2007 PhD Thesis DEVELOPMENT AND APPLICATION OF LOOKING FORWARD SCHEDULING ALGORITHM IN SHIPBUILDING MANAGEMENT RANJAN VARGHESE

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Graduate School of Chosun University

Department of Naval Architecture and
Ocean Engineering

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Advisor: Professor Duck -Young Yoon

Thesis submitted for the degree of Doctor of Philosophy

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CONTENTS

등잔 밑이 어둡다.
It's darkest underneath the lamp stand.
Meaning: What you seek could be closer than you think.

- A famous Korean Proverb

ABSTRACT

Development and Application of Looking Forward Scheduling Algorithm in Shipbuilding Management

Ranjan Varghese
Advisor: Professor Duck Young Yoon
Department of Naval Arch.& Ocean Engg.
Graduate School of Chosun University

The purpose of the dissertation was two fold:

1. To implement and test the method of looking forward scheduling algorithm (LFSA, hereafter) in a practical context; and as a result of testing and implementation.
2. Extend the algorithm into spatial arrangement problem and making relevant comparisons with the existing methodologies such as genetic algorithms.

The methodology for the study was our own indigenously developed LFSA. This was used to assist in the analysis and providing a solution to the bottleneck-forming situation between pre-erection area (PEA) and dock for the application at the Daewoo Shipbuilding and Marine Engineering Company. In the course of the design and testing with the real time block erection network and the related data several questions came up; some had a direct bearing on the applicability of LFSA and others did not. In order or to defend our claim and competence of the algorithm a computer program in the VC++ platform is developed to perform extensive tests. The issues were theoretical in nature and we have addressed them in this dissertation. They are:

i) Expanding the Scope of Usage of LFSA

ii) Analyzing the sensitivity and effects of LFSA on the developed schedules under various test conditions

A brief discussion of each topic is as follows.

Looking Forward Scheduling Algorithm

In the shipbuilding industry various problems of erection are merged due to formation of bottlenecks in the block erection flow pattern. The problem gets accumulated in real-time erection at the PE area. When such a problem is encountered, a support data of the entire erection sequence should be available. Here planning is done by reasoning about the future events in order to verify the existence of a reasonable series of openings to accomplish a goal. This technique helps in achieving benefits like handling search complications, in resolving goal conflicts and anticipation of bottleneck formation well in advance so as to take necessary countermeasures and boosts the decision support system. The data is being evaluated and an anticipatory function is quite relevant in day-to-day planning operation. The system updates database with rearrangement of off-critical blocks in the erection sequence diagram. As a result of such a system, planners can foresee months ahead and can effectively make decisions regarding the control of loads on the man, machine and work flow path. Such a forecasting efficiency helps us in eliminating conventionally used backtracking related techniques. A computer program to update the database of block arrangement pattern based on this heuristic formulation is performed and its competence is argued.

Spatial Scheduling

A genetic algorithm (GA) is a search algorithm by [5] that attempts to emulate the evolutionary mechanism of natural biological systems where the best gene is selected for the next generation (i.e. the survival of the fittest). In the optimization problems, GA approach has been successful for generating global solutions for which traditional search techniques have not been effective and to build robust search strategy, GAs employs 'evolutionary mechanism' as described using (Fig. A).
There are many severe constraint conditions in the shipyard. The primary attention in this paper is focused is into the problem domain, which is limited to the pre-erection area. A pre- erection area is defined as the area which is adjacent to the dockyard and over which the giant goliath crane runs and this area is used to place the grand blocks those are ready for the erection of the ship in the

dock. The addressed major constraints become a monstrous problem for the schedulers in the shipyard namely, space based and time based.

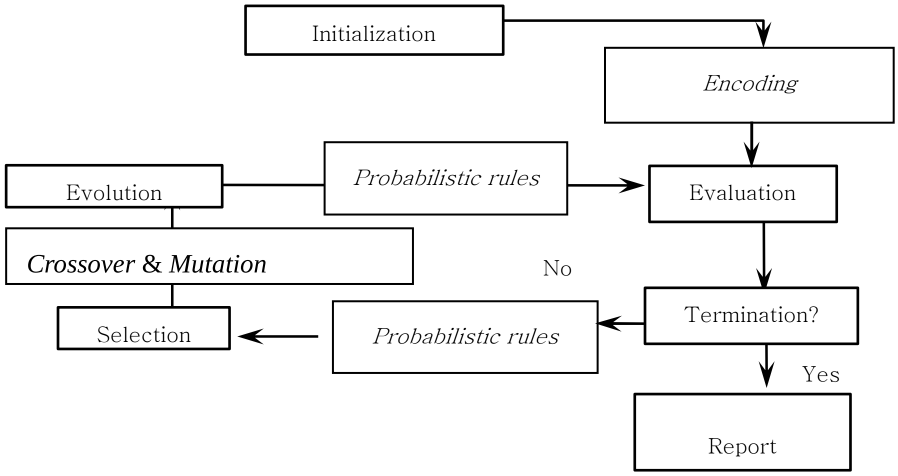

Fig. A. The general structure of genetic algorithms

A team of many schedulers using their personal expertise using a computer graphic program without any intelligent or decisional support handles the space situation. Here various pre-defined geometrical shapes are being matched manually in the graphical interface of the program. This takes a lot of manipulation and manpower as the individual cases had to be studied. The time factor is dealt with the conventional erection sequence diagram where there exist a lot of uncertainties since in this portion only the blocks on the critical path have a fixed date of erection otherwise the remaining blocks remain uncertain. This again is handled by a team of planners to resolve using their expertise and still poses a very tedious effort on the part of the schedulers.

CHAPTER 1

INTRODUCTION

1.1 Problem

Ship construction represents one of the more challenging planning problems in industry today. Examining alternative build strategies costs time and money. Design build teams can only afford to try a small number of strategies using existing software tools. The result is higher than necessary construction costs.

1.2 Business Case

Ship Production Planning Community is developing a new methodology for solving ship construction problems, based on a new, highly efficient algorithm invented by Industrial Planning Technology researchers. The technology starts with a 3D product model from a CAD system and automatically determines the lowest cost subdivision and assembly strategy, where to place seams and joints, and how to assemble the ship. The benefits are numerous:

1) A reduced construction cost through optimum use of automated facilities,
2) Rapid plan/redesign for new or upgraded manufacturing facilities,
3) Accurate cost and time estimates,
4) Reduced time and cost of planning,
5) Reduced time to delivery.
6) Forecast the peak load situation and bottleneck causing circumstances.

A design for a commercial software product using this technology has been developed and successfully prototyped.

1.3 Implementation

When commercial interests are received in this thesis, this technique is expected to be full-fledged commercial ship production software, packaged as a plug-in software engine, which will interface to existing CAD/ CAM, scheduling and ERP systems.

1.4 World Shipbuilding Faces Over-Capacity

A meeting of the OECD 2005's Council Working Party on Shipbuilding has found that the world shipbuilding industry is in crisis, with prices plummeting and future demand likely to remain weak for some years. Over-capacity in the shipbuilding industry is expected to grow reflecting increased productivity, new facilities and the conversion of naval shipyards to commercial production. The growing participation in shipbuilding by emerging nations such as China is adding to the market imbalance. The meeting participants agreed on the need for urgent action to improve market transparency through improved information and analysis of supply and demand. They also agreed on the need to enhance participation of shipbuilding countries that are not currently members of the Working Party, including OECD members such as Australia and Turkey and non- OECD countries such as China, Croatia, India, Brazil and Chinese Taipei.

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i) Expanding the Scope of Usage of LFSA
ii) Analyzing the sensitivity and effects of LFSA on the developed schedules under various test conditions

A brief discussion of each topic is as follows.

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In the shipbuilding industry various problems of erection are merged due to formation of bottlenecks in the block erection flow pattern. The problem gets accumulated in real-time erection at the PE area. When such a problem is encountered, a support data of the entire erection sequence should be available. Here planning is done by reasoning about the future events in order to verify the existence of a reasonable series of openings to accomplish a goal. This technique helps in achieving benefits like handling search complications, in resolving goal conflicts and anticipation of bottleneck formation well in advance so as to take necessary countermeasures and boosts the decision support system. The data is being evaluated and an anticipatory function is quite relevant in day-to-day planning operation. The system updates database with rearrangement of off-critical blocks in the erection sequence diagram. As a result of such a system, planners can foresee months ahead and can effectively make decisions regarding the control of loads on the man, machine and work flow path. Such a forecasting efficiency helps us in eliminating conventionally used backtracking related techniques. A computer program to update the database of block arrangement pattern based on this heuristic formulation is performed and its competence is argued.

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There are many severe constraint conditions in the shipyard. The primary attention in this paper is focused is into the problem domain which is limited to the pre-erection area. A pre- erection area is defined as the area which is adjacent to the dockyard and over which the giant goliath crane runs and this area is used to place the grand blocks those are ready for the erection of the ship in the dock. The addressed major constraints become a monstrous problem for the schedulers in the shipyard namely, space based and time based.

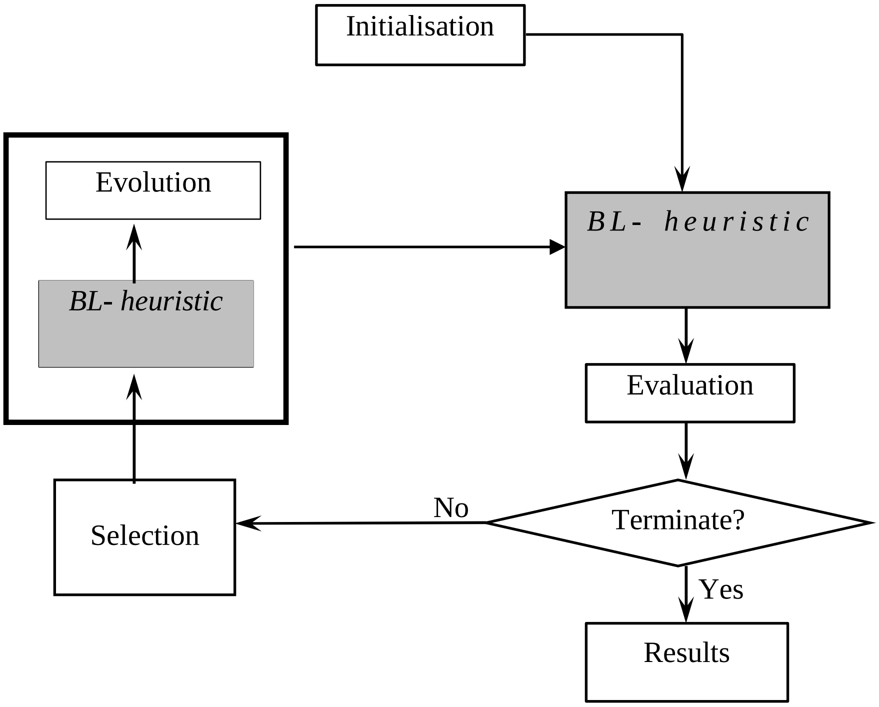


Fig. 1. The general structure of genetic algorithms

The space situation is handled by a team of many schedulers using their personal expertise using a computer graphic program without any intelligent or decisional support. Here various pre-defined geometrical shapes are being matched manually in the graphical interface of the program. This takes a lot of manipulation and manpower as the individual cases had to be studied. The time factor is dealt with the conventional erection sequence diagram where there exist a lot of uncertainties since in this portion only the blocks on the critical path have a fixed date of erection otherwise the remaining blocks remain uncertain. This again is handled by a team of planners to resolve using their expertise and still poses a very tedious effort on the part of the schedulers.

1.7 Overview of Shipbuilding Process

The shipbuilding process starting from order to delivery can be divided into design stage and manufacturing stage. Design stage can be further divided into contract design performed for the negotiation with ship owner, basic design to meet the requirements of ship owner, and detailed design performed in functional aspect. On the other hand, manufacturing process includes pre-processing, fabrication, assembly, precedence outfitting, painting, precedence block erection, block erection, outfitting, etc, and these processes occur in very complex pattern over a long period of time. Figure 1-2 shows the flow of each processes composing shipbuilding process.

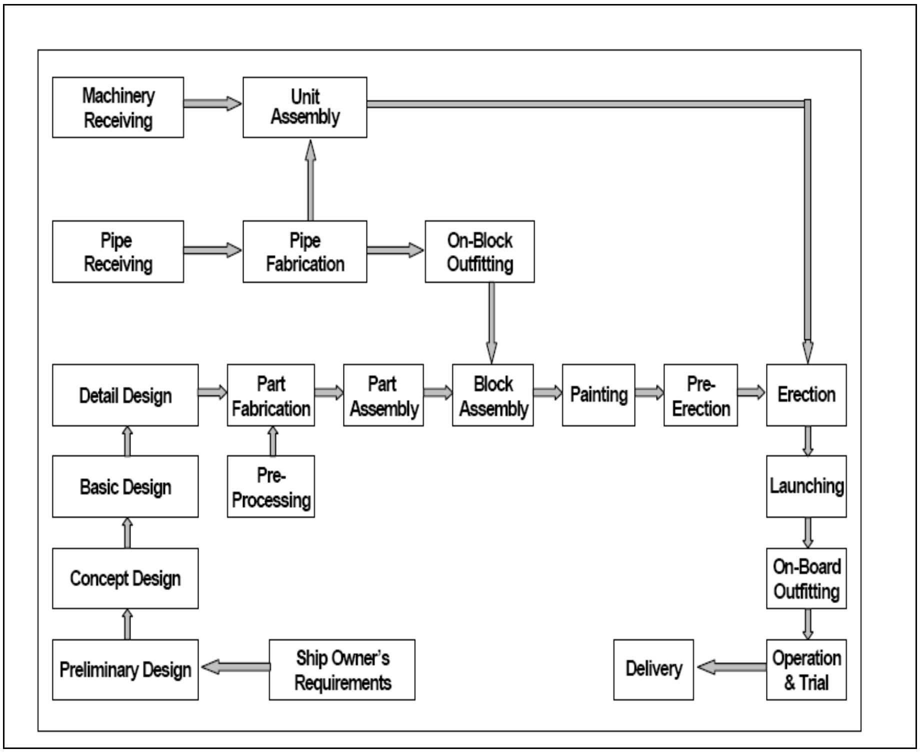


Fig. 2 Flow of Shipbuilding Process

Because of above reasons, building prototype for verification of product validity and quality assurance is practically impossible in the sense of manufacturing cost and time. Therefore, in order to increase efficiency in shipbuilding, extraction of detailed design and manufacturing information is required, and such information needs to be exchanged and integrated with simulation-based manufacturing technology.

These shipbuilding processes are different from other typical manufacturing processes in the following characteristics:

· Ship type and form is very diverse and it is difficult to standardize since the design process is done according to the user's requests.

· Material procurement and manufacturing begins while the design stage is not complete, so engineering changes and materials replacement are expected in manufacturing stage.
· Shipbuilding is labor intensive industry that is very difficult to mechanize and automate, so a lot of qualitative information are processed.
· While materials are big and heavy, required accuracy is high and structure is complex, so it is difficult to standardize manufacturing process.
· Ships with different specification are built at the same time, and a lot of information is required for management of each ships.

1.8 Motivation and Objectives

Today, most shipyards apply shipbuilding block requirements/building resources planning systems for medium-term production planning. These systems focus on the block flow aspect of production, and assume that the ships can be building with fixed lead times. Hence, they completely disregard the actual load on production capacities. No wonder that in an age characterized by market fluctuations and Chinese business pull experienced in the Korea shipyards there is a serious research thrust is to be generated that the plans for smoother production flow by intelligent automation and increasing the capacities of already optimally running yards, in order to retain in its global market share in the shipbuilding business. Recently, several approaches have been suggested to couple the capacity and block flow oriented aspects of production planning. A common characteristic of these models is that they apply a high-level description of the production activities and their complex interdependencies, which has to be encoded manually, by large group of human experts. The high-level formalism does not always reflect the context of the underlying processes, and even these methods cannot guarantee that the production plans can be unfolded to executable detailed schedules. Furthermore, the results depend largely on the proficiency and the mindfulness of the human modeler.

Our objective was to find a novel, aggregate formulation of the production planning problem which ensures that the generated plans can be refined into feasible detailed schedules. The representation of the planning problem should be generated automatically, from data readily available in de facto standard production databases. The current industrial practice in production scheduling is also dominated by heuristic approaches, such as priority rule-based schedulers. In spite of this, well-known formal methods are available to describe what makes a schedule feasible, and also to optimize the schedule according to various criteria. The most promising branch of these methods, constraint based scheduling emerged in the early eighties [BLN01]. It offers a rich and straightforward representation to model even the finest details of the scheduling problem. However, the solution of the vast instances of the resulting NP complete combinatorial optimization problems challenges currently known algorithms [Wal96]. For short-term detailed scheduling, we decided for the application of the LFSA. The objective of our research was to improve the efficiency of the currently known solution techniques, by the exploitation of typical block load of the Pre-Erection Area. For this purpose, LFSA was applied for the consistency in preserving the interdependencies of the shipbuilding blocks. During this research, concentration was laid emphasis on solving real problems that arise in the industry. This research hence developed a pilot integrated production planner and scheduler software, and used this system to test our algorithms on real-life planning and scheduling problems, originating from DSME.

1.9 Dissertation Organization

The Thesis is divided into Seven Chapters:

Chapter 1: Introduction

The introduction part of this Thesis consists of three chapters. Chapter 1 (this chapter) gives an introduction to the Thesis. It includes an introduction to the subject of interest such as ship production activities usually dealt in the shipyard, a description of the goals for the Thesis and this description of the Thesis structure and the approach made. It also gives a description of the background for the Thesis. In this chapter a description of the shipyard participating in the project is included. The research goals defined by bottleneck cause and the research performed to quench the same are described and discussed. This discussion serves as a basis for later analyses, where elaborations of the research aspects with regard to the case projects are done. To describe the research context in which this project operates the motivations, objectives and the purpose of the whole research program is included. This chapter gives an overview of the most important references to the looking-forward algorithm development with particular emphasis on the engineering background. It is my belief that the shipyard production knowledge and certain mathematical concepts of optimization theory is necessary to understand in some extend before real progress can be made by the readers.

Chapter 2: Background and Related Work

To substantiate the research in this direction by various industrial engineers, shipyard production engineers and scientists, intense search has been done to understand and the find the suitable room for modification and argue the competence of this contribution towards the scientific ship production community. This kind of justification helps the users of the techniques presented here to brainstorm and analyze it by comparing the previous researches.

The vision is described in a paper by (Jacob et al) but this is mostly a description of the wishes for the future together with a conceptual model for the system". It is my belief that this description needs to be enhanced in various ways. At first, the vision needs to be described more detailed from the conceptual viewpoint. Second, the vision can not stand alone but needs to be understood in context of the surrounding environment. In this case this means an understanding of the organization in which the changes are to be applied. The organization should be understood as a broad term including the division of labor, the IT-tools at use, the process of design and construction, the planning process etc. This part of the Thesis describes basis from which this work took the ground.

Chapter 3: Design Looking Forward Scheduling Algorithm

The fuelling of the Looking Forward Scheduling Algorithm (LFSA) vision can not be done without an understanding of the implications of it. These implications range a large number of issues: general considerations regarding the environment in which the LFSA approach is operating, what is the development strategy to use in the LFSA context, what the overall implications of the LFSA vision are and how these implications of the vision should be manifested with regard to the type of systems needed. This broad number of implications in the subject is discussed in the following chapters.

Chapter 4: Experimental Results to Prepare Fixed Erection Schedule in the Shipyard

Two case projects are dealt here. The first case project was the development of a prototype technique for the preparation of Erection Schedule in the Shipyard. The prototype is working at the time of writing and is subject to evaluation by the partners (DSME and other Shipyards). The second case project is also a prototype experiment and the subject of this is a tool to help the planning of the assembly sequence of grand blocks in the dry dock. More specifically the designed algorithm in Chapter 3 is extended to the spatial arrangement problem in the Pre-Erection Area by analyzing the load and the forecasted results.

Chapter 5: Interpretation of the results

When various shipyard block data is being tested, the program delivers a variety of results. It has to be interpreted and used in a well usable solution that in turn helps scheduler and planners in the shipyard to take appropriate decisions in dealing with the problem. This chapter therefore discusses and evaluates the various results obtained as a result of chapter 4.

Chapter 6: Application into spatial scheduling for block arrangement problem in the PE- Area.

This is the second part of the research which tests the LFSA technique into the spatial arrangement problems occurring due to the problem posed by limited spatial constraints in the Pre-Erection Area of the shipyard.

Chapter 7: Conclusions and Future Work

This part summarizes the conclusions and lessons learned during the project period and the thesis writing. As the LFSA project still is ongoing and number of suggestions regarding future work is to be sought and suggested.

Appendix

People not trained in shipbuilding, mathematical operation of optimization, genetic algorithm and decision theories should be able to understand this Thesis; therefore a terminology list is included as an appendix for reference. Also included is a list of the used abbreviations.

CHAPTER 2

BACKGROUND AND RELATED WORK

2.1 Introduction

The theoretical development of this dissertation spans a number of disciplines and it extends across area of Computer based simulations, algorithm development, Optimization theory, various shipbuilding management operations, packing problems and industrial scheduling concepts.

2.2 Erection Network Problem

2.2.1 Ship Product Modeling

R. I. Whitfield, A. H. B. Duffy, J. Meehan, and Z. Wu
Journal of Ship Production, Vol. 19, No. 4, November 2003, pp. 230–245)

This paper is a fundamental review of ship product modeling techniques with a focus on determining the state of the art, to identify any shortcomings and propose future directions. The review addresses ship product data representations, product modeling techniques and integration issues, and life phase issues. The most significant development has been the construction of the ship Standard for the Exchange of Product Data (STEP) application protocols. However, difficulty has been observed with respect to the general uptake of the standards, in particular with the application to legacy systems, often resulting in embellishments to the standards and limiting the ability to further exchange the product data. The EXPRESS modeling language is increasingly being superseded by the extensible mark-up language (XML) as a method to map the STEP data, due to its wider support throughout the information technology industry and its more obvious structure and hierarchy. The associated XML files are, however, larger than those produced using the EXPRESS language and make further demands on the already considerable storage required for the ship product model. Seamless integration between legacy applications appears to be difficult to achieve using the current technologies, which often rely on manual interaction for the translation of files. The paper concludes with a discussion of future directions that aim to either solve or alleviate these issues.

2.2.2 Agent-Based Modeling and Control of Marine Supply Chains

(J. A. Sauter, H. V. D. Parunak, and S. Brueckner)
Journal of Ship Production, Vol. 17, No. 4, November 2001, pp. 216–225

Much of the cost and timing of ship production is a function of the efficiency and performance of the supply chain. Supply chains are networks of corporations involving multiple human agents in connected but disparate processes. Computer agent based systems provide a natural mechanism to reflect real world human agent-based systems. Some ways that computer agent-based systems can assist and supplant human-based interaction and decision making in a supply chain without the need for unwieldy centralized or top-down management scheme were investigated. The SNAP agent-based supply chain modeling and analysis tool has been used to identify and correct pathological dynamics in supply chains. These nonintuitive behaviors result from standard practices common in the shipbuilding industry and are observed in simple and complex supply networks. The Agent Network for Task Scheduling (ANTS) architecture uses large populations of simple agents to schedule operations both within a factory and across a supply chain. We describe a new mechanism called least commitment scheduling that defers decisions on process sequences until the last possible moment. A Density-based Emergent Scheduling Kernel (DESK) uses probabilistic committed capacity profiles of resources over time to provide a novel costing mechanism by which agents can choose efficient yet flexible schedules.

2.2.3 Modeling and Solving the Spatial Block Scheduling Problem in Shipbuilding Company

(*Computers ind. Engng* Vol. 30, No. 3, pp. 357-364, 1996)

Much of the past success of the Korean shipbuilding industry in the international market can be attributed to cheap labor. However, as the economy grows, the labor cost has been increasing steadily, which can erode the competitiveness of the shipbuilding industry. The shipbuilding companies in Korea have traditionally focused on attaining economies of scale to maintain competitiveness and have paid little attention to the productivity of their yards. However, the changing environment is forcing them to achieve high productivity so that they can remain competitive. Efficient planning and control is vital in achieving high productivity. However, planning and control of the shipyard is a very complicated task because of the vast scope of the problem and the complexities of the problems involved in the decision-making. The manual planning and control system, which has been used, has had a limited effect in the shipyard because of the unrealistic and untimely work orders it gives. It results in work delays, accumulation of work-in-processes, etc. The manual system also cannot respond quickly to the changing conditions since it takes a long time to find a schedule manually. As a means to handle these problems, many shipbuilding companies are developing their own computerized planning and control systems [1]. In this article, we present an algorithm for the spatial block-scheduling problem, which arises in a shipyard in Korea.

