“Modeling and Simulation of a Production Line (Panel Line) in shipbuilding Industry using Tecnomatix Plant Simulation 9.0”

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ABSTRACT

Shipbuilding industry is one of the most difficult operations as far as design and production are concerned, since it is production processes where hundreds of thousands of parts are welded and joined together to only just give a single product (Ship). The technical complexity of the ship industry is highly related to the fact that different types of ships entail distinct specification requirements that affects the design and production system adversely. The construction of the ship is really a special challenge since it should in principle satisfy the requirements of the ship owner, shipyard and the Class and Flag Society which usually presents a conflict interest.

The purpose of this thesis is to examine the production line (Panel line) in shipbuilding industry through the application of modeling and simulation techniques using Tecnomatix Plant Simulation 9.0 software considering two types of ships (Tanker and Container) for which most of the stiffened panels are produced in the Panel line. During modeling, first the existing condition has been modeled and simulated considering the parameters for each work station (station time) in order to get an insight about the production rate, the effect of each work station on the overall panel line and their utilization. Next, Scenario analysis has been performed in effort to improve the production rate along the panel line applying the experimental manager and the genetic algorithm tools within the software by selecting appropriate optimization parameters from the work stations so as to improve the productivity. Furthermore the influence of the addition of a new workstation on the existing panel line has also been examined in both cases (Tanker and Container ship) that would be very useful input for the new workstation to be incorporated soon that leads to the design of a new work station.

The simulation analysis carried out in this project revealed that the same work station is acting as a bottleneck which is affecting the productivity of the panel line both for container and tanker ships considered in the analysis. Different improving alternatives have been presented in the paper and a new work station has been designed in such a way that it will not at least affect the productivity of the existing production (panel) line considering sub-station within the new work station. Finally, In order to give more flexibility to the modeling and simulation process, an interface has been established with the Microsoft access (database) where the data for the workstations’ parameters will be stored and to Microsoft excel where the final results will be exported that facilitates the use and visualization of the results. The Microsoft access and Microsoft excel files have been placed on the same interface (Model frame) in order to easily access the files at the same time. Based on the overall analysis carried out in this thesis, a conclusion has been drawn.

Key words: Ship Building, Modeling, Simulation, Panel Line, Work stations, Productivity.

ACRONYM

ABS	American Bureau of Shipping
BV	Bureau Veritas
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CMT	Computer Integrated Manufacturing
COM	Computer Optimized Manufacturing
DNV	Det Norske Veritas
FS	Frame spacing
GA	Genetic Algorithm
GL	Germanischer Lloyd
HTML	Hyper Text Markup Language
IACS	The International Association of Classification Societies
ICT	Information and Communication Technology
LR	Lloyd's Register
MTTR	Mean Time To Repair
MU	Mobile Unit
NF	Number of frames
NNK	Nippon Kaiji Kyokai
NP	Number of plates
NS	Number of stiffeners
ODBC	Object Database Connectivity procedure
PVPs	(Plate Enforced profiles , Translated from German)
QSCS	Quality System Certification scheme
RINA	Registro Italiano Navale
V & V	Verification and Modeling
VDI	Verein Deutscher Ingenieure (The Association of German Engineers)

TABLE OF CONTENTS

Contents **Pages**

LIST OF FIGURES

Figures Pages

LIST OF TABLES

Tables Pages

Declaration of Authorship

I declare that this thesis and the work presented in it are my own and have been generated by me as the result of my own original research.

Where I have consulted the published work of others, this is always clearly attributed.

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CHAPTER 1 PROBLEMS AND ITS APPROACH

1.1 Introduction

Manufacturing is a series of inter-related activities and operations involving the design, material selection, planning, manufacturing, production, quality assurance management and marketing of the products of manufacturing industries (Center for International conference on production engineering). Production is a transformation process that converts raw materials into finished products in such a way that it will have value in the marketplace to satisfying customer requirements. It is inevitable that products are made by a combination of manual labor, machinery, tools and energy and the transformation process usually involves a sequence of steps, each step bringing the materials closer to the desired final state. The individual steps are referred to as production operations. The range of production varies depending on the type of the final product and the facilities utilized to realize the final result.

