms, this research deals with the optimisation of the ship berth utilisation. The study arises out of the need for a multi-purpose port to have a significant method to determine the berth utilisation rate to reduce the ship turn-around time in future. The designed mathematical model in this study will determine berth utilisation rate which expected to assist in the analysis of increasing the productivity of a port.

This chapter presents a brief introduction to the background of the problem, statement of the problem, objective, scope, and significant of the study.

1.2 Research Background

Commonly, sea port is referred to an area where services and facilities for ship turn around take places. For centuries of time, these sea ports seem historic, commercial and infrastructural assets that form the backbone of the national and regional economies. Eventually sea ports have evolved over time (Branch, A.E., 1986).

According to the researchers in general, the development process of a sea port can be classified into three phases (Marlow, P.B. and Paixao, A.C., 2003). The first phase is on the development of first generation ports. This kind of ports existed before and until 1960's, where they comprised of basic and essential cargo transaction between land and sea transport. The second generation ports existed during the time period of 1960's to 1980's. They were much seems to be developed transport, industrial and commercial service hubs. Their integrated cargo based activities and good zonal relationship phenomenally reflects sophisticated port policies and development strategies of ports of their era (Barker, C.C.R. and Oram, R.B., 1971).

The third generation ports are those arose from 1980's onwards. They are much seen as a product of global containerization, inter-modalism, and booming trade requirements. They also became hubs of international production and distribution. At this stage, they combine traditional, specialized and integrated activities (Sanchez, R. J. *et al*., 2003). With well-planned infrastructure and information processing facilities, they became user friendly ports with much more value added service.

The multipurpose port terminal is not an innovation in port terminology and dates back for several years. It is however only in recent years that the concept has been given practical expression in number of developing ports. The rationale of multipurpose terminals' development is well received by the community. For many years, far reaching changes affecting the shape of the industry as whole and specific sectors have been taking place at an ever-increasing pace in marine transport technology (Alderton, P.M., 2000)

The share of traditional cargo vessels in marine traffic has gradually declined and new types of vessel, some specialized and others multipurpose have come to the fore. Cargo is also shipped in new forms or variations of traditional forms. These developments result in major changes in the demand for non-specialized port services and this demand cannot be satisfied technically or economically by the services offered by old style general cargo or specialized terminals. In this context, the multipurpose terminal comes into its own (Oram, R.B., and Baker, C.C.R., 1971).

Since the need of the study arises from a multipurpose port, some considerations were given in this study on the features and specifications of a multipurpose port. As highlighted earlier, the use of the word "multipurpose" is not at odds with the fact that the terminals are specialised in flexibility. The terminal's response is to be combine and flexible because the flexibility is provided within a specific spectrum of trades having identical generic characteristics (Chung P.T. *et al*., 2004). This implies a basic of two requirements. First, the terminals must be planned to accommodate heterogeneous cargoes, from general cargo in small consignments to containers, which does not mean that the terminals should accommodate every type of cargo. The second requirement suggests that, the specific subgroups of cargo to be combined must not be so large as to call for a special terminal or demand special handling within the multipurpose terminal in which they are grouped (Jagathy Raj *et al*., 2001). The philosophy implicit in the definition of a multipurpose terminal is the operations must be such as to possess a degree of rational coherence in industrial terms although not at the normal level of a specialised terminal.

As the other types of sea port, a multipurpose port also shares some important performance indicators as a measurement scale for the evaluation of various aspects of the port's operation. To fulfill their purpose, such indicators should be easy to calculate and simple to understand. They should provide insight to port management into the operation of key areas. They can be used, first, to compare performance with target and secondly, to observe the trend in performance levels (Gokkup, U., 1995). The indicators can also be used as input for negotiations on port congestions surcharges, port development, port tariff considerations and investment decisions as described by Coleman, H.W. *et al*. (1989). As such, there are two types of indicators, when it comes to the discussion of performance indicators. They are financial and operational indicators. Perhaps of more direct concern to the port management than financial indicators are operational ones.

Throughout the background study, it could be observed that there are eleven elements in the operational indicators which contribute to the analysis of performance (Talley, W.K., 1994). Those elements includes :

i. The arrival rate,
ii. Waiting time,
iii. Service time,
iv. Turn-around time,
v. Tonnage per ship,
vi. Fraction of time berthed ships worked,
vii. Number of gangs employed per ship per shift,
viii. Tons per ship hour in port,
ix. Tons per ship hour at berth,
x. Tons per gang hour and
xi. Fraction of time gangs idle.

The decision regarding which indicators to use depends on the port authorities' situational requirements. These indicators are the one which might be the important parameters in the particular performance analysis whenever it comes to the topic of productivity improvement. In this study of mathematical model development, eight parameters were referred which come out from the physical capacity and the operational efficiencies. Those parameters are:

i. Ship length
ii. Port stay
iii. Berthable length
iv. Utilisable hours per day
v. Number of days in a month
vi. Total capacity
vii. Immobilised capacity
viii. Final capacity

Capacity of a port shall outline the issues related to productivity improvements. Given that the rate of ship arrivals in the port changes over time, there is some figure of the port capacity (number of berths) which maximizes the total net benefits, that is, net benefits to both ship owners and port authority when taken as a whole. Port authority will normally insist on optimum utilisation of its capacity. The higher utilisation would minimise its costs per ship (Estache, A. *et al*., 2002).