2.2.4 Development of Repeatable Interim Products Utilizing the Common Generic Block Concept

(Journal of Ship Production, Vol. 18, No. 4, November 2002, pp. 195–202)

Productive shipbuilders provide customized or made-to-order products to customers. To date, most of these “world class” companies have succeeded by developing a series of repeatable type blocks, which may be chosen and combined to form products that respond to customer needs. Type blocks have been developed as a result of long experience in customizing ships to specific needs, while maintaining a repeatable build strategy. These are, therefore, empirically based. This paper reports on the early stages of work to develop a theory and methodology for developing type blocks for shipyards that do not currently have them in place and/or lack the historical base from which to extract common blocks. The concept, called Common Generic Block, builds these using the principles of mass customization, a block complexity matrix, grouping using clustering techniques based on production attributes, and applying a threshold value as a stopping criterion for the clustering. This paper describes the general framework of the approach and provides details on the block complexity matrix, used for determining the relative similarity of products to be included in a product family.

2.2.5 Design and Implementation of a Multi-Use Manipulator System to Improve Shipyard Manufacturing Processes

(Don Sofge, Lynn Vogel, Yuchi Huang, and John Wentz)
Journal of Ship Production, Vol. 17, No. 3, August 2001, pp. 130–134

Under a NAVSEA initiative to improve manufacturing technologies in Navy shipyards, we are developing a modular robotic manipulator system that may be adapted to a variety of different work environments and tasks. For this effort it was necessary to examine a variety of different deployment strategies to get the robotic manipulator system into the required work areas. Also, the environmental conditions present in a typical Navy shipyard blast or paint facility add additional challenges to the design process, since a factor crucial to the success of the robotic manipulator system is the reliability of the system over a long operating life. The keys to successful deployment of the Multi-Use Manufacturing Manipulator System (MUMMS) into shipyards are demonstrating that introduction of this new technology actually improves shipyard productivity and lowers costs. Other advantages are improved safety due to less worker exposure to hazardous environmental conditions and physically demanding work situations. The justification for deployment of the system must be made on a case-by-case basis for each shipyard, with realistic examination of current production costs and realistic expectations about the return on investment with this new technology. Given this crucial analysis, justification in capital expenditures for the new technology can be easily made.

2.2.6 Optimization of Block Erection Using a Genetic Algorithm

(Yasuhisa Okumoto)
Kinki University, Faculty of Engineering, 1 Takayaumenobe, Higashihiroshima, 739-2116 Japan
Journal of Ship Production, Vol. 18, No. 2, May 2002, pp. 116–119

Block erection is a very important and demanding skill in shipbuilding quality control as well as in productivity improvement. Though this work at the present time depends on skilled workers in the yards, these workers eventually become old and retire, and then the training of their successors, or other countermeasures, will be required. Recently, CAD and CIM systems have been applied widely, and also efficient measurement technology has been developed in the shipyard; thus it has become possible to apply positional control at the erection stage by computer simulation. This paper presents a computer simulation method to place a block, which has dimensional errors, in a suitable position as designed using a genetic algorithm (GA). A pilot program using a personal computer has been developed and applied to a typical hexahedron block. The simulation results showed good agreement in achieving the optimum position.

2.2.7 Resource-Constrained Shop-Level Scheduling in a Shipyard

V. Rajendra Prasad,* Mike Graul,* Perakath Benjamin,* Patrick D. Cahill, † and Richard Mayer*
Journal of Ship Production, Vol. 19, No. 2, May 2003, pp. 65–75

Ship production planning and scheduling at higher levels do not explicitly consider scheduling details at the level of individual workshops. However, the schedule of major events in ship production is collectively influenced by the actual shop-level, short-interval production schedules, which depend on resource and material availability and also on the due dates and priorities of the workloads. This necessitates development of robust, resource-constrained, shop-level scheduling systems that can support higher-level schedules in ship production. WorkShip (Knowledge Based Systems, Inc., College Station, TX) is a software tool for scheduling workload over short, regular intervals in workshops of a shipyard. A powerful scheduling engine that is based on a generic model of resource-constrained job-shop scheduling and an efficient scheduling technique drives it. Similar scheduling systems are being developed in other shops so that all systems can be used in tandem to support higher-level scheduling and help achieve optimal productivity for the shipyard.

2.3 Spatial Arrangement Problem

In the steel industry problems frequently occur when the need to stamp polygonal figures from a rectangular board arises. The aim is to maximize the use of the contiguous remainder of the board. Similar problems exist in the textile industry, when clothes are cut out of a rectangular piece of material. In order to solve these problems let us consider the following simpler approach. Given a finite number of rectangles r_i, i = 1,..., n, and a rectangular board, an *orthogonal packing pattern* requires by definition a disjunctive placement of the rectangles on the board in such a way that the edges of *r i* are parallel to the x- and y-axes, respectively. The computation of the orthogonal packing pattern with minimal height is called *orthogonal packing problem* (OPP). Baker, Coffman and Rivest propose an heuristic for the orthogonal packing problem; in addition they present an upper bound for the height of the packing pattern [2]. A recent survey on packing problems and their respective heuristics is given in [3]. The extension from rectangles to polygons can be realized in several ways. The first method places the polygons directly on the board and then the algorithm optimizes locally by means of shifts and rotations [4]. A second approach places two or three polygons in a cluster. The clusters are then placed on the board [1]. In this article we use another approach, namely an evolutionary algorithm. There are three main classes in this approach, each of which is independently developed. The first class is called *evolutionary programming* (EP). L.J. Fogel, Owens, and Walsh were the first to develop the EP-algorithms [5]. D.B. Fogel has recently improved this approach [6]. Rechenberg and Schwefel developed the second class. They called their approach *evolutionary strategies* (ES) [7-11]. Finally, Holland developed the so-called *genetic algorithm* (GA) [12]. The genetic algorithm has been perfected by De Jong [13] and Goldberg [9]. The other references used for this work are from Ref 14 to Ref 31.The paper is organized as follows. It begins by explaining the problem and its complexity. In the next section the data structure and its transformation into a packing pattern are described. Section 4 provides the genetic algorithm in combination with a deterministic algorithm, and numerical examples are presented. In Section 5 two approaches for the extension to polygons are proposed. The straightforward extension applies the genetic algorithm directly to the polygons. This method results, however, in a rather long computing time. An alternative to this method is the application of the genetic algorithm to rectangles in which the polygons are embedded; subsequently, the use of a deterministic shrinking step moves the polygons closer to each other.

2.3.1 A Spatial Scheduling System and its Application to Shipbuilding: DAS-CURVE

Kyoung Jun Lee and Jae Kyu Lee
Expert Systems with Applications, Vol. 10, No. 3/4, pp. 311 -324, 1996

The automation of spatial scheduling--which has been a major bottleneck technology in the scheduling of shipbuilding-- holds the key to success of the scheduling expert system project for shipbuilding and the like. The system DAS-CURVE has been installed at the shipyard of Daewoo Heavy Industries Ltd for several years. It has been enthusiastically accepted by the field schedulers, and continues to operate successfully. High-level managers utilize this system to simulate load and overtime requirements for the planning horizon in advance. The benefits of DAS-CURVE are not only in scheduling *per se*, but also in the identification of bottlenecks in advance so that they can be rectified. Field workers utilize the system to visualize future work and prepare in advance. Figure 23 is the typical output screen of DAS-CURVE that displays the feasible dynamic layout of a work plate for workers. The limitation of current research is the same as the assumption we made at the beginning of this paper: two-dimensional convex polygonal objects and finite orientations. Although the assumptions are quite acceptable for the shipbuilding domain, they may have to be relaxed in other domains. For such generalizations, there are many issues to be investigated. The spatial scheduling system seems applicable for many domains, such as shipbuilding, airplane assembly shops, construction, warehouses, retail stores and delivery container scheduling.

2.3.2 A spatial scheduling application at the block paint shop in shipbuilding: the HYPOS project;

Changkyu Park, Kuy-Hoon Chung, Ju-Chull Park, Kyu-Kab Cho, Tae-Hyun Baek and Eun-Il Son

This contribution has illustrated a spatial scheduling application at the block paint shop in world’s biggest shipbuilding company namely Hyundai Heavy Industries, Ulsan, South Korea. The block paint shop studied in this paper faced with difficulties in keeping the block due date, improving the workspace utilization, and balancing the workload among working teams. To resolve these difficulties, the HYPOS project developed the spatial scheduling algorithm composed of strategy simulation, block scheduling, block arrangement, and block assignment. The operations scheduling system developed by the HYPOS project showed a good performance in two experiments using real shipyard data, which are (1) the investigation of how much improvement of space utilization the HYPOS achieved over an existing study and (2) the comparison of the block operations schedule generated by the system with that generated by the operator who had a long-period experience. The system has been being operated successfully at the block paint shop in Hyundai Heavy Industries since May 2000.

2.3.3 Developing scheduling systems for Daewoo Shipbuilding: DAS project

Jae Kyu Lee, Kyoung Jun Lee, Hung Kook Park, June Seok Hong, Jung Seung Lee, According to this experience of developing large scale scheduling systems, the key ingredients of the system are managerial insight on scheduling activities and effective heuristics, research capability on constraint-directed graph search and spatial scheduling, acquaintance with the frame and rule based expert system development environment, integration with optimization model, neural network based man-hours estimator, data requirement guiding but data-dependent phased development strategy, and effective technology transfer mechanism. It was really the mixture of operations management, Artificial Intelligence and Expert Systems, Operational Research, information technology, and organizational learning. This experience tells us a lot about the gaps between academic communities: OR and AI should better understand each other for mutual benefit to solve complex real world problems (Lee, 1990, 1996; Lee and Song, 1995).

CHAPTER 3

DESIGN OF LOOKING FORWARD ALGORITHM

3.1 PRODUCTION PLANNING

3.1 Background and Master Schedule

Any manufacturing process, particular one so complex as shipbuilding, has to be planned carefully. Men, material, machinery (and money) must be coordinated and controlled at every successive stage of production in offices, steelwork ships and outfit areas. Hence an integrated planning system is essential for efficient management. The degree of sophistication will vary depending upon the size of the yard, the number and types of vessels being built, customer requirements (eg. MOD or RN contracts), etc.

Before production planning can take place in detail, a long term perspective needs to be established. The planning of all contracts to be built and those under production needs to be based upon a long range schedule describing the loading the utilization of the shops' and berth facilities. This schedule, often known as the master shipbuilding schedule, determines to a large extent the success of other schedules which must be derived from it. The schedule usually presents the construction time of each ship) determined conventionally from a rough analysis of past ships or similar type) in bar chart form.

An erection schedule for 6-9 months is made for each ship according to the master schedule. On the basis of the erection schedule, other production stage plans can be analyzed sequentially. The hierarchical approach to planning must be conducted carefully as not all stages are dependent on berth schedule and some phases can be regarded as secondarily dependent on others. For example, the lead times required for major machinery items may mean a change of launch date. The erection schedule is usually presented in bar-chart form. However, it is converted into a network layout (see Section 13.2) to form the basis of an overall plan for the vessel and shipyard.

3.2 Detailed Planning – Network Analysis

The task of detailed planning can be summarized as being to determine when, where and how each operation should be done within the framework of the master and erection schedules. Before detailed scheduling can be started, however, the ship must be broken down into groups of assemblies or operations with each group forming a convenient package.

The following information needs to be known:

- Definition of complete operation
- Breakdown of operation into elements
- Number of hours for each operation/trade
- Number of workmen required
- Man-hours for service trades

- Material required for the operation
- Equipment required for the job.

The information contained in this list forms the basis of planning and it is essential that these figures should be kept as accurate as possible. Ideally such figures would be set by a process of work measurement (see Chapter 10), but in practice is usually a combination of work measurement and existing (or historical) knowledge and information.
Detailed construction schedules show where the critical operations or bottlenecks are likely to occur and also determine the critical path to delivery. One of the most important techniques used in detailed planning is network analysis.

3.3 Network Construction

A network, or arrow diagram, is a diagrammatic representation of a project showing the chronological order and inter-relationship of all events and activities necessary for its completion. In the most common representation, individual tasks (or activities) are shown as arrows/links joining numbered events (or nodes) with arrowhead indicating the direction of progress from start to finish of the event.

Definitions of some of the terms are set out below: Event: usually denoted by a circle is a point in time representing completing or one activity and the commencement of another. A number placed inside the circle identifies events and the same pair of event numbers may not define two activities. Activity: is a task with zero duration. There are two reasons for including them. The first is concerned with representing precedence relationships, which could not otherwise be shown in the network. For example, consider the following four tasks with precedence constraints.

A followed by B, C B followed by D C followed by D D followed by – A network of the form shown in Figure 3.1.1(a) is incorrect because it includes the relationship ‘C precedes B’ – which is not required. Instead a dummy task is inserted to give the network in Figure 3.1.1(b). The dummy task shown as the dashed arrow has no ‘time requirement’; it implies that C cannot start until both A and C are complete but it does not introduce the additional and incorrect relationship between C and B of figure 3.1.1(a). The second reason for including dummy activities is to eliminate ambiguities of notation. Tasks are usually identified in networks by their start and finish nodes. However, if two tasks have the same start and finish nodes, they cannot be distinguished clearly.

For example, the four tasks:
A followed by B, C
B followed by D
C followed by D
D followed by –

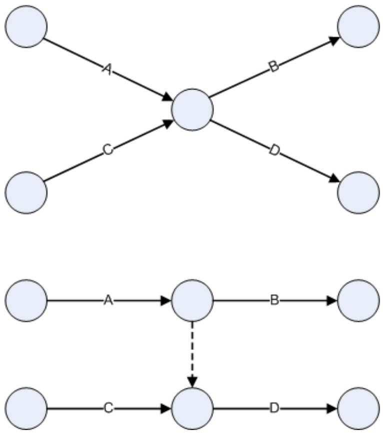
Might be shown in the network in Figure 3.1.2(a), but in this representation it is not clear whether the task (2, 3) refers to B or C. To resolve this ambiguity a dummy activity is inserted to give the network of Figure 3.1.2(b) or (c). Note that the dummy is inserted before one of the regular tasks. As noted earlier, the nodes or events in a network as usually numbered, and the individual tasks or activities are commonly referred to by their start and finish nodes. Thus a link from node i to node j is referred to as task (i, j). In this case i precedes j in the network, written i → j. The duration of the task is represented by d_{ij}.

Consider, for example, the project with activities and associated details as shown in Table 3.1 below.

Table 3.1 An Eight –Activity Project

Activity	Preceded by	Followed by	Duration
A	-	B, C	1
B	A	D, E	5
C	A	E	4
D	B	F, G	3
E	B, C	F, G	6
F	D, E	H	10
G	D, E	H	4
H	F, G	-	2

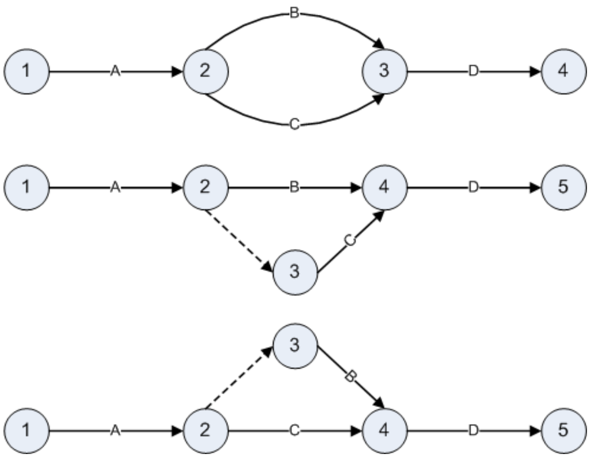
This can be drawn as a network diagram as shown in Figure 3.1.3. The dummy task (3, 4) is necessary to show the precedence relationships between tasks B, C, D and E while dummy (5, 6) is introduced for notational reasons, to enable F and G to be distinguished. Task durations are written below the links, except the dummy tasks, which have zero duration by definition.



(a)

(b)

Fig 3.1.1 Precedence Relationship for Dummy Task



(a)

(b)

(c)

Fig 3.1.2 Correct use of Dummy Tasks

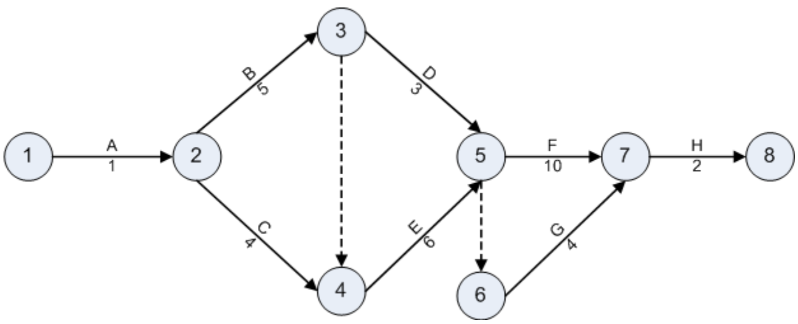


Fig 3.1.3 Network for Eight-Activity Project

Fig 3.1 Schematic Network Route Diagram

3.4 Time Calculations

From the network diagram such as the one shown in Figure 13.3 the earliest and latest times at which each event can take place without delaying the project and without violating precedence constraints. Let us try to understand the network evaluation mathematically.

The 'early time' of event j, ETj, is the earliest time by which all activities leading to j can be completed:

$ET_j = max_{j \rightarrow i} (ET_i + d_{ji})$

The earliest possible time or simply early times are calculated in a 'forward pass' through the network. Consider the example of Table 3.1 and Figure 3.1 again. The shipbuilding blocks or in other words event 1 has no predecessors, s its early time ET_i is set to zero. The event 2 has only one predecessor – 1 – so its early time is:

$$ET_2 = ET_1 + d_{12} = 0 + 1 = 1$$

Similarly, for event 3:

$$ET_3 = ET_2 + d_{23} = 1 + 5 = 6$$

Event 4 has two predecessors, so:

$$\begin{aligned} ET_4 &= max(ET_2 + d_{24}, ET_3 + d_{34}) \\ &= max(1+4, 6+0) \\ &= 6 \end{aligned}$$

Similarly,

$$\begin{aligned} ET_5 &= max(ET_3 + d_{35}, ET_4 + d_{45}) \\ &= max(1+4, 5+6) \end{aligned}$$

$$ET_6 = ET_5 + d_{56} = 12 + 0 = 12$$

$$\begin{aligned} ET_7 &= max (ET_5 + d_{57,}\ ET_6 + d_{67}) \\ &= max (12 + 19, 12+4) \\ &= 22 \end{aligned}$$

$$ET_8 = ET_7 + d_{78} = 22 + 2 = 24$$

Now let us consider another example and try to understand the network calculation through a textual approach.

Fig 3.2 is a typical example for block sequence diagram in which B1 is the seed with three children namely B2, B5 and B4. Similarly B2 has three children B5, B6 and B3. B5 has two children B8, B6 so on and so forth. This parent-child information is stored for each ship in the allocated database files. The starting day of erection/earliest network time (ENT) and ending day of erection/latest network time (LNT) is stored in block data file.

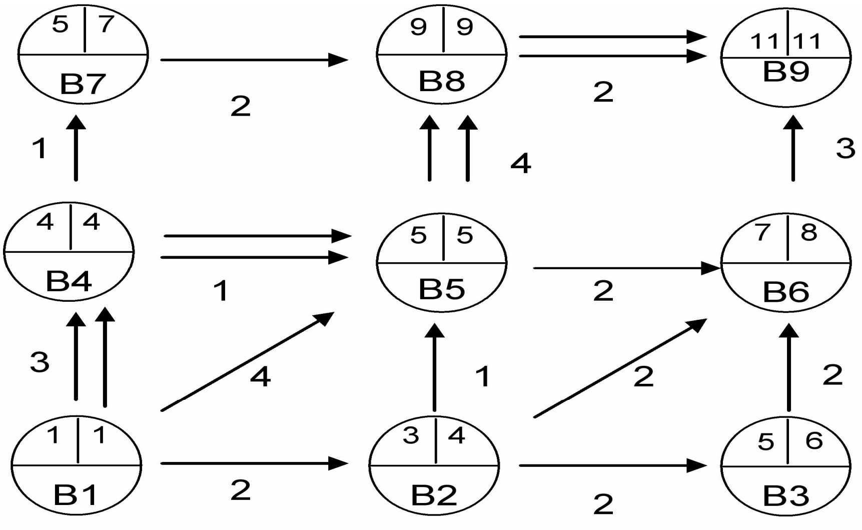


Fig3.2 An example of block sequence

A Pitch is the time that's required for sequenced operation on the child block. Then we calculate ENTs' for all the blocks and this is done by adding pitch to parent block's ENT, giving child's ENT this method is followed till the last block. But at junction nodes of block sequence (say block B5) we get an ENT value from the parent blocks B1, B2, and B4 but we consider only the highest value as a result of the addition with its pitch. Here an assumption is made that the first and the last blocks lie in critical path. A critical path is a series of linked erections that doesn't have the flexible dates hence hold the fixed dates of erection, that is, it must be done on time for the project to complete on time. If any task on a critical path is delayed, it can end up delaying the entire project's completion date thereby accumulating the load and propagating it to other networks. A block on the critical path is identified as its ENT and LNT as being same. In this illustration B9 is the last block and search in reverse direction is followed to find the parents to evaluate the LNTs' of all blocks. As discussed earlier in the case of ENT calculation at the junction here we take the lowest value after subtraction of pitch from the LNT value of the child to finalize the LNT of the concerned parent. In this way system stops at the first block as the system is not able to find more precedent parents. This concept is then is extended for fixing the time for the off-critical blocks. This is done considering the percentage area occupation of the specific block in the pre-erection (PE) area and with respect to the total PE area and the period of the delay, that is, the difference of the dates between the ENT and the LNT. The weights are decided based on the available concepts.

3.5 Solution Approach

In the PE-Dock premises, as it is the most critical areas of ship production in any shipyard every activity has to be well scheduled in order to obtain the best possible erection schedule. Every block that comes to the PE area has associated terminologies, namely PE Work Start, ENT, LNT, Probable Date of Erection, and Fixed Erection Date.

Let us discuss these factors in little detail, as follows in order to clarify the approach point of view and diagrammatically represented in fig 3.1.

3.5.1 Describing the Approach

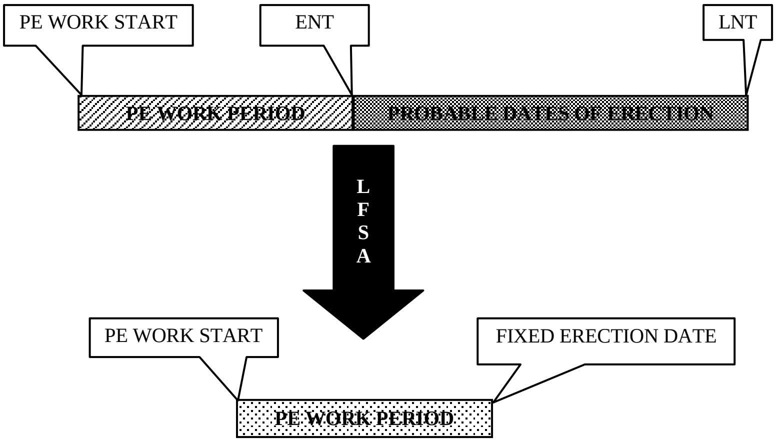


Fig 3.3 Problem Approach Description

a) PE Work Start: When the erectable block arrives in the PE Area, there are various kinds of work associated with it, such as limited amount of welding, painting, if it is a kind of sub-block it has to be mounted up together with other sub-blocks to form a grand block. The grand block is basically the block that will go to the dock and get assembled into a ship under construction. To summarize, PE work start time is the time when the work on concerned block begins.

b) ENT: Every shipyard has a primary network diagram of the shipbuilding which represents the building sequence of the ship under consideration, it is otherwise called as erection sequence network diagram. In the diagram, it mentions the earliest possible date suitable for that particular block. Hence ENT is expanded as the earliest possible network time.

c) LNT: To follow-up from (b), it is the latest possible date of erection of the block in order to execute the building in time as per the schedule.

d) Probable date of erection: The date of erection has to be sought between the time span of the ENT and LNT. The schedulers working on these projects have room to think and choose the better option and dates of erection in this given span.

e) Fixed date of Erection: Followed from (e), various considerations and thought are sought along with various technical parameters, mathematical logics and like to take a decision to erect a block on one particular date. This one particular date is called the fixed date of erection.