Ship production is of very unique in nature where hundreds of thousands of components are assembled together systematically in order to get the final result (single product). The distinguishing feature of job shop production is low volume and hence the manufacturing lot sizes are small, often of one kind (shipbuilding). It is commonly used to meet specific customer orders, and there is a great variety in the type of work the plant must do. Therefore, the production equipment must be flexible and general purpose to allow for this variety of the work. Also the skill level of job shop workers must be relatively high so that they can perform a range of different work assignments [1].

Manufacturing (production) planning and control entails the acquisition and allocation of limited resources to production activities so as to satisfy customer demand over a specified time horizon. As such, planning and control problems are inherently optimization problems, where the objective is to develop a plan that meets demand at minimum cost or that fills the demand that maximizes profit. The underlying optimization problem will vary due to differences in the manufacturing and market context [2]. Since shipbuilding is very complex in nature, it demands a special attention when planning the production activities which requires appropriate product data and resource availability at the right time, in the right place, in the right quantity. Simulation can be used in order to study carefully the production planning that leads to Simulation Based Production in shipbuilding.

Simulation powerfully supports managing the interaction of product and production flow – especially for the production of complex products in very small series as in shipbuilding. In recent years interest in simulation modeling has greatly increased. Many manufacturing companies are investing in advanced manufacturing technology including flexible manufacturing system (FMS), various computer aided manufacturing (CAM) systems, etc. The availability of a well constructed and validated computer model allows the systems designers, the engineers and the managers to understand in advance the detailed consequences of their decisions and the investments prior to actually making binding commitments [3].

Production simulation is a very useful tool concerning the possibilities of gains in the process of production and as result, cost reduction. In order to achieve an optimum integration of design versus production, it is necessary to model not only the ship but also the shipyard facilities and integrate them into a single simulation model. In production, the acquisition of valid source of information with regard to the main characteristics of the manufacturing function plays a vital role in simulation based production planning.

In this paper, the panel line of a ship building has been modeled and simulated in order to examine the flow of the plates in the panel line and how each work station is affecting the overall production line and an attempt has been made to optimize the bottleneck workstation so that the productivity would be improved. The assessment about the effect of the new work station that will be incorporated after the completion of the research which is still undergoing has also been included in the study.

1.2 Statement of the Problem

In production, the acquisition of valid source of information with regard to the main characteristics of the manufacturing function plays a vital role in simulation based production planning. The availability of relevant data is not sufficient enough to carry out the simulation based production planning unless the data are organized to be used by the tools developed. Having a model about the panel line helps to make decisions in advance with good accuracy and that saves time and resource. It also provides information about each the utilization of each work station and how the overall panel line is being affected by each other. The addition of new work station can easily be examined with simulation techniques since the method provides the flexibility of adding new workstation to the existing system and investigate its influence on the overall production line. The study has been carried out in light of the following problem questions.

- What are the relevant production process data for the simulation tool?
- What is the effect of each work station on the overall panel line?
- What is the effect of the new work station on the existing panel line?
- How to optimize and maximize the productivity along the panel line?

1.3 Objective of the Thesis

The general objective of this thesis is to analyze and optimize the panel line of a shipbuilding using modeling and simulation techniques. The specific objectives of the thesis can be summarized as follows

- ➢ To identify the relevant data and synthesize it for modeling
- ➢ To model and simulate the panel line
- ➢ To identify the bottleneck in the production line
- ➢ To carry out scenario analysis and find out optimal solutions
- ➢ To investigate the effect of the new work station on the existing panel line

1.4 Research Methodology

Depending on the nature of the research to be carried out, different type of methodology can be followed and in this study, the following methodology has been followed thoroughly.