To the date, utilisation of a berth is commonly measured by berth occupancy rate. However, degree of utilisation indicated by common formula of berth occupancy rate is still questionable, especially when high accuracy is needed for optimisation of berth utilisation purposes. This is because parameters used in berth occupancy rate formula are too generic. In expectation of high accuracy analysis, we may need a modal or formula which also gives its concern to additional factors that contributes to the evaluation process.

In a multipurpose port, each of the berth's capacity will be significantly different compare to the difference in the same context for a container or conventional port (Wen C.H *et al*., 2007). As highlighted earlier, berth of a multipurpose port will be serving almost all types of cargo transactions. So the basic structure of berths itself will vary in multipurpose ports. When berths shares common features as in a container or bulk port, a common formula for evaluating the utilisation rate of a berth will be logical. But when it comes to a multipurpose port which stays further from this fact, additional features are necessary in a formula determining the utilisation rate.

A model or formula for determining much a precise berth utilisation rate shall have significant and considerable variables in it. These variables may ensure the accuracy of the data, especially for a multipurpose port which have unique specification of berth. When factors contributes to the less accuracy in getting berth utilisation rate been identified, improvement measures will be taken by port authority. These corrective measures will assist in reducing the turnaround time of vessels in port.

Turnaround time is an important factor in port industry which portrays the capability and ability of a port operator in providing services (Jovanovic, S. *et al*., 2003). Reduced turnaround time of a vessel will enhance the port's ability in providing efficient and effective services and make ways for high port productivity, with the aim to achieve optimum port performance (Golias, M.M. *et al*., 2006). The benefits of designed model include giving the port operators a valuable opportunity to determine the rightful corrective measure to achieve optimum utilisation rate to obtain desired turnaround time.

1.3 Problem Statement

To the date, there is less clear guidance for a multipurpose port on getting a precise data in the terms of berth utilisation rate (Hemant G., 2015). Previous researchers narrow down on getting the data based on generic theoretical considerations and less successful to incorporate the actual port operation scenarios in the analysis. Most of the researchers were carried out analytically using queuing and berth capacity models that lack in comprehensiveness and details. There is a need to provide much a relevant model as a guideline, to obtain a precise berth utilisation rate, that both realistic and one which meet the actual port operations environment.

1.4 Objective of Study

This study is intended to,

i. Design a mathematical model to obtain a precise berth utilisation rate for productivity enhancement of a port

ii. Validate the designed model using comparative case study

1.5 Scope of Study

Since this study investigates issues concerning berth utilisation of a multipurpose port with assumptions of optimal conditions, where certain limitations were drawn to the following scopes:

i. The study is to focus on multipurpose port at the straights of Singapore.

ii. Queuing theory and berth capacity model will be referred in order to complement the comparative studies of the newly developed model.

iii. Mathematical model development based on eight selected parameters.

iv. A case study on a major and busiest multipurpose port for model validation, using data collected from January 2012 to December 2014.

1.6 Significance of Study

The mathematical model formulated in this study prominently helps to increase the port productivity. The findings of the research based on the model analysis are as follow:

i. It is capable in deriving a precise berth utilisation rate for any type of cargo commodity berth at a multipurpose port

ii. The sensitivity of the parameters can be used as guidance to increase to the productivity of the port

iii. Assist the port authority to make some operational changes from the precise productivity analysis

iv. Provide a solution procedure that can be a basis for sea port operators and researchers in addressing the similar problem

Once the reliability of the designed model is proven, it would be extended to regional multipurpose port operators for implementation and commercialization purposes.

1.7 Organisation of Thesis

The remainder of the thesis is organized as follows. Each chapter has been portioned into few parts while each part can have its own sections. Sectioning and partitioning has been carefully done so that the flow of the thesis as a whole is maintained.

Chapter 2 review the previous research works on overall operational works in the berth to identify the important issues in the calculation of berth utilisation rate. This chapter is divided into several main parts. The first part discusses about the uniqueness of cargo operations in a multipurpose port. The subsequent part presents the berth capacity model in general. The third part discusses the underlying principles of queuing model. Following part deals with the heuristic approach in the context of mathematical simulation models. Last part of this chapter presents a background of the port of understudy, different types of cargo handling operations and the cargo movement through various part of the port. The problem faced due to berth capacity is then presented. The management goals and the specific objectives of the port are defined.

Chapter 3 discusses about research methodology taken in this study. The flow of the research and methods used to achieve the objective of the study is presented.

Chapter 4 addresses the development of mathematical tool based on the chosen parameters. Assumptions and limitations of the developed model were discussed prior to the mathematical model development.

Chapter 5 focuses on validation of the designed model. The accuracy of the drawn data from the model was displayed through comparative case study results. Discussions were made based on the drawn results.

Chapter 6 presents the summary of the findings and the future work that could be continued from the current work with different scope for both operational and economical growth.

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