3.5.2 Terminologies and concepts

The block presence to could be logically understood as follows:

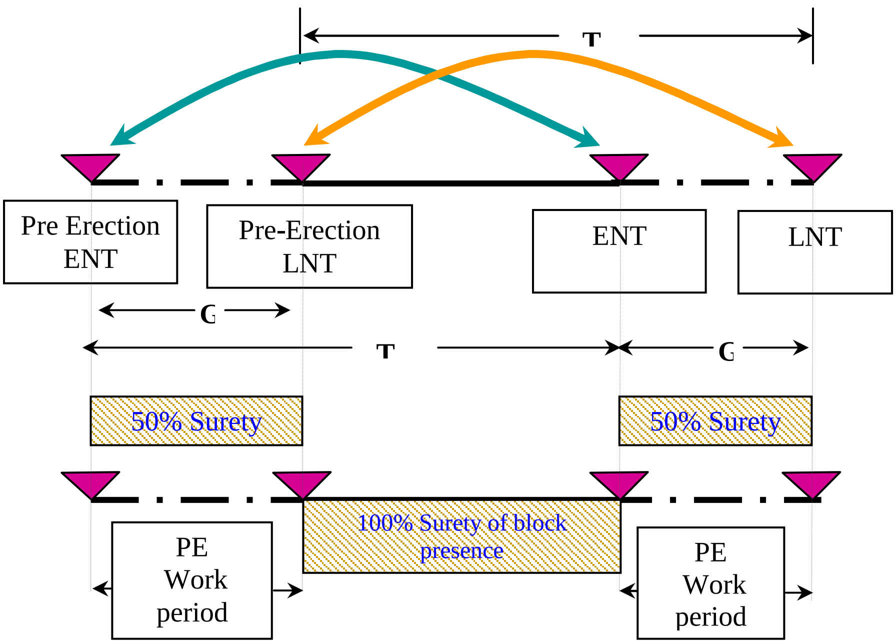


Fig 3.4. Logic of block presence in the PE Area

The probability of finding a block in the PE area in the first segment i.e (G) will be 1/G.

Similarly the probability of finding the block in the second segment will be 100% and it could be evaluated as follows:

$$\frac{1}{G} + \frac{G-1}{G} \times \frac{1}{G-1}$$

$$= \frac{2}{G}$$

Likewise and so on.

3.6 The technical analysis

As we know from the knowledge of mathematics Moving averages are one of the best techniques to test the noise in the pulsating time related data. This technique is very popular among the stock brokers and in the share market to predict the trend of the share prices to determine being bullish or bearish.

There are few types of moving averages, the most important (for the technical analysis) are "simple" MA (SMA), where all points have equal weight and exponential MA (EMA), that are assigning higher weight to the latest points, therefore making the method more sensitive to the resent changes in a stock price.

This approach is better for most applications, however being more sensitive it can produce more false signals. Some traders would suggest using the traditional MA instead (all points having equal weight) for the situations when signals should be more reliable.

To calculate the EMA, use the following approach:

Current_EMA = ((2/ (1+Number_of_periods_for_EMA)) x (Current_Price - Previous_EMA)) + Previous_EMA

Hence, it is decided to keep the interest to the Simple moving averages level.

3.7 Understanding the Use of MA in Stock Market

To argue our test basis lets analyze the real shipyard block data.

Regardless of the implementation details, all MA techniques are based on analyzing the DISTANCE between the moving average and the original chart, or between two moving averages.

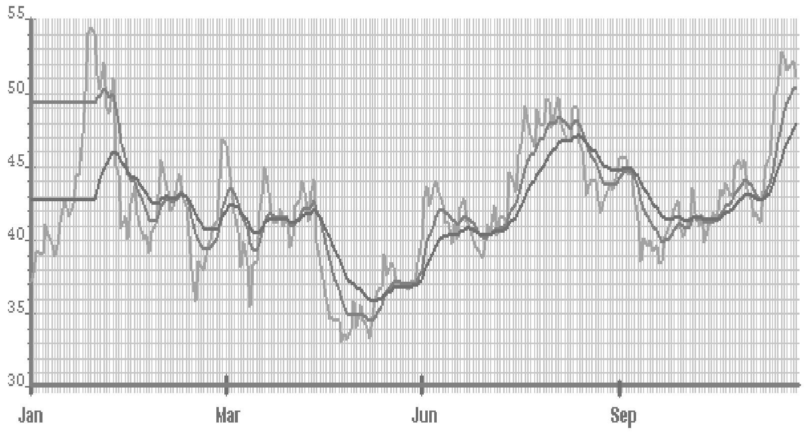


Fig 3.5 Typical Moving Average curve

On the picture above we have the stock price and the moving averages. Let's see what information we can extract from this chart.

3.7.1. The trend, the support and the resistance

As we know, the moving average is always behind the actual data. So if the stock price is increasing, the line for the price will be above the line for the moving average, as the price rises BEFORE the MA.

Therefore as long as the price is going up, the MA will form the line below the price. You might notice that (leaving aside the fact that this line is not so straight) it is a support line.

Same logic applies to the price declining - the MA will form the resistance line above the price.

What will happen if the trend changes? The price line will cross the MA. We have a "trend change" indicator! And unlike the line drawn by the ruler, this one can be coded as part of a computer algorithm. We may also use the intersection of two lines (price and MA) as a signal. Indeed, the trend changes - it is time to trade.

3.7.2. Volatility

The only problem with the approach above is the price volatility. What if the stock jumps up or down for no particular reason, and then returns? It will generate a false signal, wouldn't it?

To fix this problem, we need to make our price line smoother, and we already know how to do it. We use Moving Averages, studying intersections of two (or more) MA's, rather then of MA and price.

In a typical "minimum" case (that is probably the best for practical applications) we would have two moving averages, one for the short period and one for the long period. A simple rule applies: the intersection of these two lines is a trading signal.

As you can see, the two moving averages are much less noisy then price line, but they are still moving fast sometimes, and in different directions, so the signals are not necessarily clear. This is one of the problems with the MA's - they work fine when the trend is present, and do not work when the stock price is moving sideways. The false signals generated by MA in that case are called "whipsaw".

If we select longer intervals for the average, there will be less signals and each of them will represent a larger move of the stock price. The number of false signals will be less, too.

3.7.3 Bringing the Stock market Idea to Shipbuilding Block movement

The technique that we conceive here is appropriate for the Long Term schedulers (yearly Schedules), Middle term schedulers (monthly schedules) and the short term / daily schedulers. This technique is one of the most often used by the different simulator software as performing the technical analysis of stock trend using this method is easy and very straightforward. As mentioned, the Looking forward scheduling algorithm (LFSA) works well both for a "long term", middle term and intraday scheduling systems.

Lets us bring our attention to the daily schedule preparation based on the shipyard data available.

3.8 Shipbuilding Blocks for erection

The test of the algorithm has been made based on the erection network diagram of hull number 2035, a 50K tons Bulk Carrier.

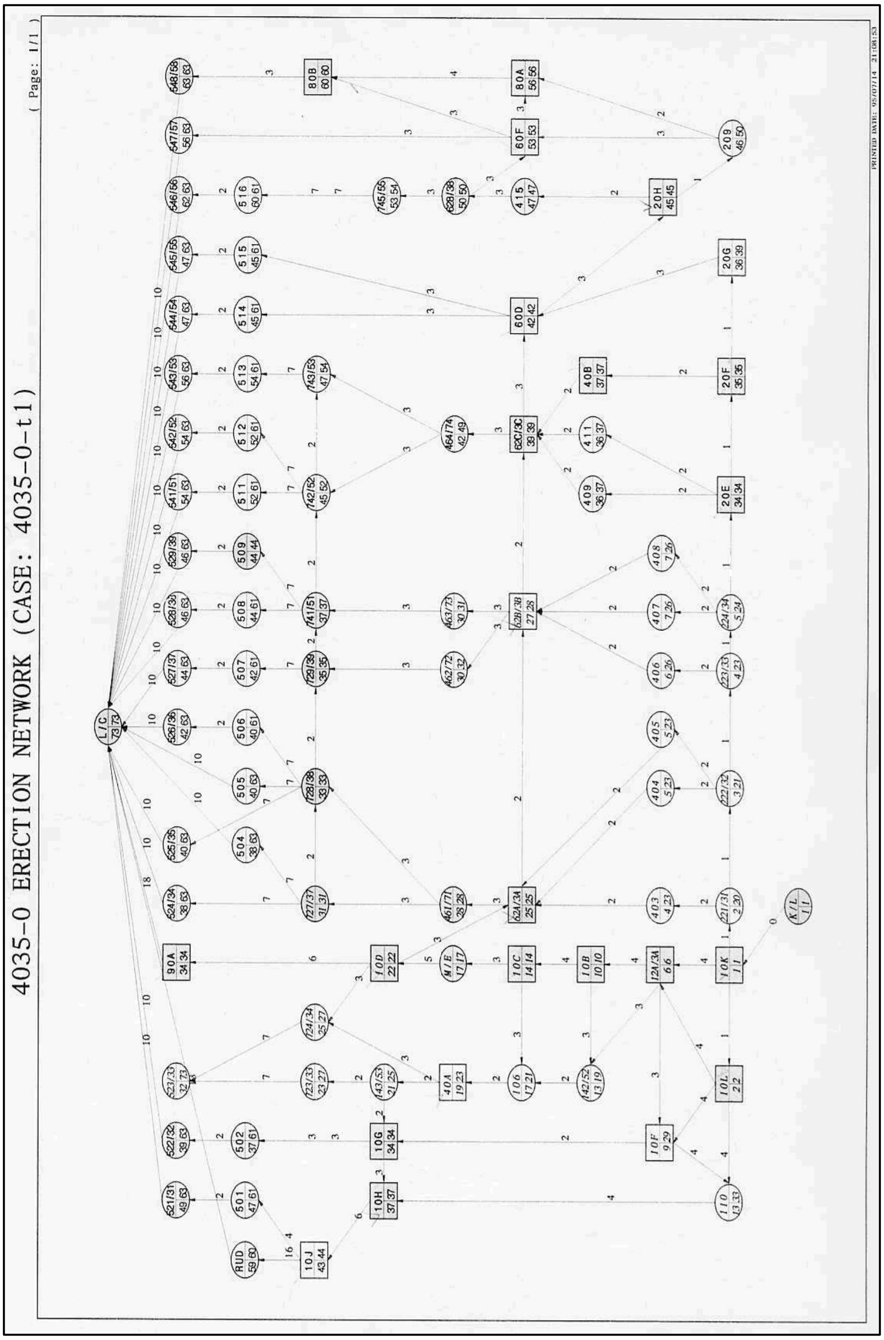


Fig. 3.6. Erection Network Diagram

Table 3.2 Erection Network Evaluation

BL.Name	Breadth	Length	Area	ENT	LNT	PE Period	PE Start	Erection day	Property
KL	11	26.5	291.5	1/10/2004	1/10/2004	1	1/9/2004	1/10/2004	ON Critical
10A	23	25.5	586.5	1/10/2004	1/10/2004	2	1/8/2004	1/10/2004	ON Critical
20A	17	32	544	1/12/2004	1/18/2004	2	1/14/2004	1/16/2004	OFF Critical
20B	40	14.3	572	1/14/2004	1/22/2004	2	1/14/2004	1/16/2004	OFF Critical
20C	19.4	44.8	869.12	1/13/2004	1/22/2004	2	1/16/2004	1/18/2004	OFF Critical
20D	20.2	23.8	480.76	1/15/2004	1/26/2004	2	1/21/2004	1/23/2004	OFF Critical
20E	38	14.3	543.4	1/17/2004	1/28/2004	2	1/19/2004	1/21/2004	OFF Critical
20F	16.6	31	514.6	1/17/2004	1/29/2004	2	1/26/2004	1/28/2004	OFF Critical
22G	19.4	44.8	869.12	1/18/2004	1/31/2004	2	1/21/2004	1/23/2004	OFF Critical
80A	19.4	44.8	869.12	1/21/2004	2/3/2004	2	1/19/2004	1/21/2004	OFF Critical
10B	33.2	14.3	474.76	1/13/2004	1/13/2004	1	1/12/2004	1/13/2004	ON Critical
261	40	14.3	572	1/14/2004	1/20/2004	2	1/15/2004	1/17/2004	OFF Critical
40A	22	33.2	730.4	1/16/2004	1/24/2004	2	1/14/2004	1/16/2004	OFF Critical
40B	25.3	21.5	543.95	1/15/2004	1/24/2004	2	1/21/2004	1/23/2004	OFF Critical
40C	37	15.9	588.3	1/17/2004	1/28/2004	2	1/15/2004	1/17/2004	OFF Critical
40D	37	15.9	588.3	1/18/2004	1/30/2004	2	1/23/2004	1/25/2004	OFF Critical
ME	17.7	44.8	792.96	1/13/2004	1/17/2004	1	1/15/2004	1/16/2004	OFF Critical
10C	37.9	14.3	541.97	1/17/2004	1/17/2004	2	1/15/2004	1/17/2004	ON Critical
10D	18	35.6	640.8	1/21/2004	1/21/2004	2	1/19/2004	1/21/2004	ON Critical
62A	18	40.6	730.8	1/16/2004	1/22/2004	2	1/15/2004	1/17/2004	OFF Critical
62B	11	26.5	291.5	1/18/2004	1/24/2004	2	1/19/2004	1/21/2004	OFF Critical
62C	23	25.5	586.5	1/20/2004	1/26/2004	1	1/24/2004	1/25/2004	OFF Critical
62D	17	32	544	1/22/2004	1/28/2004	1	1/26/2004	1/27/2004	OFF Critical
62E	40	14.3	572	1/24/2004	1/30/2004	1	1/28/2004	1/29/2004	OFF Critical
62F	19.4	44.8	869.12	1/26/2004	2/1/2004	1	1/25/2004	1/26/2004	OFF Critical
62G	20.2	23.8	480.76	1/28/2004	2/4/2004	2	1/30/2004	2/1/2004	OFF Critical
10E	18.4	44.8	824.32	1/23/2004	1/23/2004	2	1/21/2004	1/23/2004	ON Critical
510	16.6	31	514.6	1/23/2004	1/31/2004	2	1/21/2004	1/23/2004	OFF Critical
80B	38	14.3	543.4	1/30/2004	2/6/2004	1	1/30/2004	1/31/2004	OFF Critical
511	19.4	44.8	869.12	1/31/2004	2/8/2004	1	2/2/2004	2/3/2004	OFF Critical
512	33.2	14.3	474.76	1/27/2004	2/8/2004	1	1/28/2004	1/29/2004	OFF Critical
513	40	14.3	572	1/29/2004	2/8/2004	1	2/4/2004	2/5/2004	OFF Critical
514	19.4	44.8	869.12	2/2/2004	2/8/2004	1	2/7/2004	2/8/2004	OFF Critical
515	22	33.2	730.4	2/1/2004	2/8/2004	1	2/4/2004	2/5/2004	OFF Critical
RUD	18	40.6	730.8	2/4/2004	2/4/2004	2	2/2/2004	2/4/2004	ON Critical
91A	25.3	21.5	543.95	1/26/2004	2/13/2004	2	1/28/2004	1/30/2004	OFF Critical
90A	37	15.9	588.3	1/27/2004	2/15/2004	1	1/30/2004	1/31/2004	OFF Critical
301	37	15.9	588.3	2/3/2004	2/11/2004	1	2/5/2004	2/6/2004	OFF Critical

302	17.7	44.8	792.96	1/30/2004	2/11/2004	1	2/8/2004	2/9/2004	OFF Critical
303	37.9	14.3	541.97	2/1/2004	2/11/2004	1	1/31/2004	2/1/2004	OFF Critical
304	18.4	44.8	824.32	2/5/2004	2/11/2004	1	2/9/2004	2/10/2004	OFF Critical
305	18	35.6	640.8	2/4/2004	2/11/2004	1	2/4/2004	2/5/2004	OFF Critical
LC	11	26.5	291.5	2/17/2004	2/17/2004	1	2/16/2004	2/17/2004	ON Critical

Table 3.3 Sample Tabulation of Looking Forward to 10 Days.

Name	ENT	Name	Area		10
KL	1/10/2004	KL	291.5	291.5	
10A	1/10/2004	10A	586.5	878	
20A	1/12/2004	20A	544	544	
20C	1/13/2004	20C	869.12	869.12	
10B	1/13/2004	10B	474.76	1343.88	
ME	1/13/2004	ME	792.96	2136.84	
20B	1/14/2004	20B	572	572	
261	1/14/2004	261	572	1144	
20D	1/15/2004	20D	480.76	480.76	
40B	1/15/2004	40B	543.95	1024.71	572.755
40A	1/16/2004	40A	730.4	730.4	616.645
62A	1/16/2004	62A	730.8	1461.2	631.075
20E	1/17/2004	20E	543.4	543.4	631.015
20F	1/17/2004	20F	514.6	1058	595.563
40C	1/17/2004	40C	588.3	1646.3	606.917
10C	1/17/2004	10C	541.97	2188.27	581.818
22G	1/18/2004	22G	869.12	869.12	611.53
40D	1/18/2004	40D	588.3	1457.42	613.16
62B	1/18/2004	62B	291.5	1748.92	594.234
62C	1/20/2004	62C	586.5	586.5	598.489
80A	1/21/2004	80A	869.12	869.12	612.361
10D	1/21/2004	10D	640.8	1509.92	603.361
62D	1/22/2004	62D	544	544	603.421
10E	1/23/2004	10E	824.32	824.32	634.393
510	1/23/2004	510	514.6	1338.92	627.023
62E	1/24/2004	62E	572	572	630.026
62F	1/26/2004	62F	869.12	869.12	630.026
91A	1/26/2004	91A	543.95	1413.07	625.591
512	1/27/2004	512	474.76	474.76	643.917
90A	1/27/2004	90A	588.3	1063.06	644.097
62G	1/28/2004	62G	480.76	480.76	605.261
513	1/29/2004	513	572	572	598.381
80B	1/30/2004	80B	543.4	543.4	598.321
302	1/30/2004	302	792.96	1336.36	595.185

511	1/31/2004	511	869.12	869.12	630.637
515	2/1/2004	515	730.4	730.4	646.477
303	2/1/2004	303	541.97	1272.37	613.762
514	2/2/2004	514	869.12	869.12	646.279
301	2/3/2004	301	588.3	588.3	657.633
RUD	2/4/2004	RUD	730.8	730.8	671.883
305	2/4/2004	305	640.8	1371.6	687.887
304	2/5/2004	304	824.32	824.32	713.119
LC	2/17/2004	LC	291.5	291.5	687.929