- ✓ ***Literature survey***: Literature survey of different and relevant information for the study with regard to Ship Production, Computerized Production planning, simulation, maritime production systems plan from books, journals, articles and manuals in the research center.
- ✓ ***Data collection***: Appropriate data for the study have been gathered from the shipyard (drawings and spread sheet).
- ✓ ***Data analysis and synthesis***: having gathered all the required and necessary information (data) relevant to this thesis, it has been analyzed, synthesized and organized so that it would be suitable as useful input for modeling and simulation.
- ✓ ***Model Development***: the model for the panel line in the ship building industry has been developed considering the Sankey diagram that provides information how the

parts are flowing in the panel line. Scenario analysis and experimentation have also been carried out for two different ship types (Container and Tanker) using Tecnomatix Plant Simulation 9.0

- ✓ ***Conclusion***: based on the findings from the overall data analysis, synthesis, and simulation results, a conclusion has been drawn.

1.5 Expected Result of the Thesis

The model developed and analyzed using the simulation software for the panel line in the ship building industry will give an insight for the ship yard with regard to the production line and helps them how to get the optimal output even without carrying out the actual task of producing the stiffened panels. It will also provide for the top management an alternative with different scenario so that they can make decisions effectively and efficiently in advance since simulation will only provide options not solutions. The result from the simulation analysis about the addition of new work station namely Plate Enforced Profiles (PVPs, translated from German) will also give an insight to the effect of the addition of new work station to the existing work station and this can used as in input for the research dealing with PVPs.

CHAPTER 2 LITERATURE REVIEW

2.1 Production

Production involves the conversion of raw materials in to final products which are useful for the purpose the final outputs are intended to function properly. There are different ways of classifying the production activities and the most common classification is based on the quantity of product made. In this classification, there are three types of production namely [1]:

- Job shop,
- Batch shop and
- mass production

Ship production lies under the category of job shop production where the main objective is to meet the specific requirement of the customers and sometimes the term project is used instead of job shop production.

Fig 2.1 summarizes some of the important characteristics of these different types of production plants [1]. It would be noted that the production ranges of the three major categories overlap to some degree. The reason is simply that it is difficult to draw a clear dividing line between the different types.

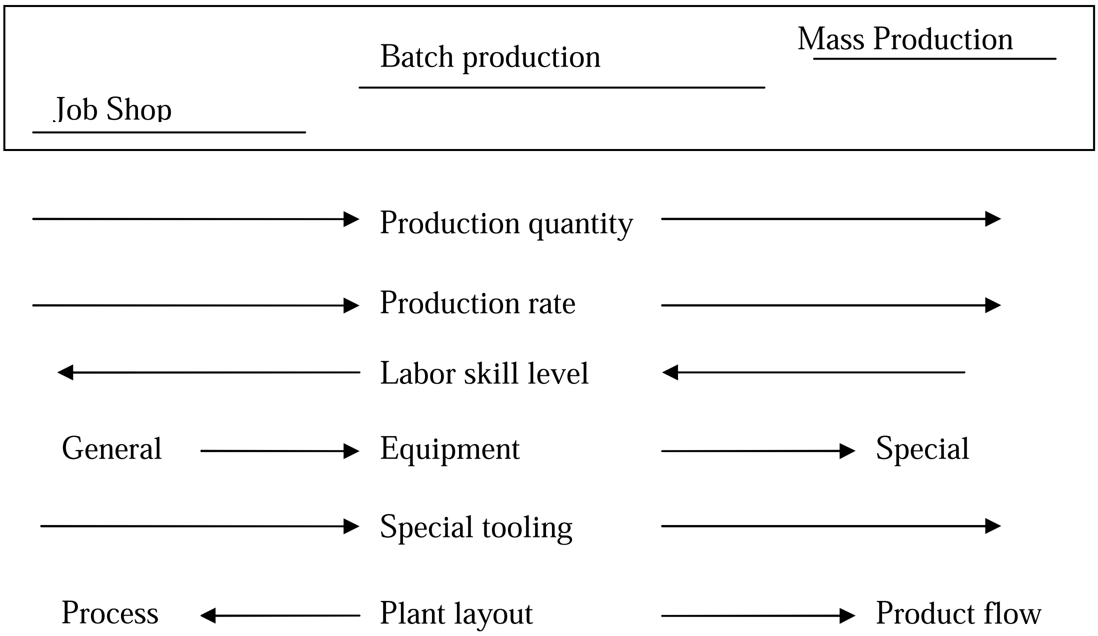


Figure 2.1 Types of production

2.2 Manufacturing Systems

A manufacturing system is a complex, organized assembly of human beings and machines implementing basic tasks and processes to transform input materials into output products. Key goals of manufacturing are [1]

- ✓ to increase the shareholders value
- ✓ to satisfy customer needs at minimum cost
- ✓ to enrich society and to increase the overall quality of life

Specific Goals of Manufacturing

- Maximization of revenue (from sales)
- Minimization of costs (from manufacturing)
- Customer satisfaction (product quality and customer service)
- Minimization of inventory and Minimization of environmental impact

Although manufacturing systems are generally quite complex, they almost involve the following essential components: ***Workstations, Materials handling and Storage subsystems***. Manufacturing system functions can be performed by humans or automated. The following essential functions can be identified in most manufacturing systems: ***Procurement, Production and Distribution***

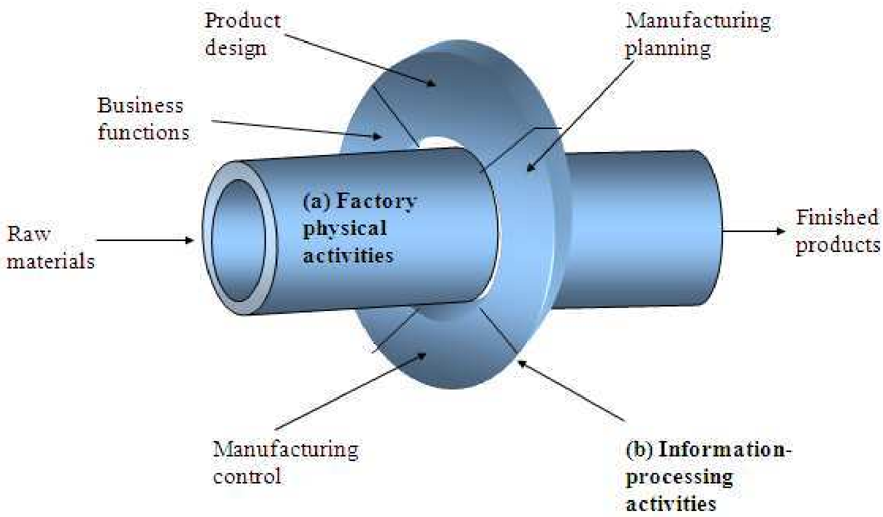


Figure 2.2 Model of Manufacturing [1]

Effective production scheduling has been an important area of concern for many years in manufacturing [4]. One of the major objectives of Production Planning and Control (PPC) is summarized as follows:

- Maximize concurrency of operations and minimize conflicts.
- Determine the sequence of operations leading to the completion of each job.
- Determine the timing of these events.
- Check material availability and update job priorities.
- Minimize production cost and lateness.

2.3 Performance Measures of Manufacturing Systems

Performance measures are devices to aid decision makers differentiate among competing manufacturing arrangements or to improve the performance of an existing system. There are severla fundamental measures of performance concern and Askin Standbridg (1993) suggested the following performance measure in manufactruing systems.

1. Production volume
2. Quality
3. Cost
4. Customer service

In order to quantify the above four major points, one has to carefully carry out the performance analysis that is conducted to evaluate the existing or planned systems so as to compare alternative configurations or to find an optimal configuration of a system. Basically, there are three alternative techniques for analyzing the performance of a system.[5]

i. *Measurement*: measuring the performance of the system can provide the exact answers regarding the performance of the system. The system in question is observed directly and no details are abstracted away, and no simplifying assumptions need to be made regarding the behavior of the system. However, measurement is only an optional if the system in question is already in action. The measurements that are taken may or may not be accurate depending on the current state of the system. For example, if the utilization of a network is measured during an off-peak period, then no conclusions can be drawn either about the average utilization of the network or the utilization of the network during the peak usage periods

ii. *Analytical model*: models like Markovian models can provide exact results regarding the performance of the system. The results are exact, in that they are not estimates of the performance of the system. However, the results provided by the analytical models may or may not be accurate, depending on the assumptions that have been made in order to accurately model industrial sized systems with analytical models.