3.9 Experimental results on block data

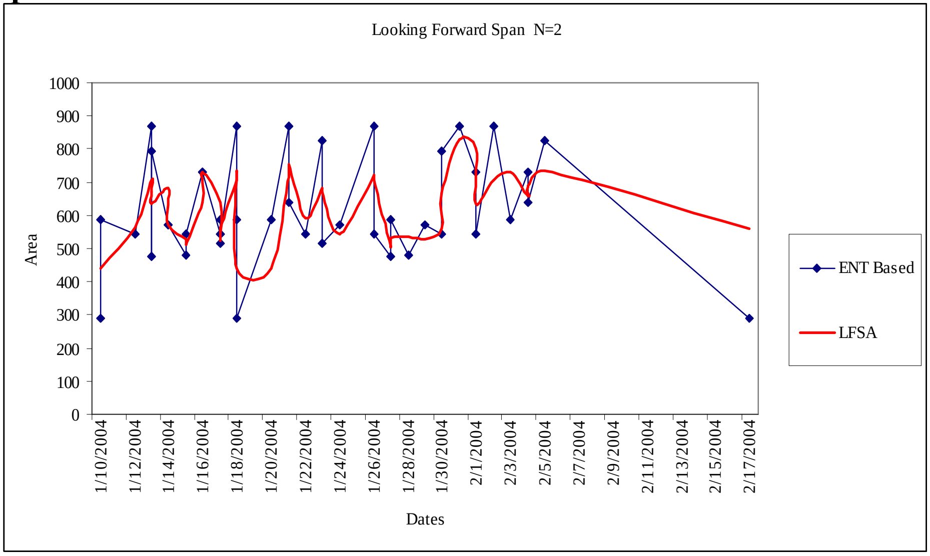


Fig 3.7 Looking forward to 2 days

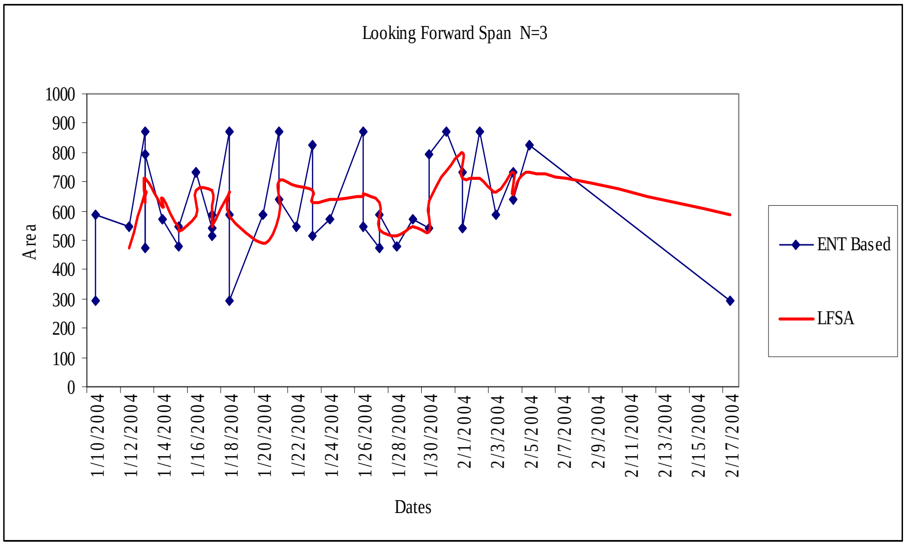


Fig 3.8 Looking forward to 3 days

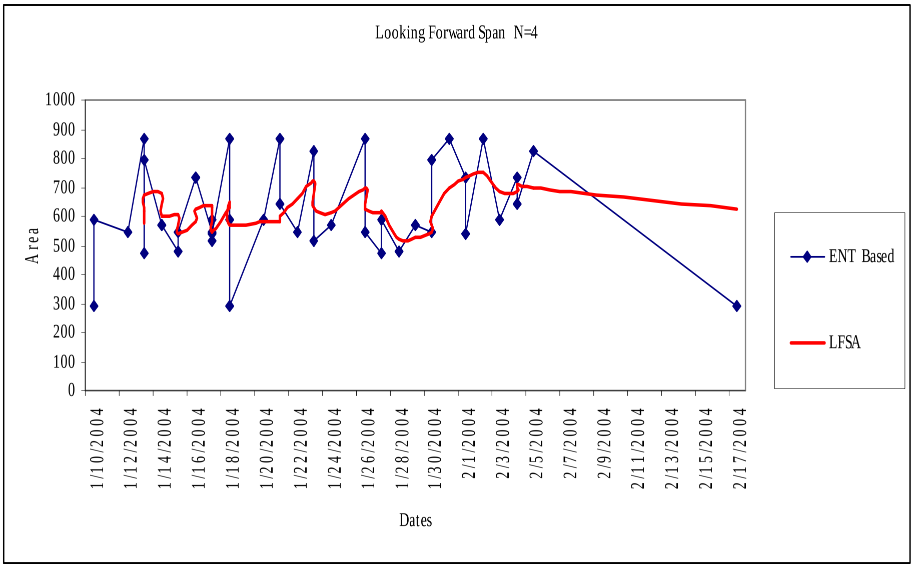


Fig 3.9 Looking forward to 4 days

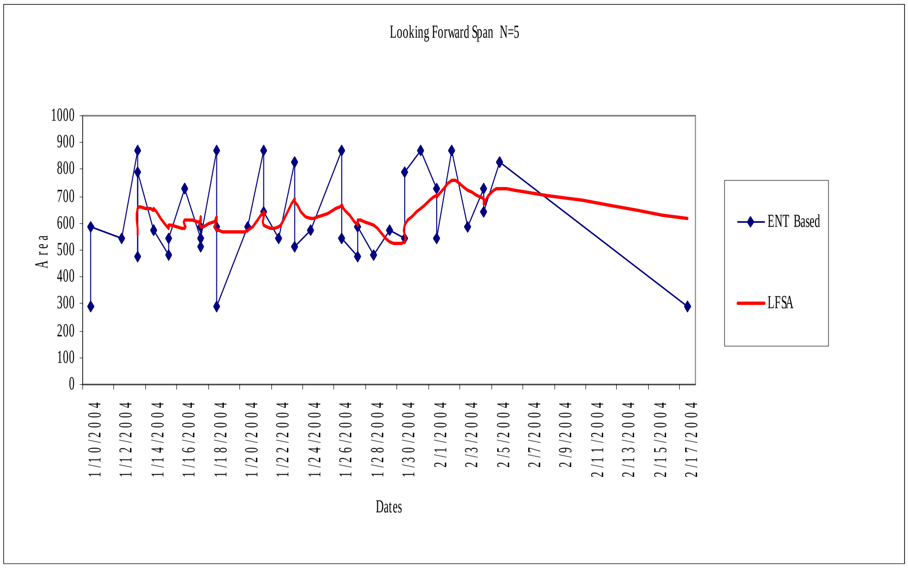


Fig 3.10 Looking forward to 5 days

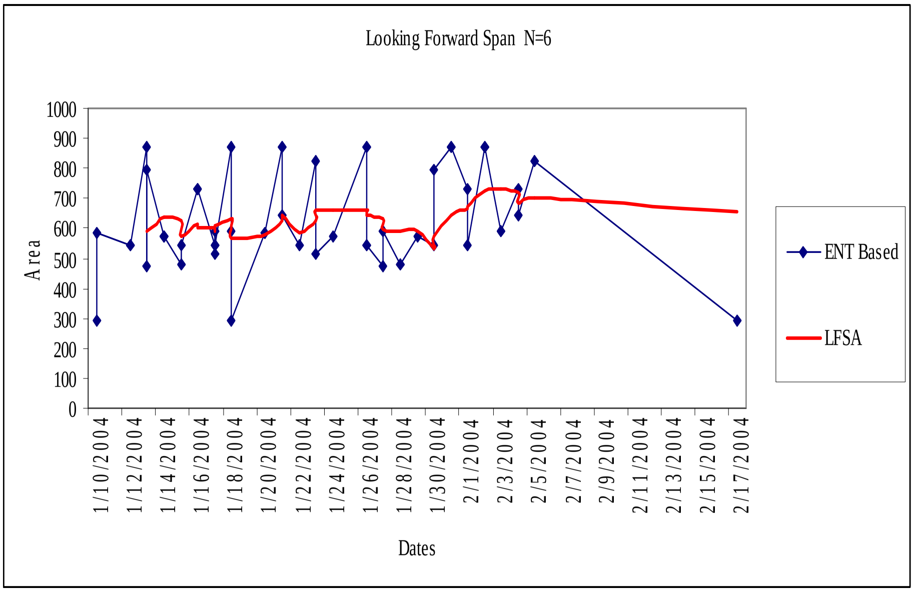


Fig 3.11 Looking forward to 6 days

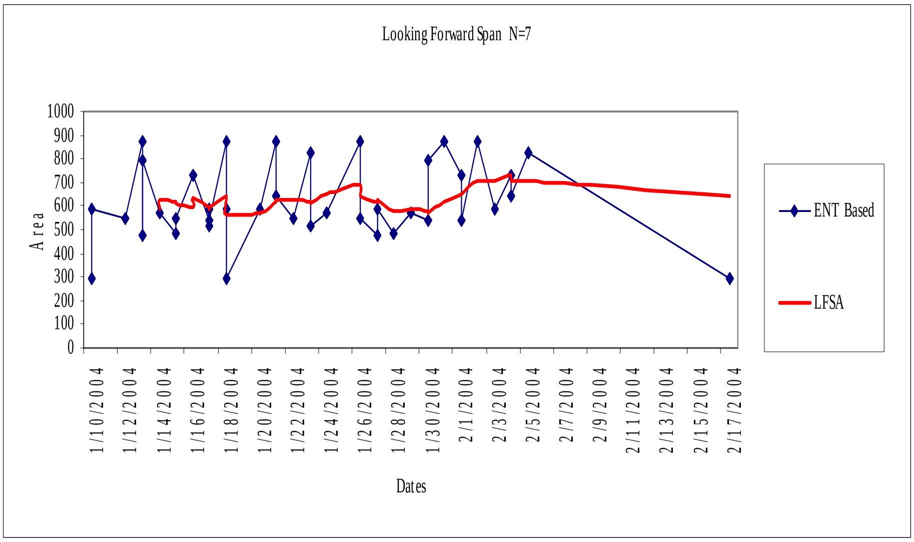


Fig 3.12 Looking forward to 7 days

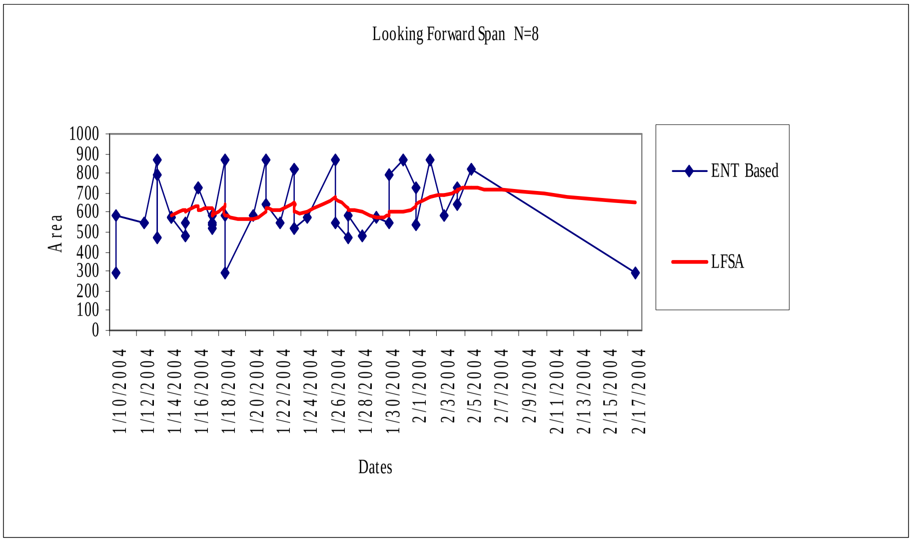


Fig 3.13 Looking forward to 8 days

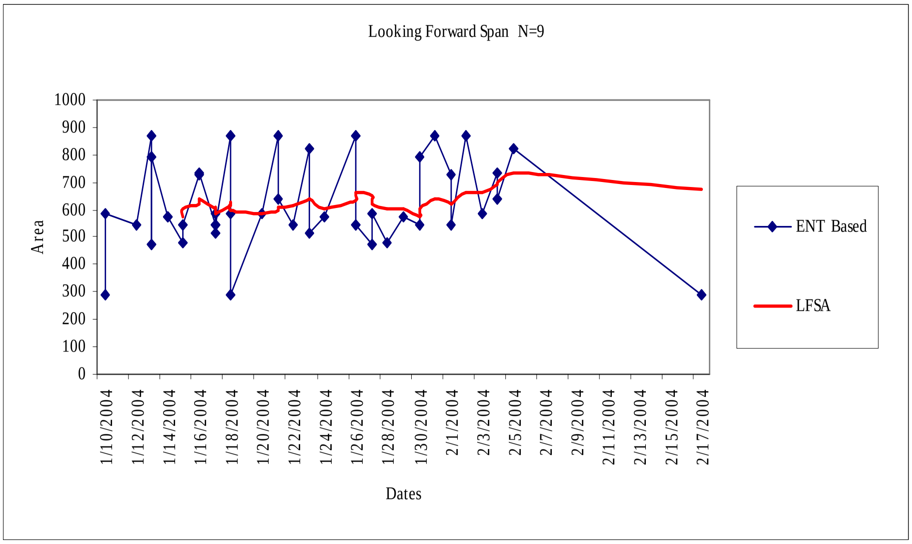


Fig 3.14 Looking forward to 9 days

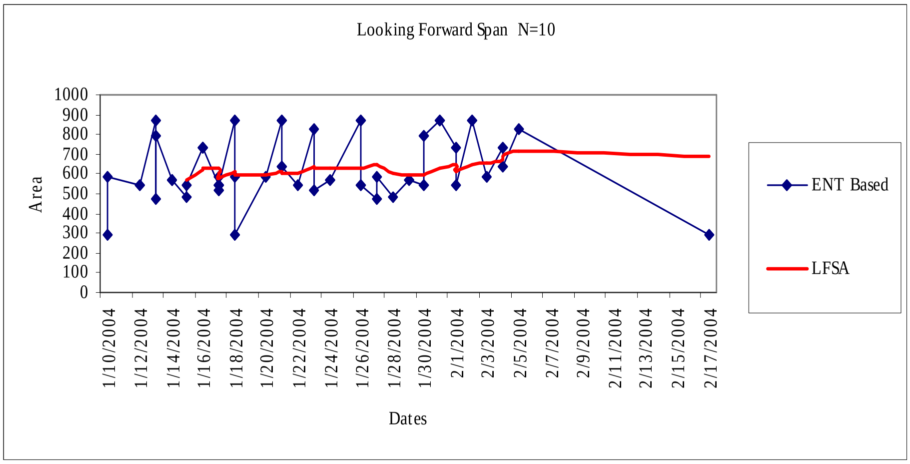


Fig 3.15 Looking forward to 10 days

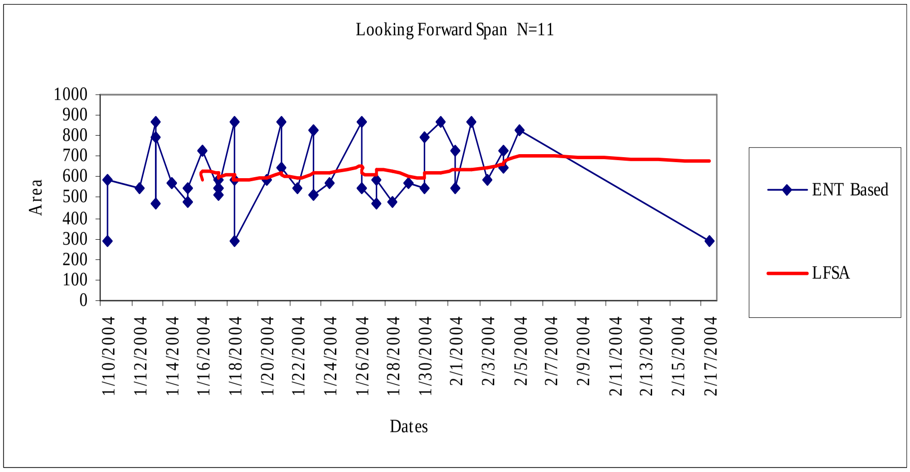


Fig 3.16 Looking forward to 11 days

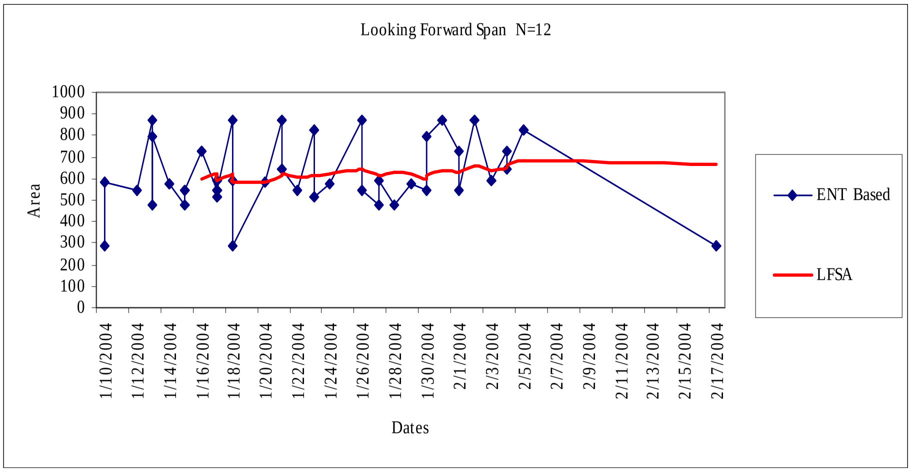


Fig 3.17 Looking forward to 12 days

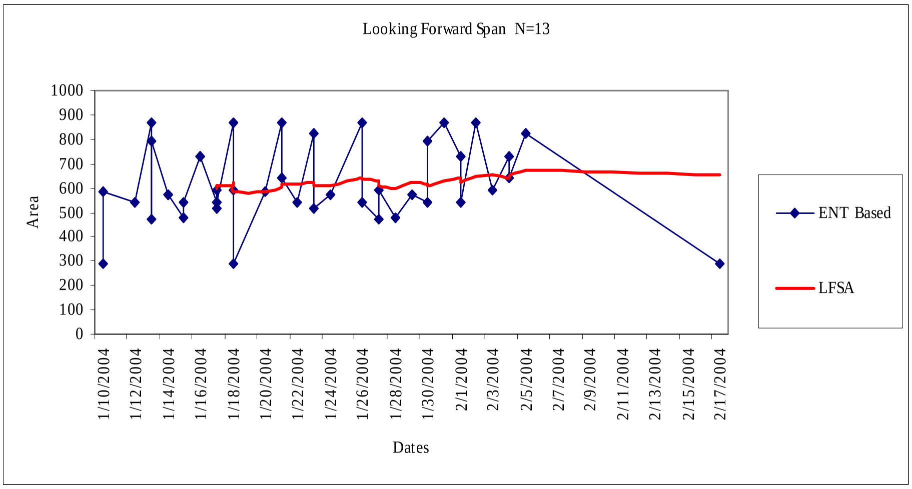


Fig 3.18 Looking forward to 13 days

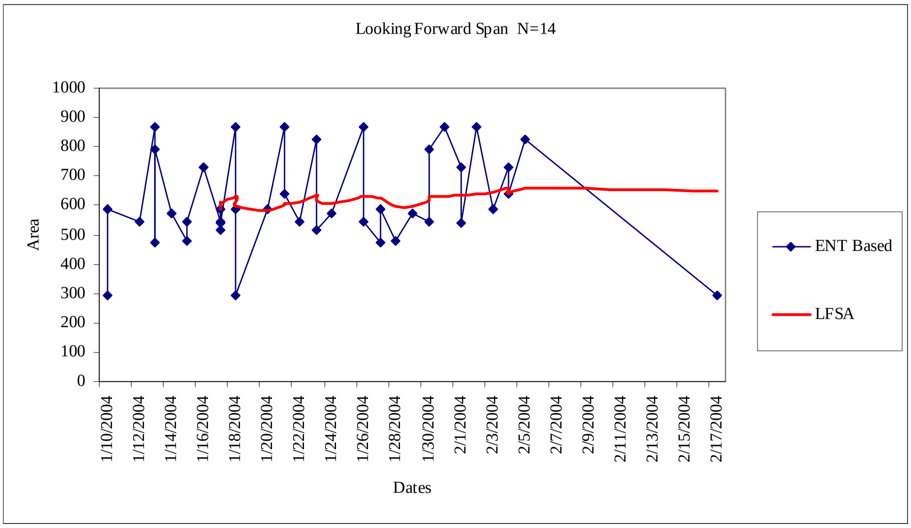


Fig 3.19 Looking forward to 14 days

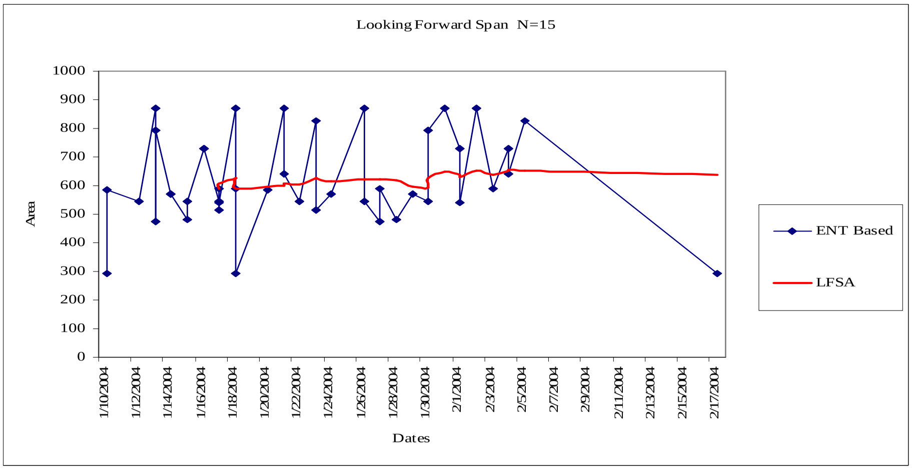


Fig 3.20 Looking forward to 15 days

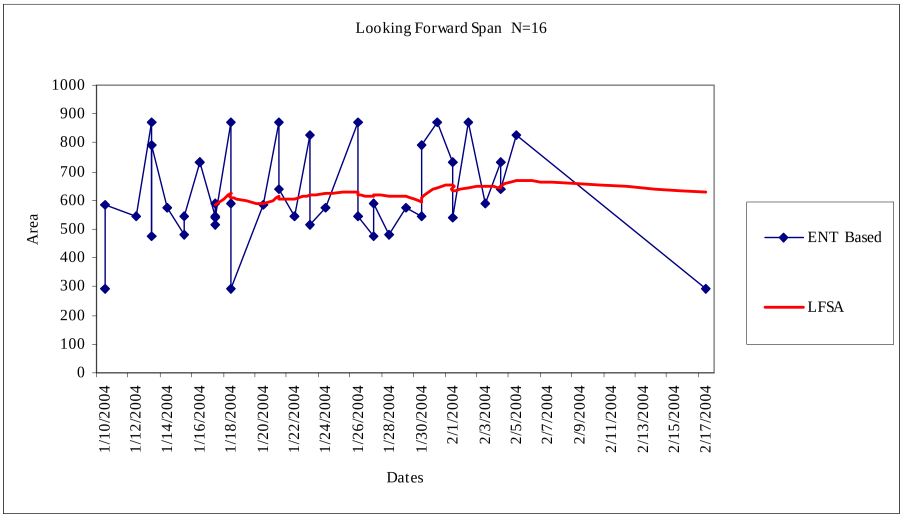


Fig 3.21 Looking forward to 16 days

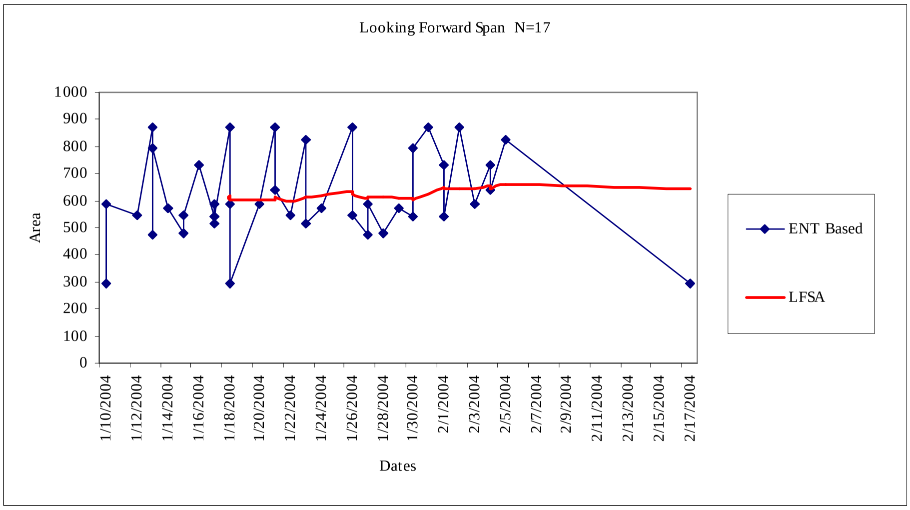


Fig 3.22 Looking forward to 17 days

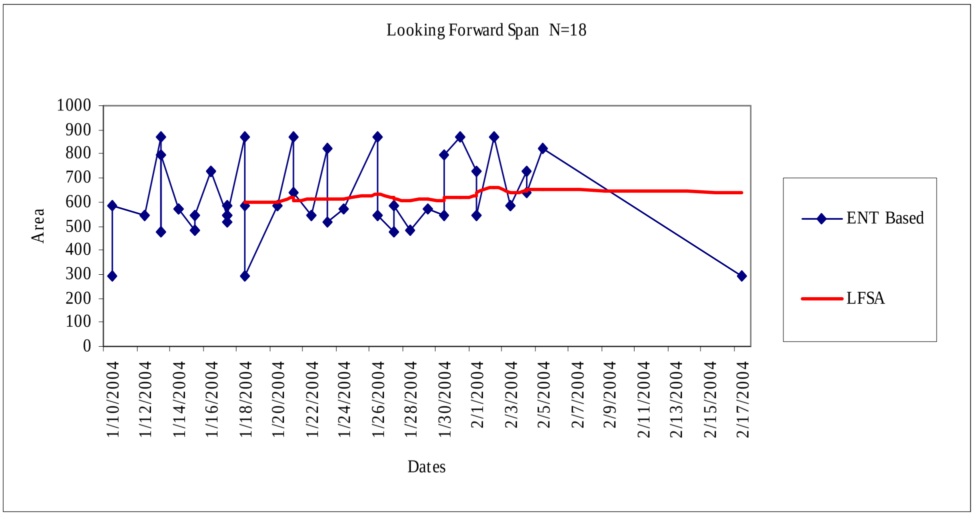


Fig 3.23 Looking forward to 18 days

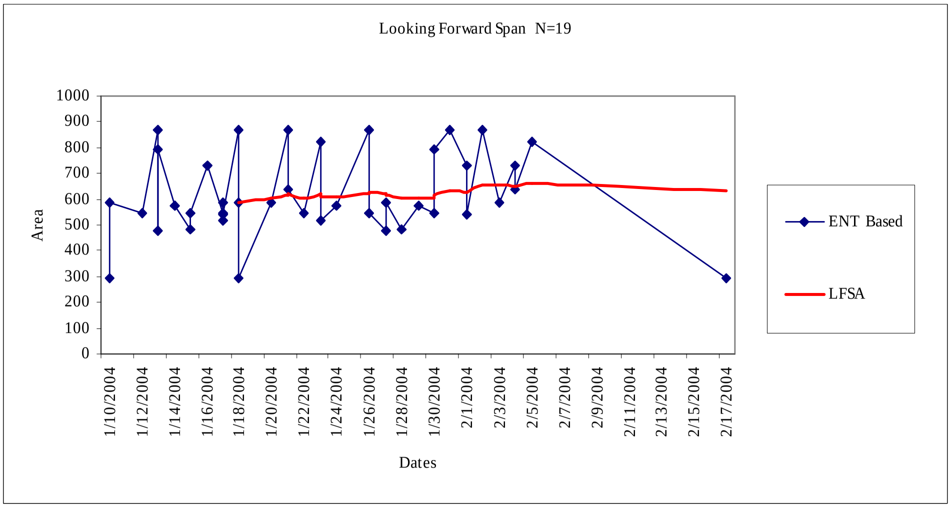


Fig 3.24 Looking forward to 19 days

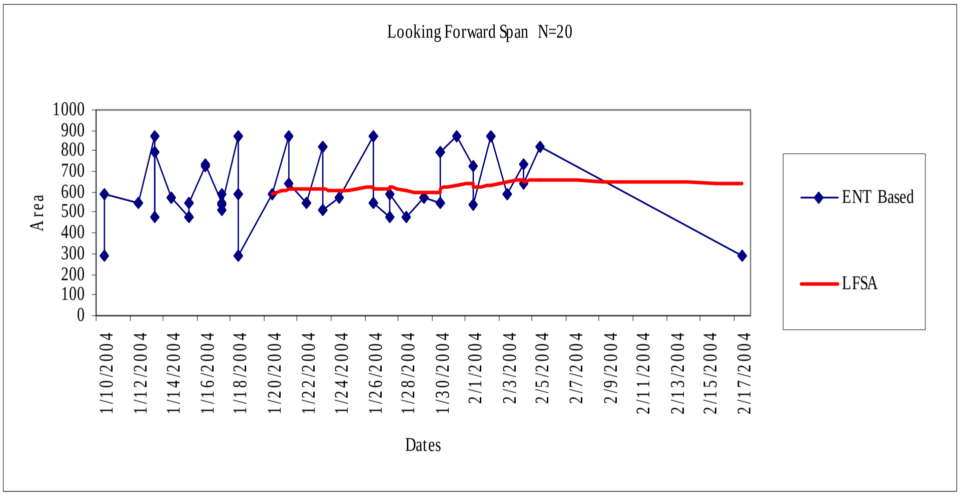


Fig 3.25 Looking forward to 20 days

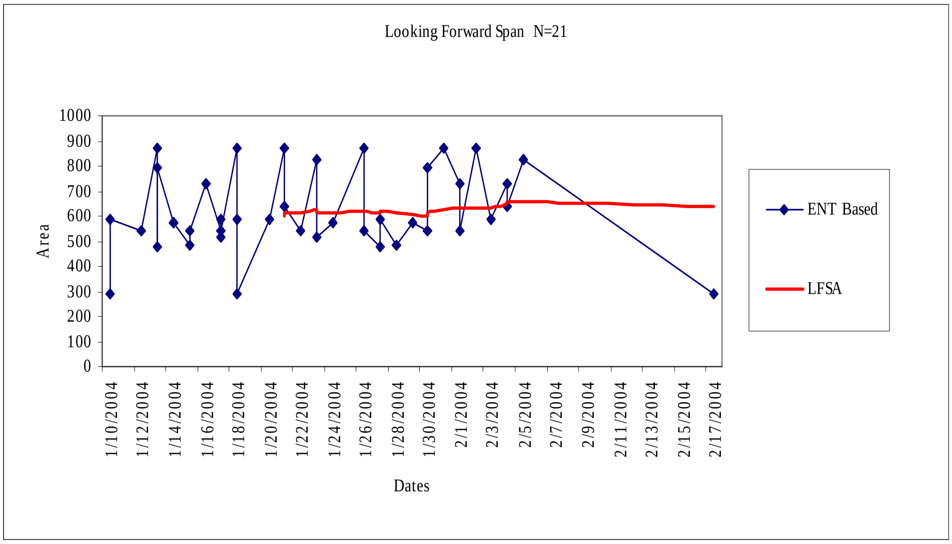


Fig 3.26 Looking forward to 21 days

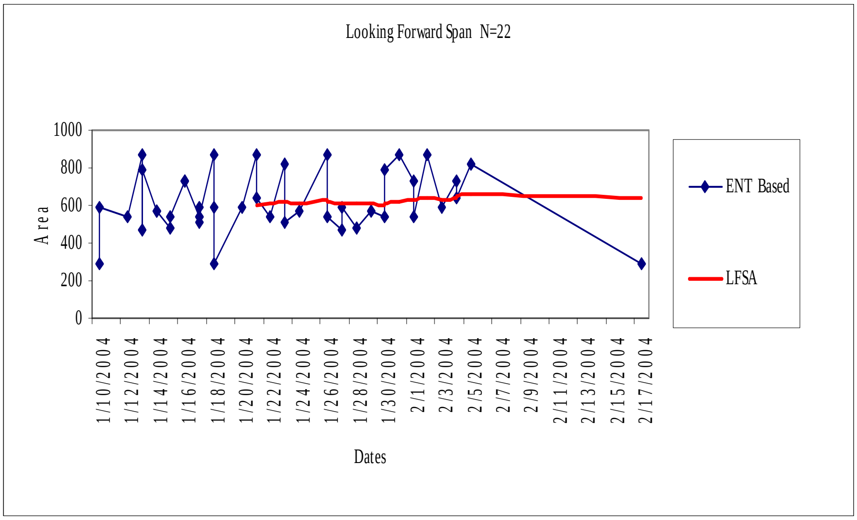


Fig 3.27 Looking forward to 22 days

Now based on the 21 variations that being tested here for the intraday scheduling or the systems that is being presented here speaks of lower lever schedulers who will interested in daily schedules.

The value of looking forward schedule is obtained as 10 and 17 in the graphs displayed above. Here the curve appears to smoothers meaning the noise is negligibility low and there is not enough friction in the value. This gives the good solution by optimal load leveling as the schedule.

We can also analyze sway in the trend. When the block flow is rising and LFSA indicator is falling (negative divergence), or vice versa, it can be considered an indication of "something going on" and can be used to predict changes in a trend. That's right, the lagging indicator that is supposed to follow the block flow, is predicting the block transit behavior.

On the figures above, the blocks formed a double peak with the second peak higher than the first one. In the same time (plus the delay due to the use of MAs) the LFSA curve formed two peaks, but the subsequent peak was smaller, which created the divergence. Soon the block flow broke the support line.

One of the solutions to the LFSA data being late is the LFSA curves. The histogram is the difference between the LFSA and 9 days Moving Average of LFSA, therefore it is a derivative on the derivative. The centerline crossovers and divergences are easier to identify when data is represented this way.

Usually, the longer and sharper the divergence is, the better which significantly helps in the decision making process.

The most important and strong signals are those confirming an existing trend.

3.10 Parameters

There are many trading systems that are using different periods for the fast and slow moving averages. 17 and 10 days is one of the most frequently used combinations. Sometimes schedulers can perform optimization, trying to find the numbers that are the best for a particular candidate blocks.

You can speed up the optimization process by performing the testing using software. Not only will it test different combinations of intervals, but also it can use some additional twists on the technique, like reversing the signals or using shorts.

3.11 Conditions for Implementation

In order to use buy and sell signals successfully, we need to apply them when (OK, almost when) the trend is changing. To do it, we need to have a trend to reverse. The MA-based indicators are not very useful in a situation when the price is moving sideways, or for trend that are not yet established.

Indicators can and should be used together, and it is particularly useful to avoid using similar indicators (MA and LFSA).

3.12 The Live Shipyard Scheduling In the Tandem Shipbuilding Process

3.12.1 Semi-Tandem Shipbuilding process

A 300,000 dead weight ton building dock is supported by a unique and efficient Semi tandem system which allows 2 ships to be built simultaneously and launched independently. In tandem shipbuilding, erection of the hull of the next ship is started on the inland end of the berth while the preceding ship is still there.

To illustrate lets understand the fig 3.28

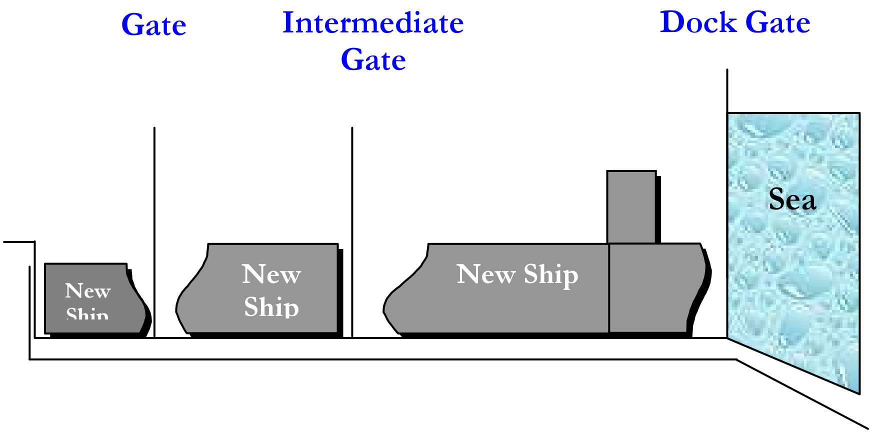


Fig 3.28. Semi –Tandem Method of Ship Building

At DSME, dry-dock can be divided into the different stages of new building and sections being separated by intermediate gates. One of the remarkable features is that this gate can be set at two different positions to accommodate ships of varying sizes in the process of building. In case of newbuilding, two and a half vessels can be built in dry-dock simultaneously (semi-tandem built method) but there are parallel arrangements in the dock thereby making it almost 6 vessels being built in different stages. The adoption of the semi-tandem process enables economical and efficient annual production.

The shipyard under considerations has one dry dock and two (2) sets of 900 Ton gantry crane with its modern and compact newbuilding facilities. While the dry dock can accommodate ship construction up to 550,000 DWT class ships, all physical facilities are efficiently arranged and identified for the construction of two (2) ULCC beam ships in parallel and two (2) more ships by semi-tandem method simultaneously. This unique layout enables the shipyard to maximize utilization of all facilities to build 20 ships per year.

Tandem building means you have one nearly complete ship in the outer dock, separated via an intermediate gate to the inner dock where you can start the engine room of the next vessel. After launching the one, you remove the intermediate gate and slide the aft-ship (on rails) to the outer dock and continue. This method gives better possibility to balance workloads and keep high throughput levels for a single dock. It means that the dry-dock has to be perhaps 400 m long instead of the 260-270 m needed depending on the vessel size.

3.13 Experimental Results of two ships- Simulations

Table 3.4 Numerical Area day values of the load on PE at various looking forward conditions

Weeks								Area Variations on various looking forward conditions as plotted in the graphs below							
30	872.92	872.92	872.92	872.92	872.92	872.92	872.92	872.92	872.92	872.92	872.92	872.92	872.92	872.92	872.92
31	872.92	872.92	872.92	872.92	872.92	872.92	872.92	872.92	872.92	872.92	872.92	872.92	872.92	872.92	872.92
32	1964.92	1418.92	1236.92	1964.92	1964.92	1964.92	1964.92	1964.92	1964.92	1964.92	1964.92	1964.92	1964.92	1964.92	1964.92
33	1964.92	1964.92	1600.92	1418.92	1964.92	1964.92	1964.92	1964.92	1964.92	1964.92	1964.92	1964.92	1964.92	1964.92	1964.92
34	1964.92	1964.92	1964.92	1691.92	1528.12	1964.92	1964.92	1964.92	1964.92	1964.92	1964.92	1964.92	1964.92	1964.92	1964.92

35	4745.92	3355.42	2891.92	2660.17	2302.72	2064.42	4745.92	4745.92	4745.92	4745.92	4745.92	4745.92	4745.92	4745.92	4745.92
36	5405.92	5075.92	4038.92	3520.42	3209.32	2819.92	2541.78	5405.92	5405.92	5405.92	5405.92	5405.92	5405.92	5405.92	5405.92
37	6225.00	5815.46	5458.95	4585.44	4061.34	3711.93	3306.36	3002.18	6225.00	6225.00	6225.00	6225.00	6225.00	6225.00	6225.00
38	8451.00	7338.00	6693.97	6206.96	5358.55	4792.95	4388.94	3949.44	3607.60	8451.00	8451.00	8451.00	8451.00	8451.00	8451.00
39	9248.00	8849.50	7974.67	7332.48	6815.17	6006.79	5429.38	4996.33	4538.17	4171.64	9248.00	9248.00	9248.00	9248.00	9248.00
40	10528.00	9888.00	9409.00	8613.00	7971.58	7433.97	6652.68	6066.71	5610.96	5137.15	4749.49	10528.00	10528.00	10528.00	10528.00
41	10544.00	10536.00	10106.67	9692.75	8999.20	8400.32	7878.26	7139.10	6564.19	6104.26	5628.68	5232.37	10544.00	10544.00	10544.00

42	11480.00	11012.00	10850.67	10450.00	10050.20	9412.67	8840.27	8328.48	7621.42	7055.77	6592.96	6116.29	5712.96	11480.00	11480.00
43	11470.00	11475.00	11164.67	11005.50	10654.00	10286.83	9706.57	9168.99	8677.54	8006.28	7457.06	6999.38	6528.12	6124.17	11470.00
44	9082.00	10276.00	10677.33	10644.00	10620.80	10392.00	10114.71	9628.50	9159.32	8717.98	8104.07	7592.47	7159.58	6710.54	6321.36
45	5050.00	7066.00	8534.00	9270.50	9525.20	9692.33	9628.86	9481.63	9119.78	8748.39	8384.53	7849.56	7396.90	7008.90	6599.83
46	494.00	2772.00	4875.33	6524.00	7515.20	8020.00	8378.29	8487.00	8483.00	8257.20	7997.99	7726.99	7283.75	6903.83	6574.57

These results could be observed in the following graphs plotted.

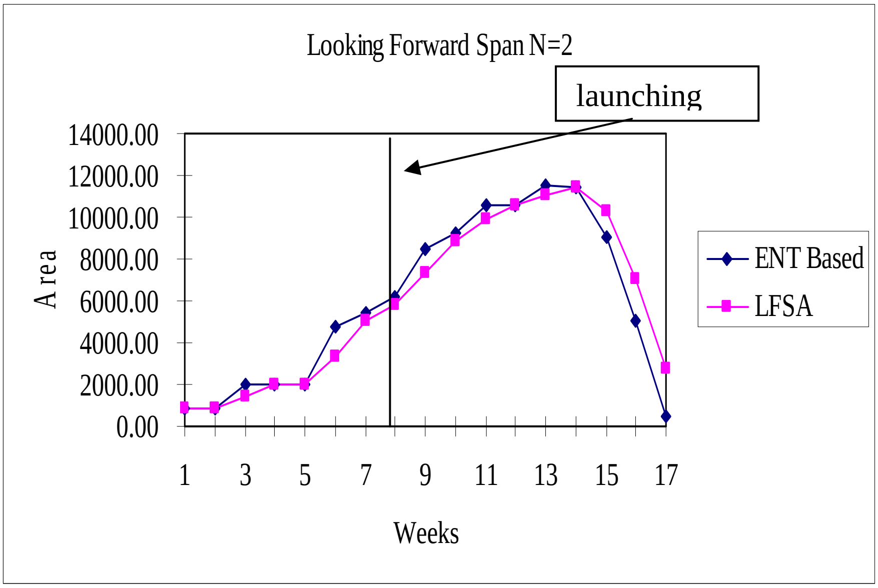


Fig 3.29 Looking forward to 2 days

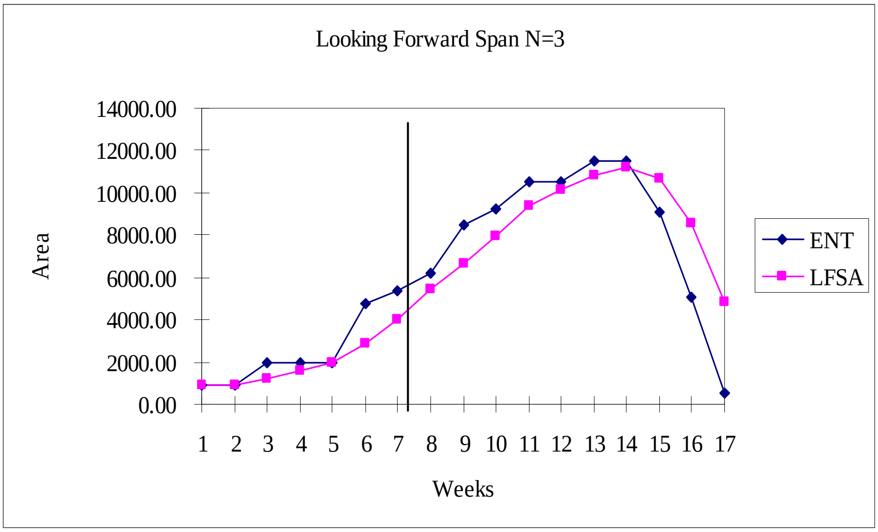


Fig 3.30 Looking forward to 3 days

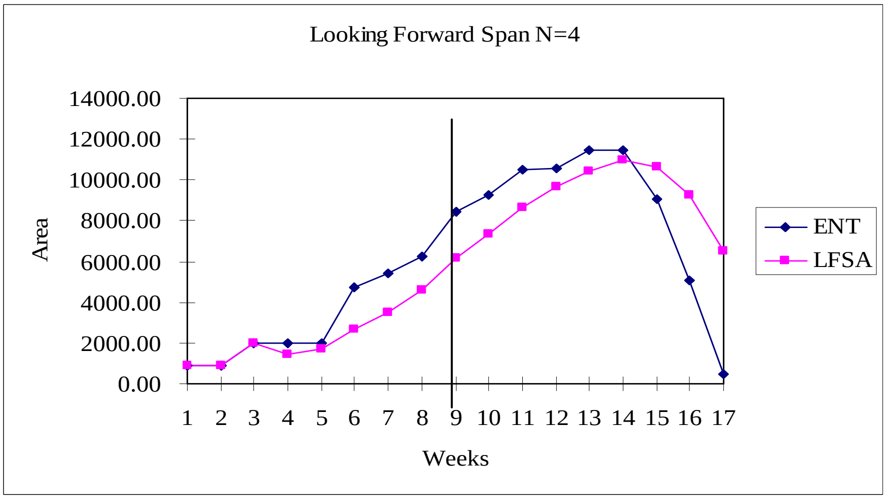


Fig3.31 Looking forward to 4 days

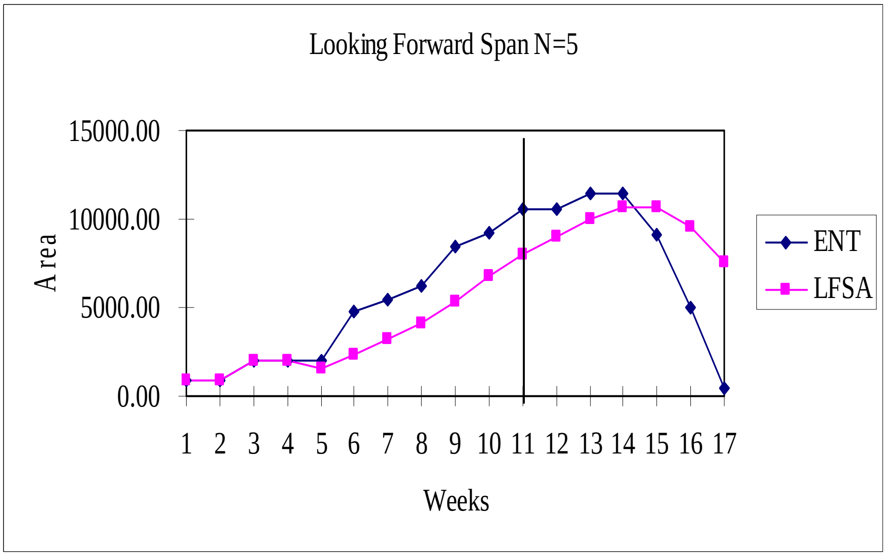


Fig 3.32 Looking forward to 5 days

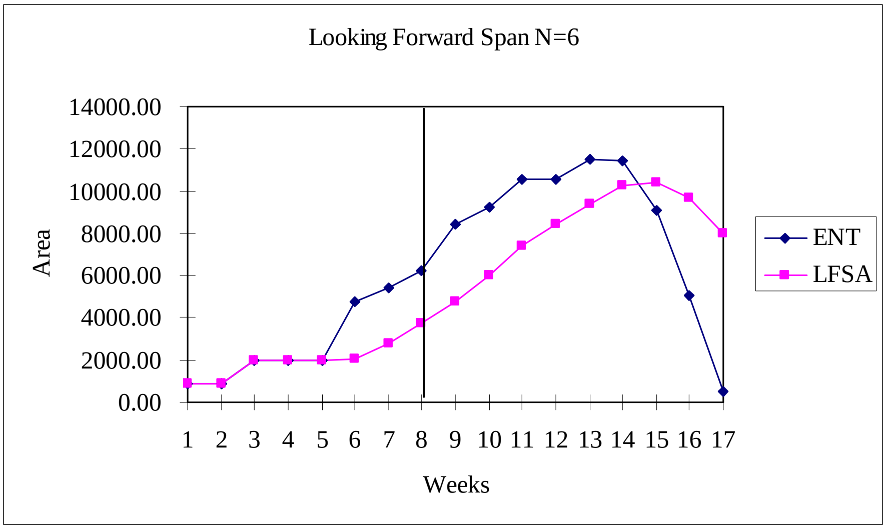


Fig 3.33 Looking forward to 6 days

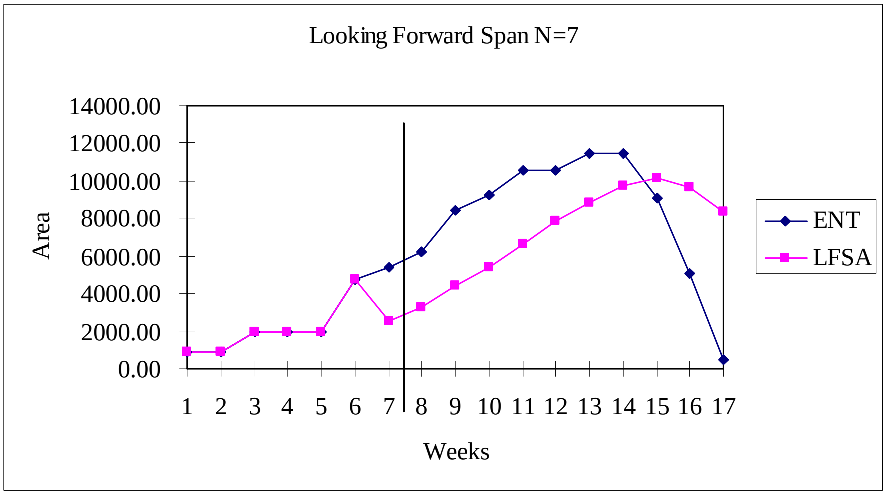


Fig 3.34 Looking forward to 7 days

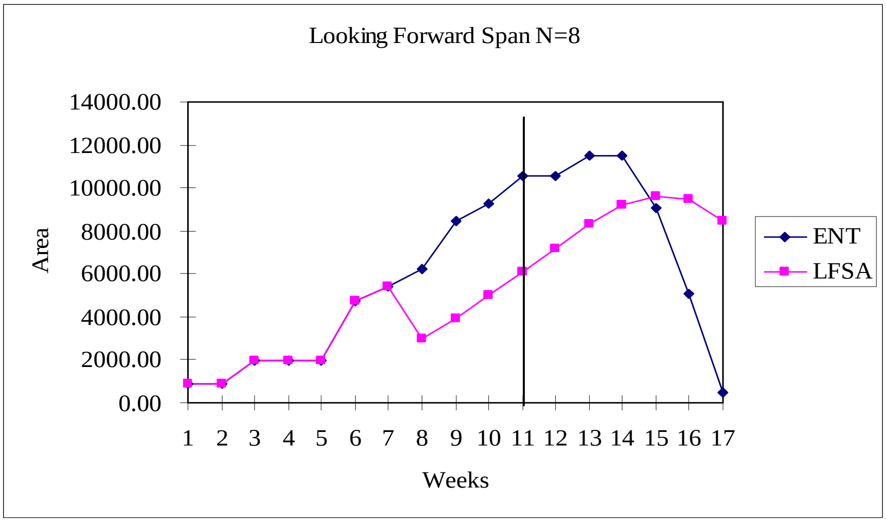


Fig 3.35 Looking forward to 8 days

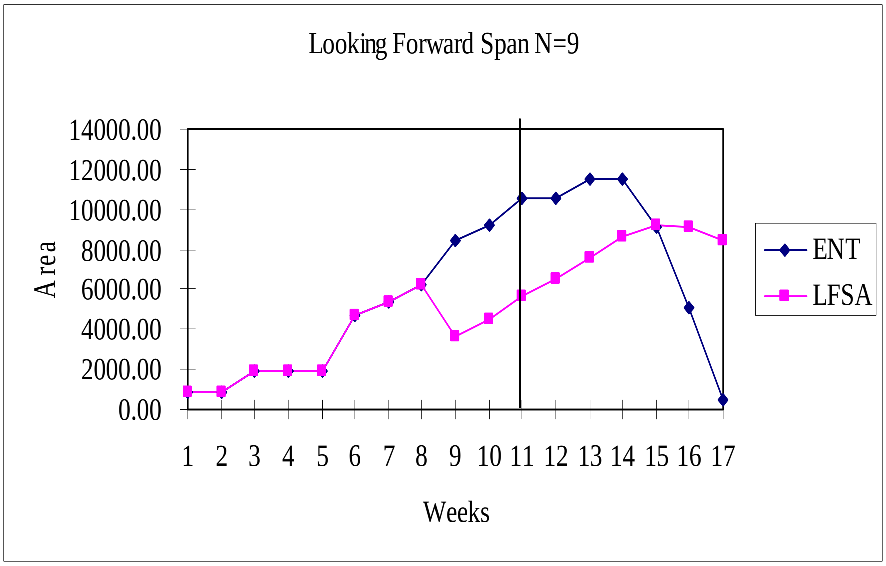


Fig 3.36 Looking forward to 9 days

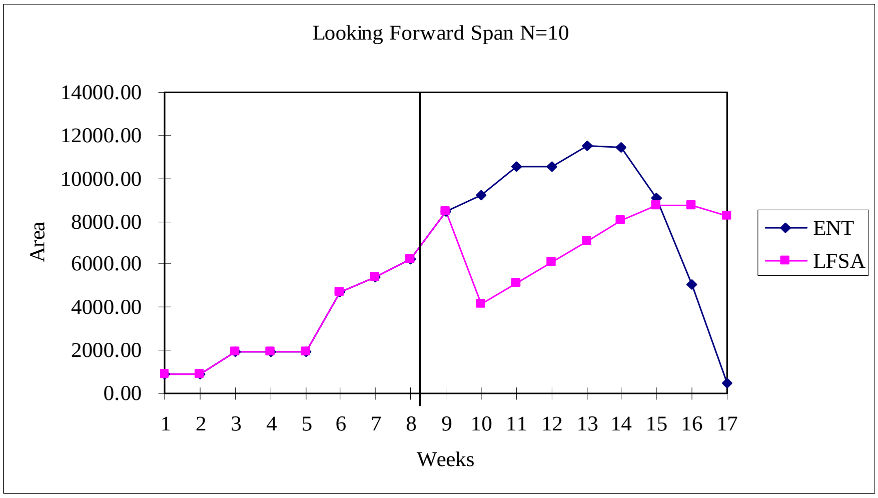


Fig 3.37 Looking forward to 10 days

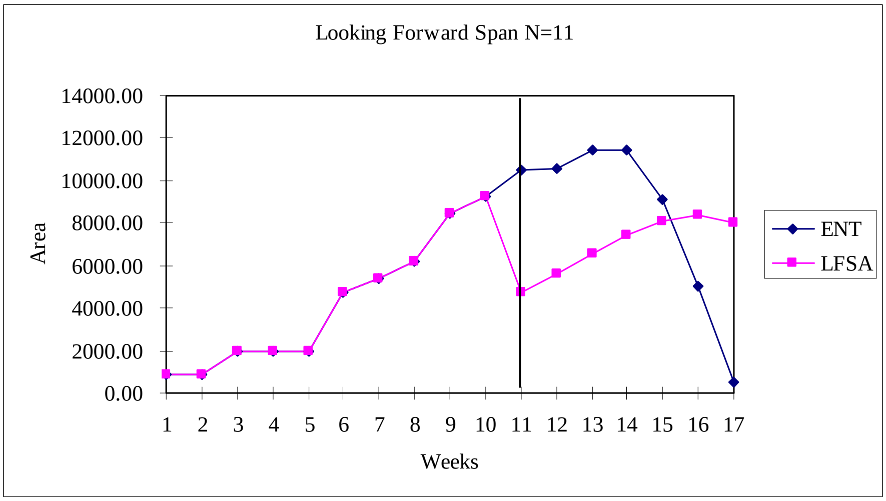


Fig 3.38 Looking forward to 11 days

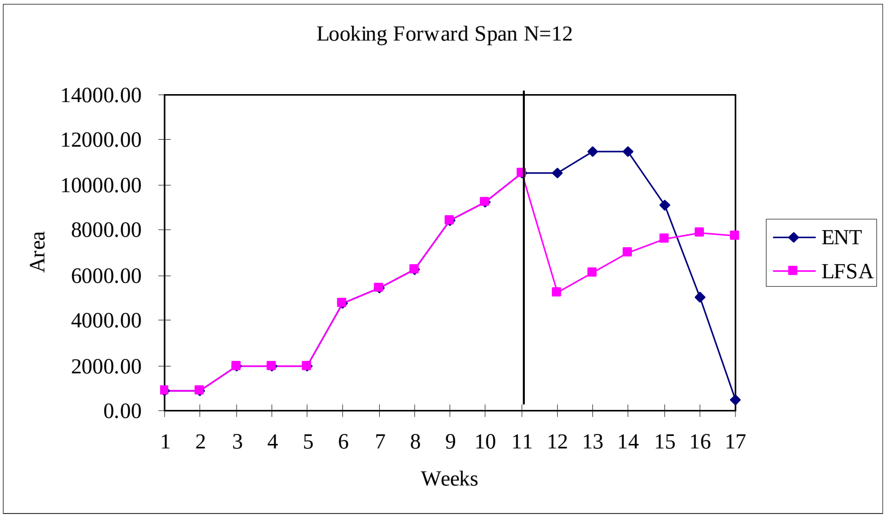


Fig 3.39 Looking forward to 12 days

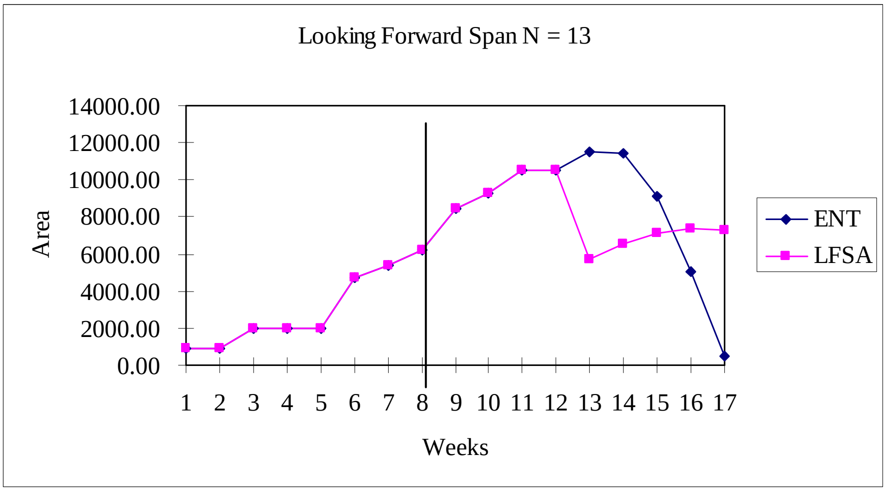


Fig 3.40 Looking forward to 13 days

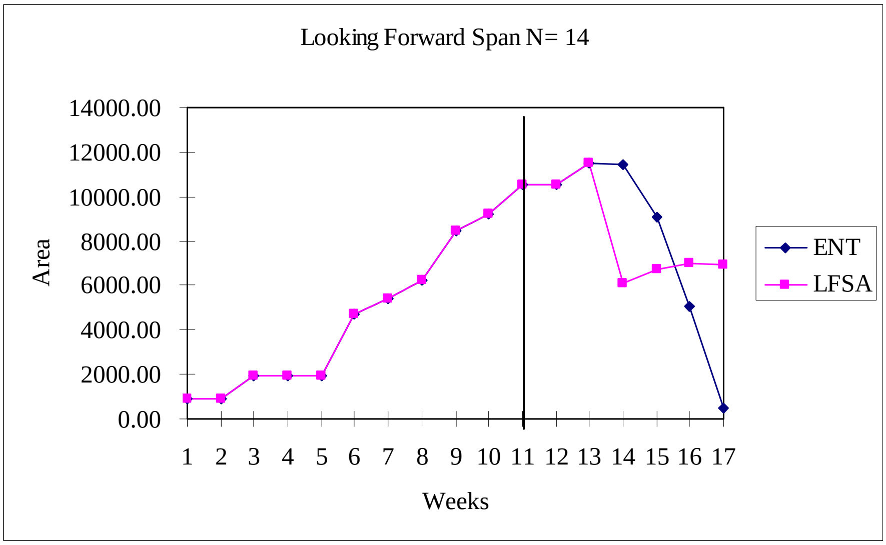


Fig 3.41 Looking forward to 14 days

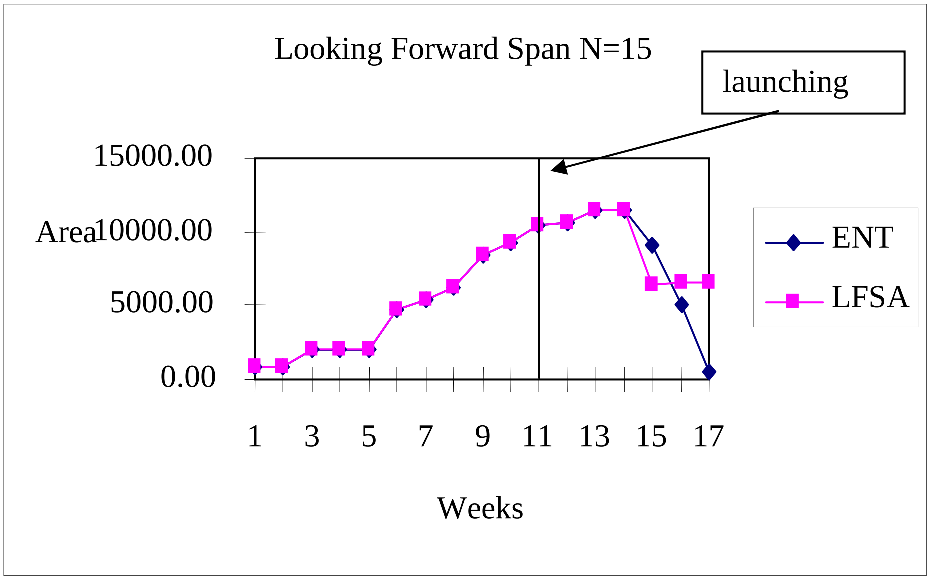


Fig 3.42 Looking forward to 15 days

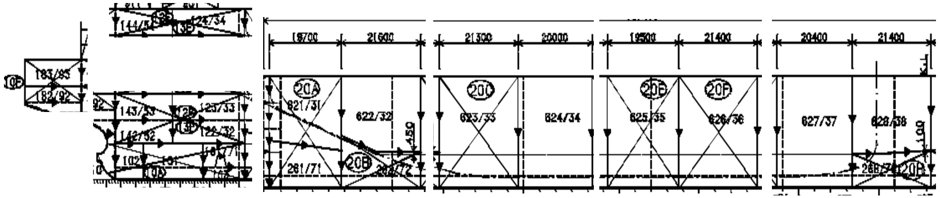
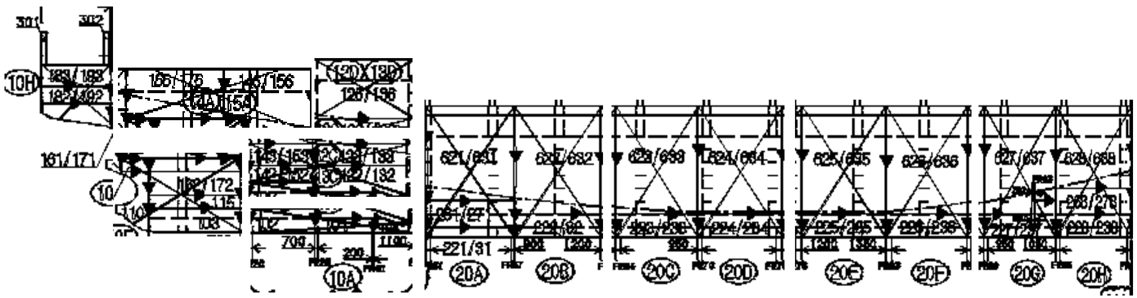
Now based on the 14 variations that being tested here for the weekly scheduling or the systems that is being presented here speaks of middle level schedulers who will interested in schedules.

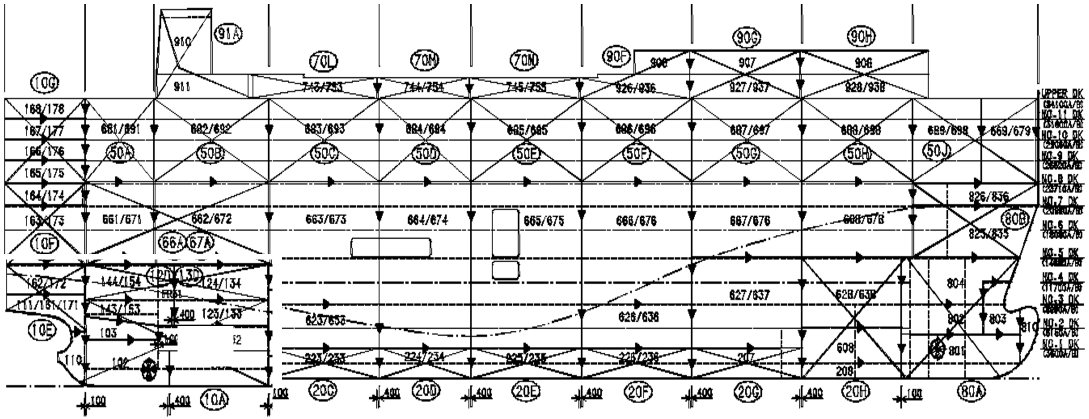
The value of looking forward schedule is obtained by concluding it as the mean working periods of the blocks. Here the curve gets smoothers as the span of the looking forward increases meaning the noise is negligibility low and there is not enough friction in the value. This gives the good solution by optimal load leveling as the schedule.

We can also analyze sway in the trend. When the block flow is rising and LFSA indicator is falling (negative divergence), or vice versa, it can be considered an indication of "something going on" and can be used to predict changes in a trend. The lagging indicator that is supposed to follow the block flow, is predicting the block transit behavior.

Here we observe the results were reasonably better when we implied the algorithm into the weekly schedule where we were looking forward for couple of weeks to schedule the rest of the days. This was by the analysis of two ships with a launching date well defined in between.

5.0

TYPE	FLOATING DOCK Sequence and 3,600 ton SEQUENCE	Remarks
115K C.O.T		* E/R Possibility of Bigger size (2,810ton) * TWO(2) RING BLK Necessary detail Checking Specification of moving method
8400TEU CONT'		* E/R No possibility of bigger size - Fix holder less (3EA necessary) - PRE-SIGHTING Condition not matching - M/E launching on sea condition

Ro/Ro		* FULL SHIP Erection Scheduling - E/R Possibility of bigger Size (M/E excluding) - PE period 8weeks necessary(F/S completion) - Other Engineering method : same application of year 2004

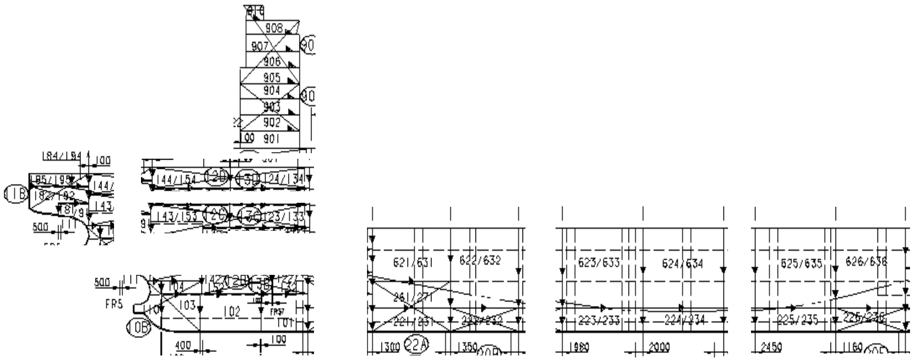
2500TEU CONT'		

Fig 3.43. Ship Erection Block of four Ships considered for full simulation of LFSA

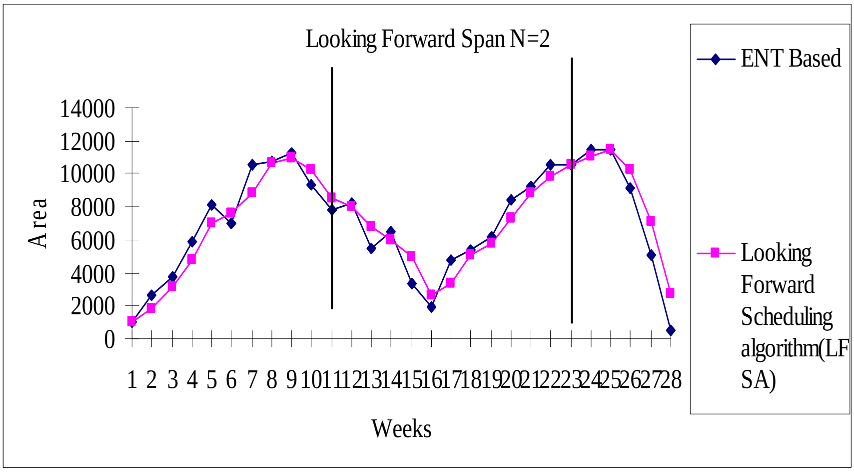


Fig 3.44 Looking forward to 2 days

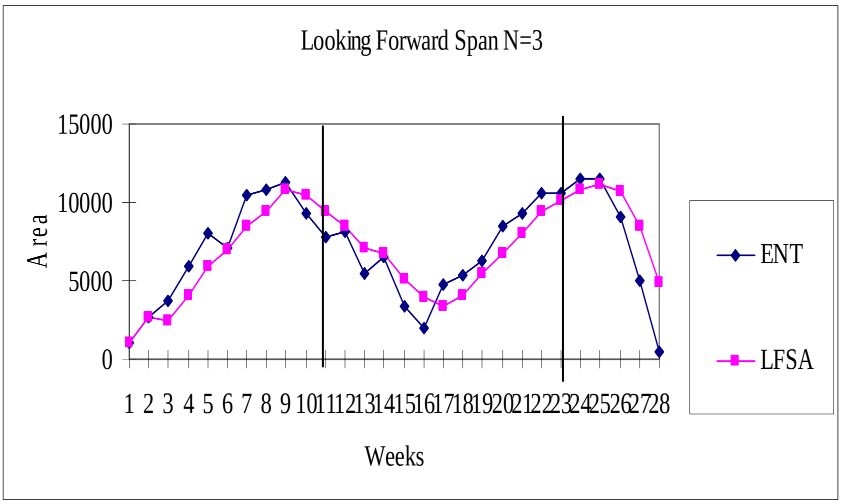


Fig 3.45 Looking forward to 3 days

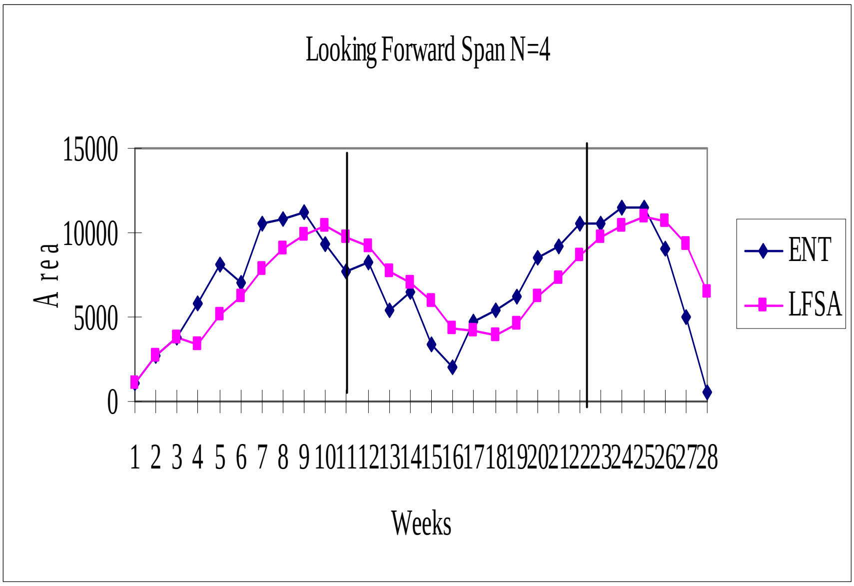


Fig 3.46 Looking forward to 4 days

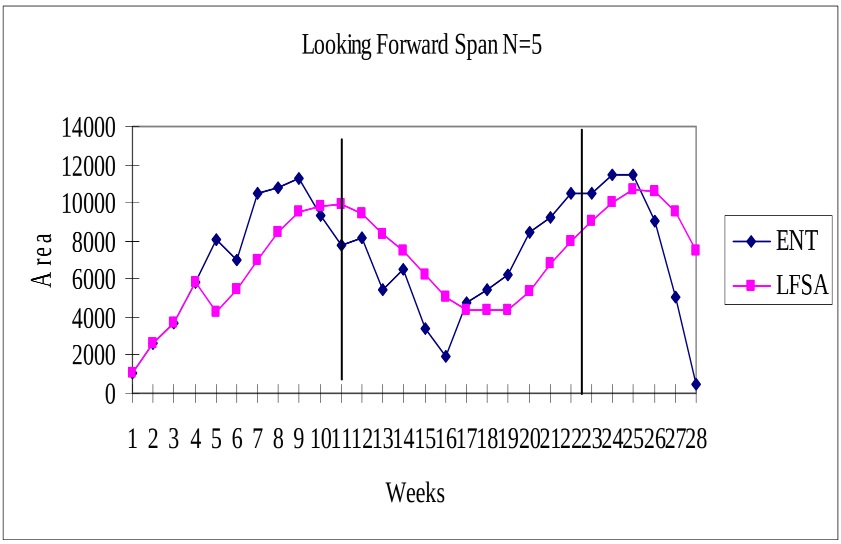


Fig 3.47 Looking forward to 5 days

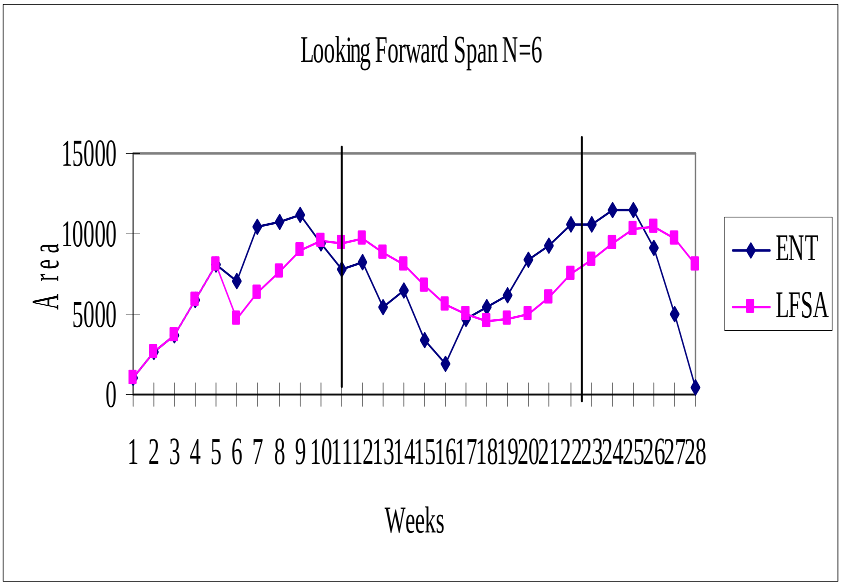


Fig 3.48 Looking forward to 6 days

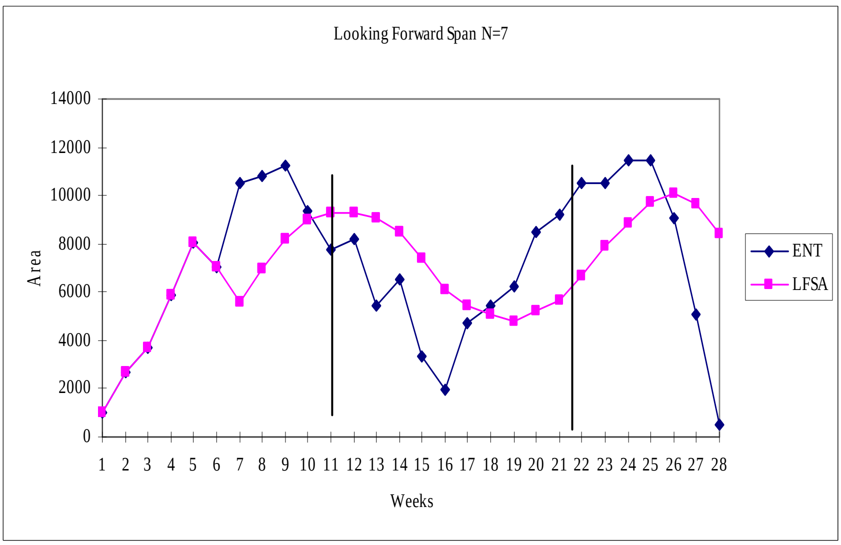


Fig 3.49 Looking forward to 7 days

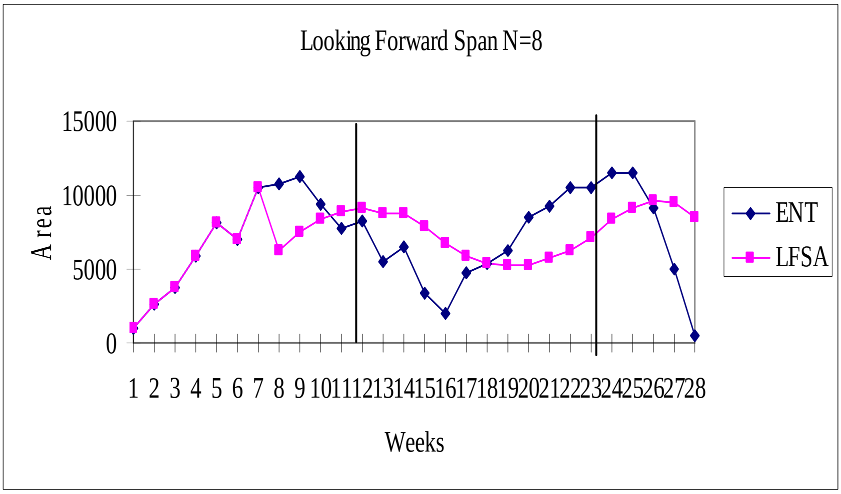


Fig 3.50 Looking forward to 8 days

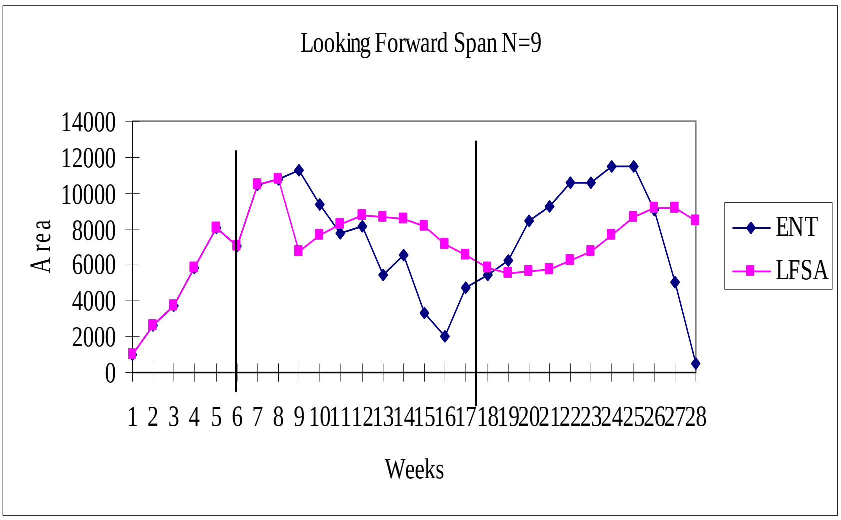


Fig 3.51 Looking forward to 9 days

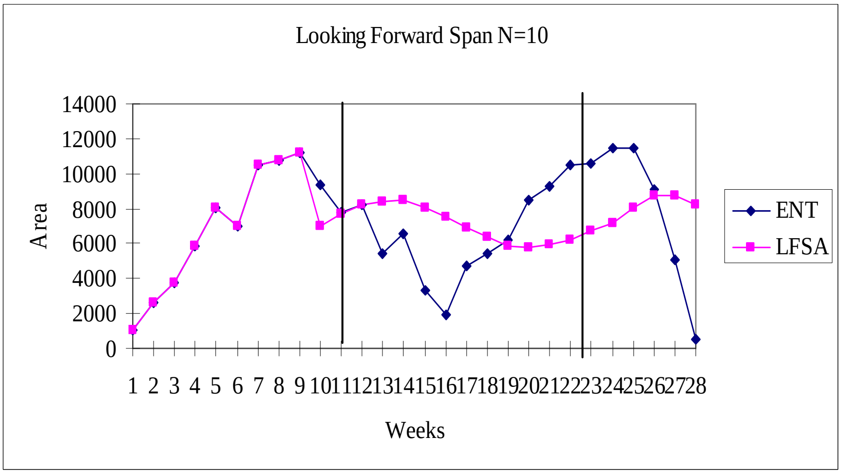


Fig 3.52 Looking forward to 10 days

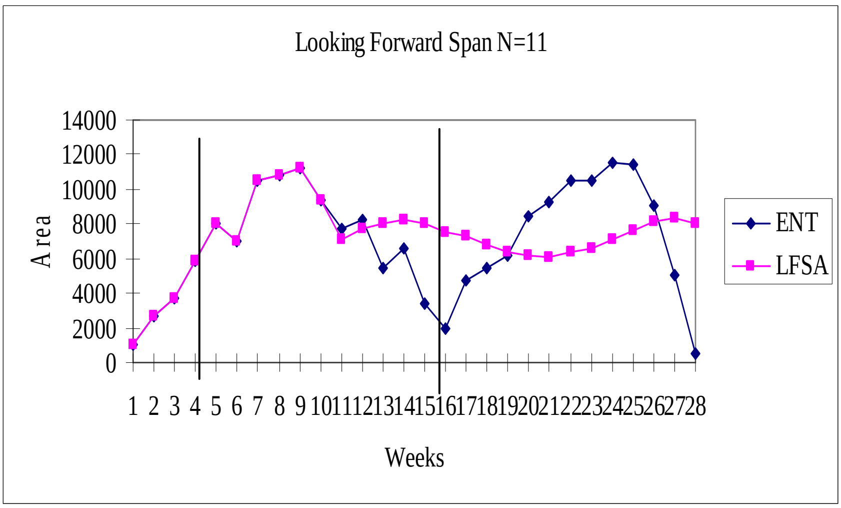


Fig 3.53 Looking forward to 11 days

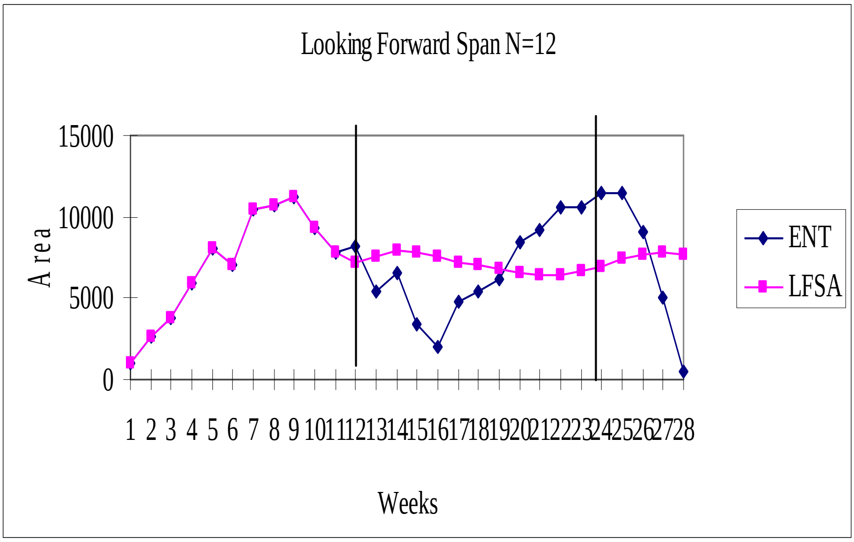


Fig 3.54 Looking forward to 12 days

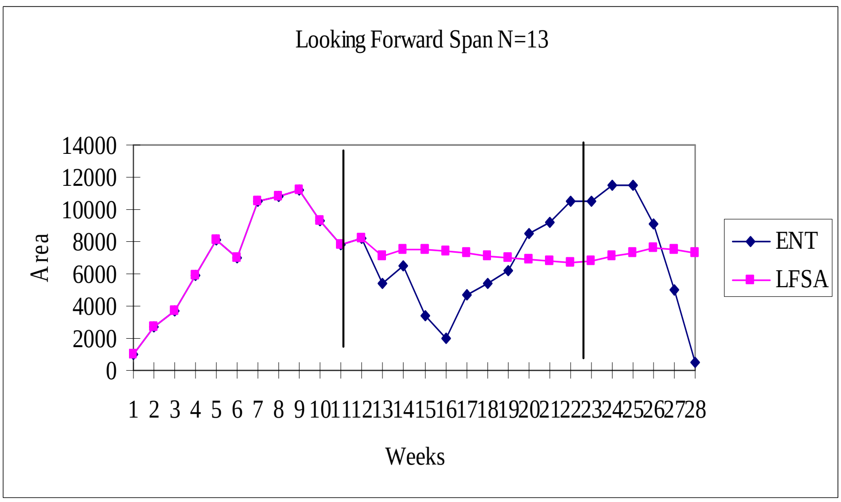


Fig 3.55 Looking forward to 13 days

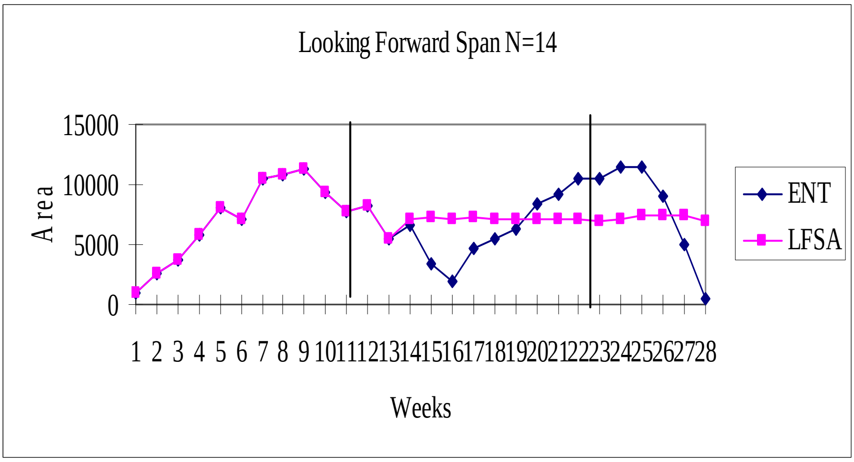


Fig 3.56 Looking forward to 14 days

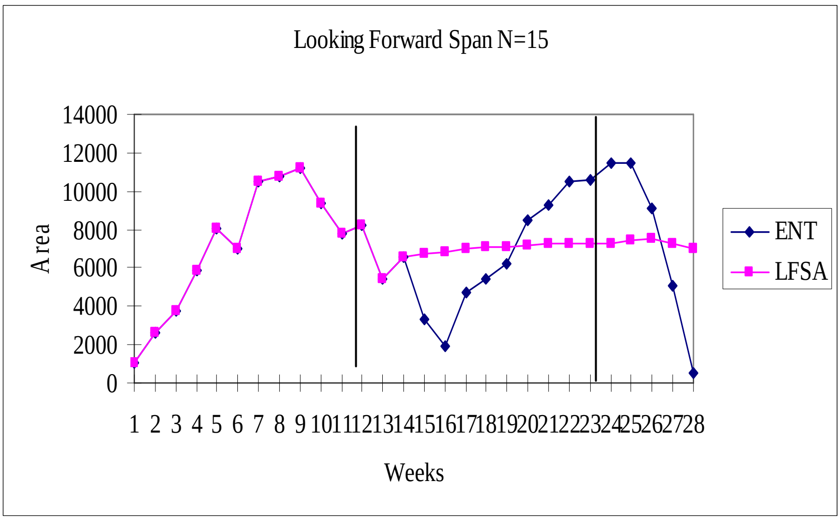


Fig 3.57 Looking forward to 15 days

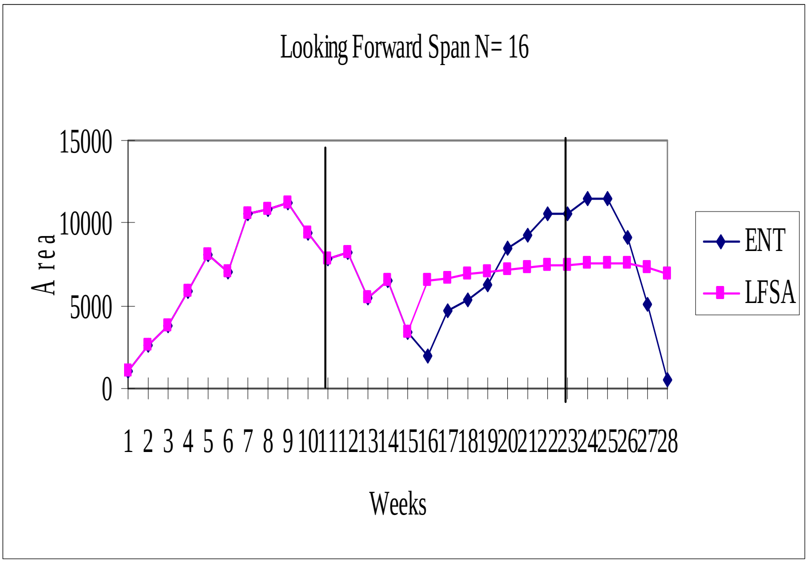


Fig 3.58 Looking forward to 16 days

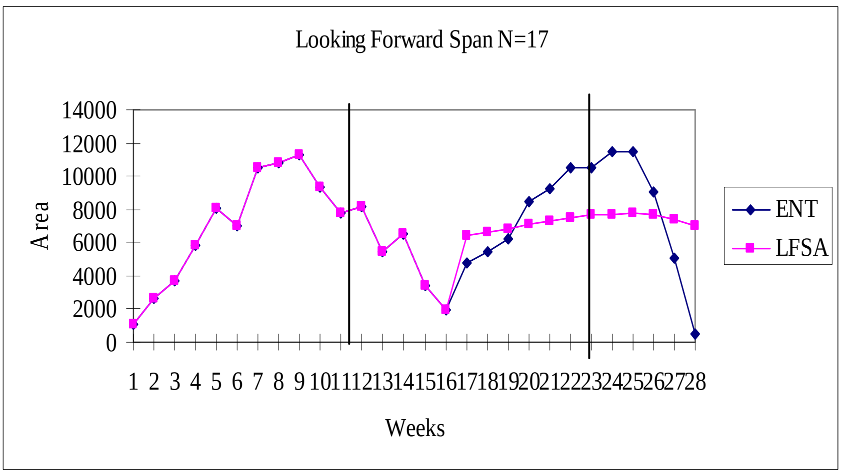


Fig 3.59 Looking forward to 17 days

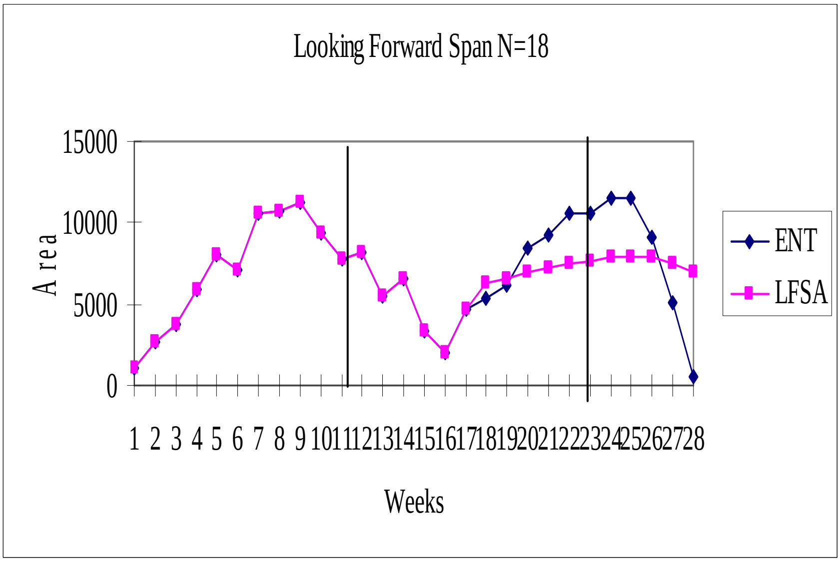


Fig 3.60 Looking forward to 18 days

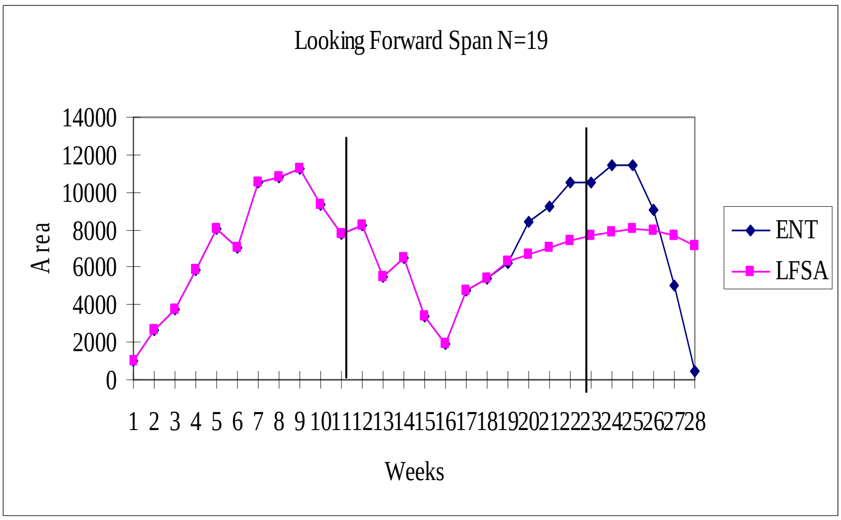


Fig 3.61 Looking forward to 19 days

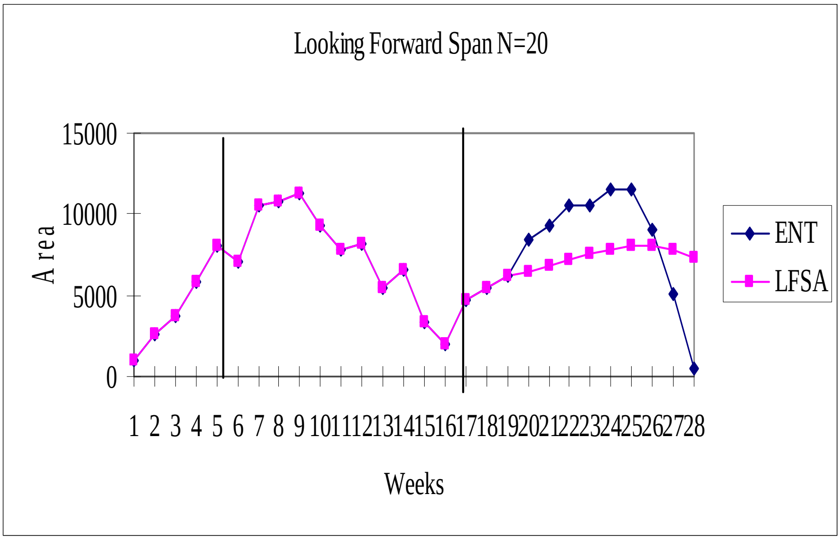


Fig 3.62 Looking forward to 20 days

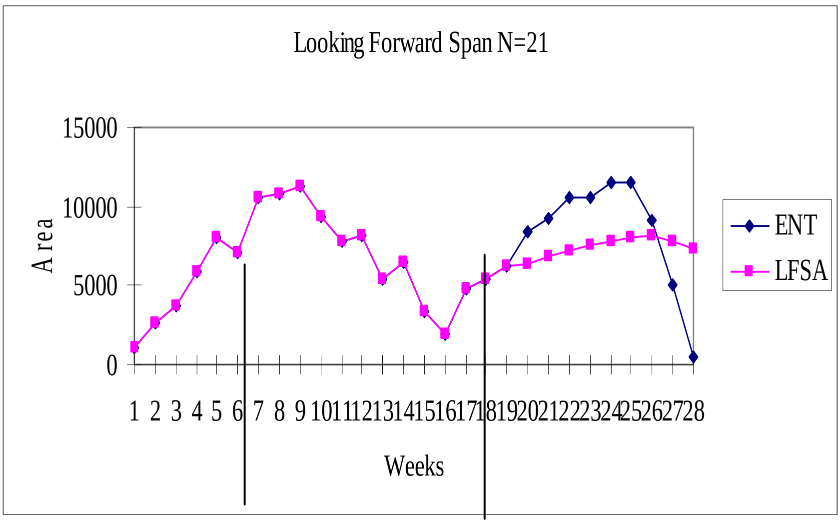


Fig 3.63 Looking forward to 21 days

In this experiment we have examined our core research finding, the LFSA method and tested for dynamically balancing the load in a live shipyard based four ship erection process will 2 launch cycle in a semi-tandem mechanism of shipbuilding. We showed that in order to cover a larger class of ideas and samples for schedulers. The numerical convolutions explained in section 2 model opens the door to new area of thought where a rather strong mathematical model will rather be serendipity. As such a problem to describe in a mathematical model will be a tyrant problem of its own that is based on queue length, time since the last decision and/ or those that are some hybrid of the two.

By examining the resulted graphs in the full-fledged graphs with four ships we gain valuable insights into the structure of an optimal policy in the PE load balancing system. In particular, we note that when the computational costs are small, and the holding costs equivalent, the main concern is to avoid the surge LFSA policy seems sufficient.

CHAPTER 4

Genetic Algorithm for Optimal Ship Erection Block Arrangement in Pre Erection Area of a Shipyard

4.1 Introduction

A genetic algorithm (GA) is a search algorithm by (Holland, J. H., 1975) that attempts to emulate the evolutionary mechanism of natural biological systems where the best gene is selected for the next generation (i.e. the survival of the fittest). In the optimization problems, GA approach has been successful for generating global solutions for which traditional search techniques have not been effective and to build robust search strategy, GAs employs ‘evolutionary mechanism’ as described using basic GA and popularly known as Simple GA (Fig 4.1).

The problem here is to find the optimal arrangement pattern for the shipbuilding blocks in the pre-erection (PE) area. There are many severe constraint conditions in the shipyard and the geometrical boundary limits of the PE area and underutilisation of the available area are the main reasons of bottleneck formation during the course of shipbuilding. A PE area is defined as the area which is adjacent to the dockyard and over which the giant goliath crane runs and this area is used to place the grand blocks those are ready for the erection of ship in the building dock. The space and time based constraints on accumulation pose a monstrous problem for the schedulers dealing with the erection at the shipyard.

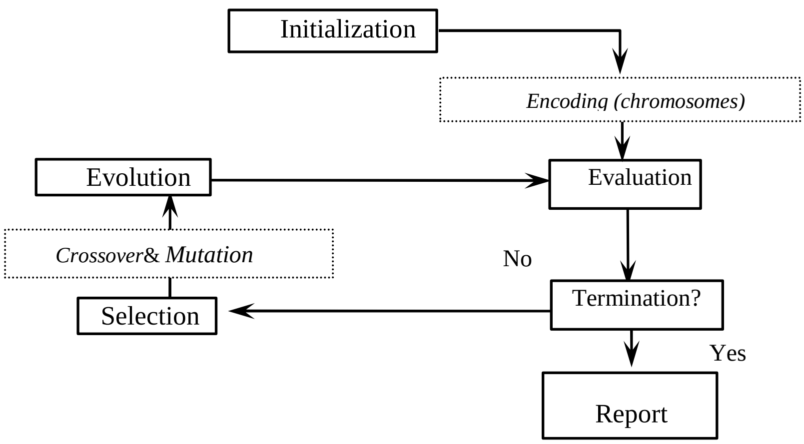


Fig 4.1 The general structure of simple genetic algorithms

A team of many schedulers using their personal expertise using a computer graphic program without any intelligent or decisional support handles the space situation. Here various pre-defined geometrical shapes are being matched manually in the graphical interface of the program. This takes a lot of manipulation and manpower as the individual cases had to be studied. The time factor is dealt with the conventional erection sequence diagram where there exist a lot of uncertainties since in this portion only the blocks on the critical path have a fixed date of erection otherwise the remaining blocks remain uncertain. This again is handled by a team of planners to resolve using their expertise and still poses a very tedious effort on the part of the schedulers.

The simple GA (Fig 4.1) works as follows. A population of individuals of a fixed size is initially randomly generated. Each individual is characterised by a string of genes and represents one possible solution to the problem being tackled. Strings can then be evaluated in terms of a metric giving a measure of how good the solutions are. This is known as the fitness value. The solutions are checked to see if they have met the search terminating criteria. If this is not the case a loop is entered. Using the fitness value the population undergoes natural selection. The strings, which are better, have more chance of surviving than other weaker ones. The surviving individuals are then paired up at random and mated (commonly known as crossover) with a probability to form new offspring strings. The idea is to derive better qualities from the parents to have even better offspring properties. The reproduction of the mating is continued till the full population is generated. This population is then mutated with a probability where small random changes are made to the children in order to maintain diversity. The newly generated strings are then re-evaluated and given fitness score and the process repeats until stopped. This is usually done after a fixed number of generations or terminated by levelling out of the average population fitness. The best strings found can then be used as near-optimal solutions to the problem.

PART A: Technique Development

4.2 Spatial Genetic Algorithm

4.2.1 Introduction

The Spatial Genetic Algorithm (SGA) basically a hybrid genetic algorithm. The hybridisation is done on the simple genetic algorithm with the BL (Bottom-Left) heuristic (explained later). The combination is made to produce better encoding of the genes as per other problem requirement.

When genetic algorithm is applied to spatial arrangement problem, the solution process is divided into two steps: location and allocation. First, at the allocation level, the chromosomes of binary bits are converted to starting solutions and used to assign the position as per the heuristic. Then, the assignment solution is converted into fitness value with which the selection process finds the best or the global optimum solution for this location problem.

In making of a successful spatial optimisation algorithm, GAs need to redesign their concepts and search procedures to meet spatial evolutionary algorithm from the theoretical computing technique. At first, the genetic operations should reflect spatial referenced information.

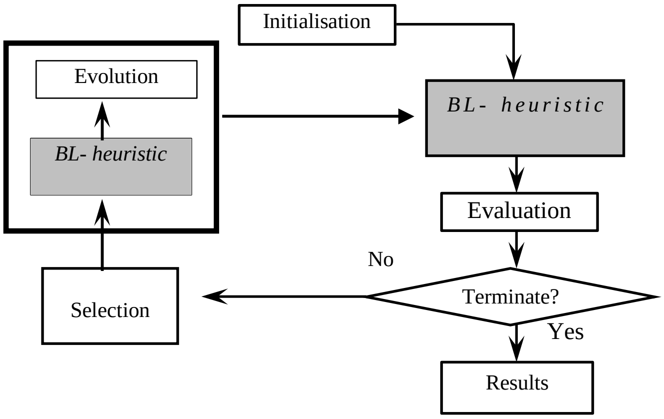


Fig 4.2 The structure of a spatial genetic algorithm for optimal block arrangement problem

For this, the chromosomes are required to form starting solutions indicating random generation. In this initialisation process, the initial locations of centres are randomly picked from a problem boundary or region if a search area is defined. The genetic operators, crossover and mutation, are applied to create new offspring or potential solutions at each generation. After that, the solution process is used to select the best individuals for the next evolutionary procedure. This process is continued until a termination condition is met. The description of the structure of spatial genetic algorithm (SGA) combining location optimisation routine and the position of BL (Bottom-Left) heuristic is given in Fig 4.2. The most distinguished feature of this SGA is to employ a current (or conventional if useful) location optimiser in the evolution procedures.

The use of location optimisation technique transfers the GA to suite spatial algorithm and incorporates the positive features of the current algorithm into the SGA. The typical benefit of this approach is to reduce computing time to obtain the global or near global optimal solution in the location problem. This is also a starting point towards the building of spatial hybrid GA that integrates simple GA techniques and current (traditional) search methods. The hybridisation approach for location optimisation was discussed in details by (Kim and Openshaw, 1999). Although most terminologies of the SGA are identical to the generic GAs, the following sections describe the main structures of the SGA redesigned for solving the shipbuilding block placement.

4.2.2 The Problem

Spatial Arrangement problem undergoes a process to determine the optimal locations for the shipbuilding blocks in the PE Area. In general, the model has an objective to maximise accessibility to material handling devices in terms of block movement distance or maximising spatial utilisation by reducing the scrap area (the usable unoccupied spaces between the blocks. In the model, the best possible optimal solution has to meet the objective function.

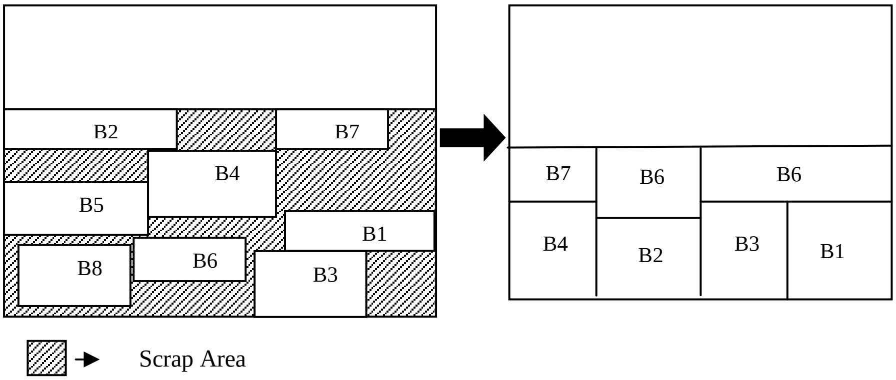


Fig 4.3(a). Haphazard block layout in PE Area Fig 4.3(b). Target Spatial Layout in PE Area

The objective function (δ) has a primary requirement to reduce the scrap area (underutilized space) in the PE area. It addresses the requirement of optimal arrangement pattern of blocks so that it occupies minimum possible area in the PE space. These problems are very serious issues in large industries like that of ship building industry. A feel of the problem and the purpose the objective function can be had from Fig 4.3 (a) and Fig 4.3 (b). Along with spatial occupancy criteria, a consideration has to be made in such a way that the blocks are arranged in easily accessible position to man and other material handling devices operating in PE and at dock premises.

$$\text{Minimise } \delta = \sum_{i=1}^{n} \sum_{j=1}^{p} w_i c_{ij} \lambda_{ij}$$

Where, w_i is weight i.e. block erection ranking obtained from erection sequence diagram, and c_{ij} is block transit distance from PE area to erection site or the dock, n is the number of blocks, and p is the number of block arrangement pattern at the PE Area i is the block location in the PE and j is the block erection point on the ship location, and λ_{ij} is allocation decision variable (1 if assigned, or 0 if not). It is easy to see that there is always an optimal solution with all $\lambda_{ij} \in \{0, 1\}$, i.e. each demand (maximal spatial occupation) satisfies from a single permutation order. The search for the best placements rearrangement sample or the chromosome in GA terms, the model employs solution technique and algorithm because the solution process reflects a NP-hard combinatorial problem. As a new approach, evolutionary algorithms and heuristics are proposed for this problem.

4.3 Bottom-Left heuristic

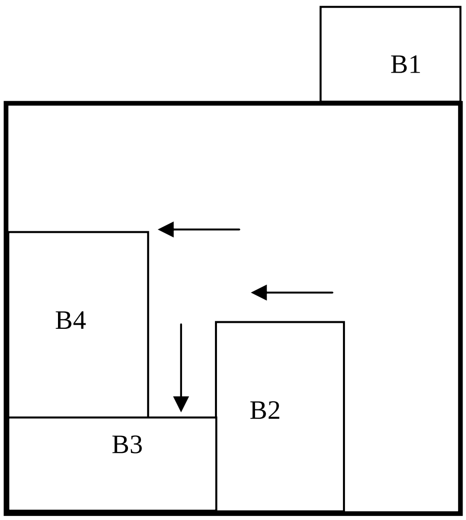


Fig 4.4. The illustration of Bottom Left Heuristic

The most important stage in the development of the algorithm is its objective. The objective here is to place the shipbuilding blocks in the PE area optimally minimizing the scrap area. In order to create meaningful chromosome samples. The bottom left heuristic (Jakobs **S, 1996)** is adopted here (fig.4) and it serves the block placement algorithm while an assumption of rectangular global (Pre Erection area) and the local layout (block plan area) is made. Here each block is moved as far as possible to the bottom and as far as possible to the left. An ideal position is found when the rectangle coincides with the boundary layout at the lower and left side. In (fig.4), we can see placement of permutation order (3, 2, 4, 1). In order to avoid the gaps in the arrangement, we have to ensure that the blocks are well seated in the best possible way as our heuristic is based on the allocation of the lowest sufficient large region in the partial layout rather than on the series of bottom-left moves, as it will ensure the minimization of the scrap area (the left over area).

This concept is observed for the present problem and a variety of spatial search techniques namely, maximal remnant space utilization strategy, maximal free rectangular space strategy, initial positioning strategy, and edging strategy are in use. The rotations of blocks are restricted in this problem.

4.4 Initialisation

Within the problem space, the initial locations of the blocks are converted from the binary bit chromosomes which are randomly selected from the area boundary information. The most simple but computationally effective method is to employ maximum and minimum location values of the area. For example, given the rectangular region, each variable of the solution, a X and Y coordinates of the blocks can take a value from the problem domain, i.e P.E Area{X_{min},

X_{max}}, {Y_{min}, Y_{max}} and the spatial precision value, M_j, is determined by the X and Y coordinates ranges of weight w_i.

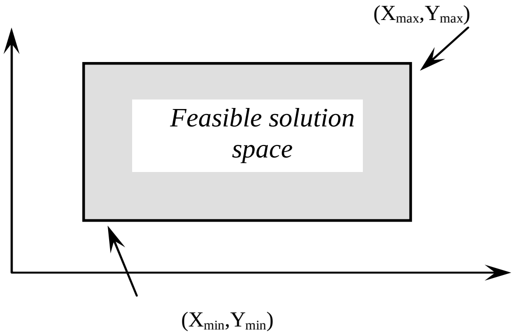


Fig 4.5 Solution space description

The problem search boundary is limited in the region described by Fig 4.5. In Fig 4.6 the algorithmic description of the SGA is demonstrated where I is number of the bits allocated in the chromosomes during in the preceded run and *m* is the expected number of bits in each chromosome.

procedure spatial genetic algorithm
begin
  $k \leftarrow 0$
  define X_{min}, X_{max}, Y_{min}, Y_{max}
  repeat
    $k \leftarrow k + 1$
    while $I < m$ **do**
      X^k_i = rand (X_{min}, Y_{max})
      Y^k_i = rand (Y_{min}, Y_{max})
    Return (X^k_i, Y^k_i)
  until k = population size
end

Fig. 4.6. Spatial GA initialisation description

The above procedure explains that several starting solutions are generated randomly and the SGA uses the solution sets to determine the starting locations of candidate blocks, which will be searched for finding the optimal locations of the centres. After decoding the starting solutions, the genetic algorithm produces an optimal solution, and the solution value is then used in the evaluation stage to explore the best parents.

4.5 Crossover and mutation

The spatial crossover (Fig 4.7) decides the evolution steps that how to choose parents and how the parents produce their offspring while working with the spatial genetic algorithm. There are a variety of crossover strategies for generating good offspring and to determine the rates (Back,

T. and H. P. Schwefel, 1993; Grefenstette, J. J, 1986). In this paper, a simple method is applied to the genetic operator, which selects two parents by random probability of weighted selection (Goldberg, D. E, 1989) and the rate is set to 90% (0.90) to enhance the selection rate.

```
procedure spatial crossover
        select 1st parent individual, k1
        if random rate < crossover rate (i.e. Pc = 0.90) then
                select 2nd parent individual, k2
        else
                select k2 in last generation
        endif
        if k1 = k2 then
                stop
                go to spatial mutation
        else
                calculate crossover cutting points for k1 and k2
  1st cutting point, k1,  = rand * strLEN + 1
      2nd cutting point, k2,  = rand * strLEN +1
                endif
end
```

Fig 4.7 Pseudo- Code of the adopted crossover

While the crossover step reflects the information exchange of parents' level, the use of mutation attempts the change of the new offspring itself. Since the new offspring consists of some features of its parental outstanding, in evolutionary system, the offspring should also experience small changes in its chromosome. For this, the mutation operator randomly alters a small percentage of the genes by changing '0' to '1' or visa versa. This also keeps the GA from converging prematurely and forces to exploit other search spaces on the problem surface. The mutation rate like the crossover varies, but the values between 1% and 20% are commonly used (Grefenstette, J. J, 1986).

4.6 Selection

After creating new sets of offspring, evolutionary system needs to consist new generation group (population) which corporate parental and offspring genetic features that contain better fitness values. For this, selection strategy is employed after the evolution stages. The procedure is to create a new population for the next generation from either all parents and offspring or part of them. This is related to the problem of sampling space (Gen, M. and R. Cheng, 1997). In this paper, an enlarged sampling space method is used, which is illustrated in (fig 5). The obvious advantage of this technique supports the SGA to improve their algorithm performance in terms of solution quality by increasing crossover and mutation rates without too much perturbation. By using this method, the SGA keep constant genetic operation rates during the evolution process.

4.7 Termination Criteria

Several termination techniques and strategies have been proposed to genetic algorithms

(Michalewicz, Z, 1996). The simplest termination condition is to stop GA running if the total number of new generations exceeds a predefined maximum number such as 100 times. Another way is to check a condition of the population, such as measuring convergence conditions of the population or the evolution progresses in each generation and then, terminate the GA running if the results are met the condition. However, the disadvantages of the former way are uncertainty of meeting the best or global optimal solution at the terminated generation or large computing costs if bigger stopping number is given. For the latter way, it is difficult to identify the adequate measuring conditions, which varies in each optimisation problem. In this paper, the SGA employs the combined termination strategy that stops the GA running when the best solution has not changed 10 times after exceeding a predefined generation numbers such as 100 times.

PART B: EXPERIMENTAL VALIDATION

In Part A the concepts and the technique for solving optimisation problem of shipbuilding blocks in the PE Area have been conceived using indigenously developed Spatial Genetic Algorithm Technique. The developed computer code is tested for its competence and various sets of data experimented. The procedure of the experiment is illustrated in Fig 4.8.

4.8 Conditions of Experiments

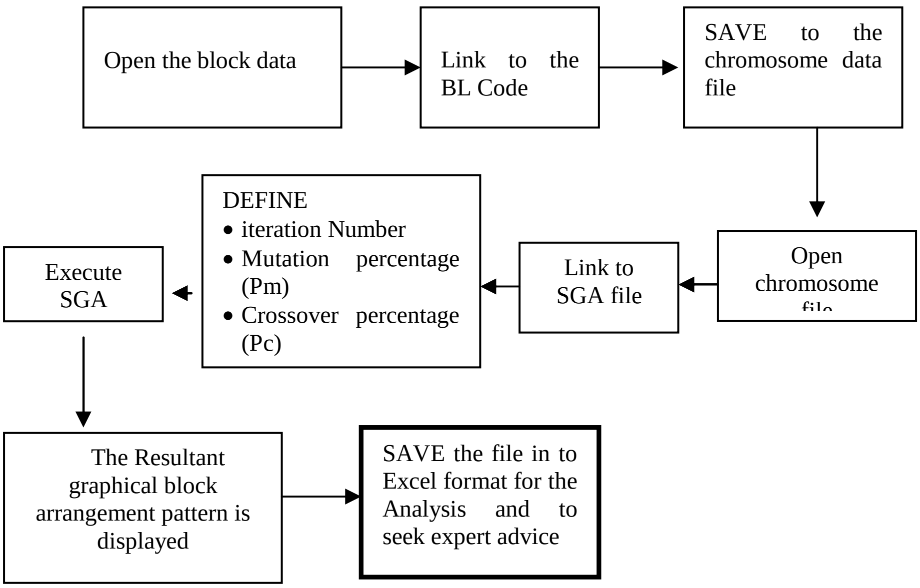


Fig 4.8 Procedure of the Experiment

There 30 finished blocks to be allocated in the PE as has to wait for their respective erection sequence to come. The Pre- Erection Area at the client Shipyard is 150 m x 80 m. The finished blocks have to be assigned a place. This placement has to be executed in the best possible way.

The experiments are conducted with the following conditions:

Number of blocks = 30
Geometrical Constraints:
Length of PE Area = 150 m
Width of PE Area = 80 m
Number of iterations = 3000
Probability of Mutation = 0.3
Probability of Crossover = 0.7

Table 4.1 Block Dimension input data

p1(0)	(21,20)
p2(1)	(21,20)
p3(2)	(18,20)
p4(3)	(18,20)
p5(4)	(18,20)
p6(5)	(18,20)
p7(6)	(21,21)
p8(7)	(21,21)
p9(8)	(21,21)
p10(9)	(21,21)
p11(10)	(21,21)
p12(11)	(21,21)
p13(12)	(21,21)
p14(13)	(21,21)

p15(14)	(21,21)
p16(15)	(21,21)
p17(16)	(22,23)
p18(17)	(22,23)
p19(18)	(22,23)
p20(19)	(22,23)
p21(20)	(22,23)
p22(21)	(22,23)
p23(22)	(22,23)
p24(23)	(19,23)
p25(24)	(20,13)
p26(25)	(19,12)
p27(26)	(18,14)
p28(27)	(18,14)
p29(28)	(18,12)
p30(29)	(18,14)
p31(30)	(18,14)
p32(31)	(18,14)

The experiments are performed using the live shipyard block data to argue the competence of the proposed algorithm. The best placement block arrangement sample will be characterized by the area that is not occupied after placing the blocks. This area is referred to as scrap area.

Once the conditions are set and the live shipyard data (Table 4.1) is being fed into the developed system. This algorithm is tested with the aspect ration based method and the comparative results are obtained.

4.9 Aspect ratio based method

The aspect ratio based method is applied here for testing and it is popularly known for graphical optimization. Many of the research have been conducted using this algorithm for the placement optimization. In this mechanism blocks are weighted in the ascending order of its aspect ratio and placed using BL algorithm in the PE area. Here the weights are given as per the aspect ration of the block unlike the genetic algorithm way. The codes has been prepared and tested for its competencies.

4.10 Comparative Results

The comparative result analysis was made and the explanations are giving here under with the use of Fig 4.9 and Fig 4.10. The current methods are basically involved with the conventional trial and error method done by most experienced engineers in the production-planning department of the shipyard.

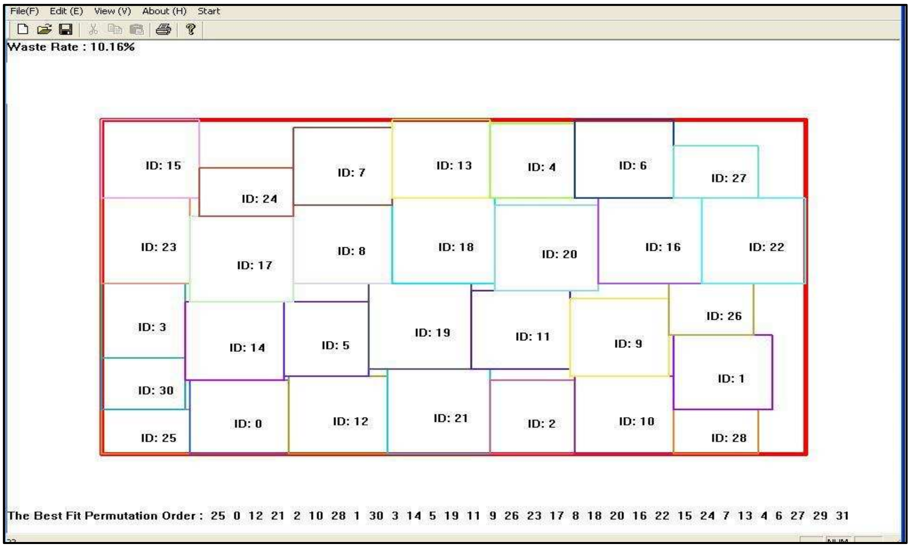


Fig 4.9 Genetic Algorithm based block Placement method results

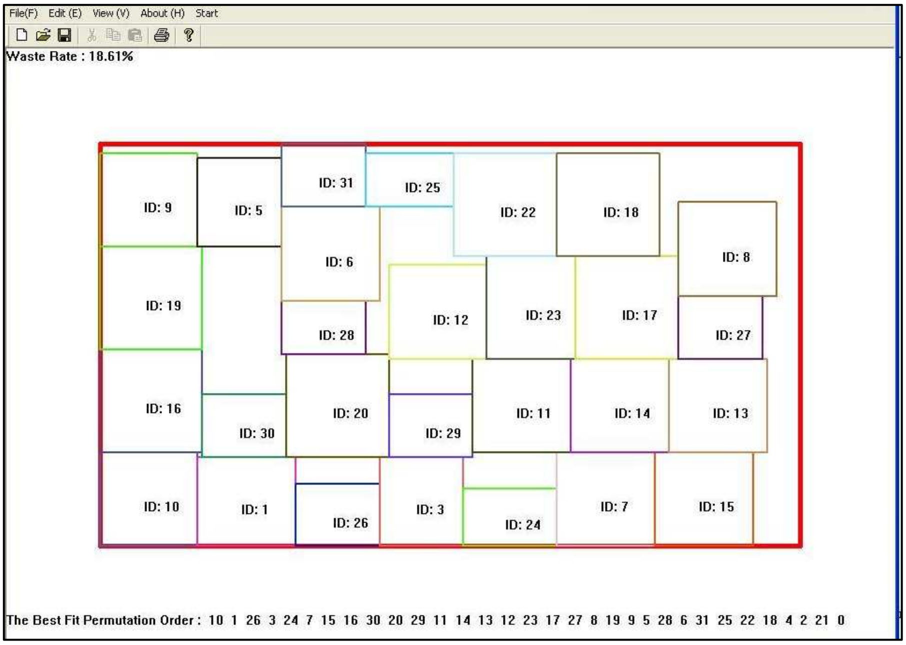


Fig 4.10 Aspect- Ratio based block Placement method results

This kind of approach is very tedious and at the same time consumes lot of labour to take the decisions yet failing to make percentage decrease in the space wastage in the yard. As the name signifies in trial and error method there is no guarantee of the better results since the numbers of blocks are high in number, thus the placement samples could be very large in number. The placement sample for ‘n’ blocks would be n!   Describes its complications. Therefore a genetic algorithm based approach is implemented as described in the previous sections and adopted and the results are compared with Aspect ratio based method that is also recommended to be used as per the available literatures. In order to argue the competence of our hybridized genetic algorithm based method this method has been compared with the conventional trial and error method and the Aspect ratio based method.

While observing the shipyards live data the observation has been made that on an average wastage of 25% area in the PE erection Area leading to high load fluctuation in the spatial occupancy. Therefore the research has been performed to get the better results and comfortable way for the user. The experiments on the proposed algorithm shows the Aspect ration based method produces the 18.61 % spatial area wastage. The application of genetic algorithm gives the considerable good results of 10.16% wastage of space the lesser computational expense.

CHAPTER 5

CONCLUSIONS AND FUTURE WORK

5.1 Conclusions on Erection Sequence Network

The technique argued here has been implemented and has produced convincible results. The system developed updates the block data list once the best fit chromosome is produced Open/Load Block Data and Pitch Data. The saved changes into the excel spreadsheets for MIS analysis. The developed scheduling algorithm has generated optimal schedule and candidate block set. This contribution has illustrated a forecasting scheduling application at the PE area. The PE area has been studied by performing various experiments and an observation has been made which shows the credible improvements in the load balancing with adjustment of the fluctuations in the load. The developed erection sequence generator program is capable of handling any desired number of blocks required in a shipbuilding process with multiple project and database modifications facilities. It is presumed that the shipbuilder will find this proposed algorithm for the application on their specific cases.

The developed erection sequence generator program is capable of handling any desired number of blocks required for ship building, with multi tasking abilities, database modifications facilities for customizing and producing the network related solutions has been developed. This software is successfully clubbed up with virtual shipyard interface. This could produce self explained graphical color output of the spatial layout of pre-erection area, which helps in reconsidering and give proper MIS to take concerned corrective actions and further optimizing the block flow pattern. The main advantage of such efforts is that without any additional investment in man and machine, an eventually stupendous erection network working strategy is evolved. A little modification can help the system to perform well in other related complex scheduling networks.

5.2 Conclusions of Genetic Algorithm on Spatial Arrangement Problem

Especially, the developed product data model helps shipbuilding industry to systematically categorize the complex structures of the product data handled during the life cycle of a ship under construction. The model is of high relevance for realizing information technological solutions as well as improving the information and communication structures of shipbuilding projects.

With the suitable communication structure hosted by a communication platform, clearly distinguished construction and design tasks can be transferred to floor or system operators for fulfilling these tasks. The results of the work of these network partners concerning their work packages have to be re-transferred to the coordinating the shipbuilding project that integrates these results into the overall context.

As previously stated the objective of this current two-year project is to provide proof-of-concept relating to the establishment of a distributed problem-solving environment involving a coupled data modelling component and an optimization component. An initial architecture involving time and space has been developed and results so far support the feasibility and potential utility of this distributed problem solving approach. A stand-alone demonstrator has provided an indication of further system requirements during the initial development stage.

CHAPTER 6

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