iii. *Simulation-Based Performance analysis*: this can be used as an alternative to analytical techniques. Simulation can represent the real world by numbers and other symbols that can be readily manipulated. The availability of computers makes simulation possible for us to deal with extraordinary large quantity of details, which can be incorporated in, to a model and the ability to manipulate the model over many 'experiments' (i.e replicating all the possibility that may be embedded in the external world and events would seem to recur). It can rarely provide the exact solution, but it is possible to calculate the how precise the estimates are. Furthermore, large and more complex models can generally be created analyzed without making restrictive assumptions about the system. There are two main drawbacks for using simulation; it may be time consuming to execute the necessary simulations and difficult to achieve results that are precise enough. Simulation based performance analysis of a model involves a statistical investigation of output, the exploration of the large data sets, the appropriate visualization, and the verification and validation of simulation experiments.

2.4 Simulation

Today Simulation is arguably one of the most multifaceted topics that can face an Engineer in the dynamic business environment. It can also be considered as one of the most important tools to a corporation, regardless of the industry. Simulation helps to improve the Quality, safety and productivity of the industrial business environment through the representation of the whole activities with different model development taking in to account all the business parametrs.

2.4.1 Simulation Model

In building the model the whole activities of the business is simulated starting from the reciept of orders (raw material) and delivering the product (finished goods). It is also possible to only consider parts of the business componets that are very critical to the profitability of the specific company for example production simulation, logistic simulation, maintenance etc. The benefit of incorporating the simulation technique in the process of carrying out the business is to get an insight in advance about the whole system thereby decisions could be made with a reasonable accuracy. While modeling the system, all the activities are grouped in to a specific cluster taking into account all the parametrs to be included for each work station or department and it is also necessary to communicate about the capacity and objective of each department in accordance with the strategic objective of the company in order to avoid interest conflict among the participating bodies within the company.

2.4.2 Basic Steps and Decisions for Simulation

2.4.2.1 Basic steps

The application of simulation involves specific steps in order for the simulation study to be successful. Regardless of the type of problem and the objective of the study, the process by which the simulation is performed remains constant. The following briefly describes the basic steps in the simulation process [6]:

1. Problem-Definition
   The initial step involves defining the goals of the study and determing what needs to be solved. The problem is further defined through objective observations of the process to be studied. Care should be taken to determine if simulation is the appropriate tool for the problem under investigation.
2. Project-Planning
   The tasks for completing the project are broken down into work packages with a responsible party assigned to each package. Milestones are indicated for tracking progress. This schedule is necessary to determine if sufficient time and resources are available for completion.
3. System-Definition
   This step involves identifying the system components to be modeled and the preformance measures to be analyzed. Often the system is very complex, thus defining the system

requires an experienced simulator who can find the appropriate level of detail and flexibility.

4. Model-Formulation

   Understanding how the actual system behaves and determining the basic requirements of the model are necessary in developing the right model. Creating a flow chart of how the system operates facilitates the understanding of what variables are involved and how these variables interact.

5. Input-Data-Collection and Analysis

   After formulating the model, the type of data to collect is determined. New data is collected and/or existing data is gathered. Data is fitted to theoretical distributions. For example, the arrival rate of a specific part to the manufacturing plant may follow a normal distribution curve.

6. Model-Translation

   The model is translated into programming language. Choices range from general purpose languages such as fortran or simulation programs such as Arena.

7. Verification-and-Validation

   Verification is the process of ensuring that the model behaves as intended, usually by debugging or through animation. Verification is necessary but not sufficient for validation, that is a model may be verified but not valid. Validation ensures that no significant difference exists between the model and the real system and that the model reflects reality. Validation can be achieved through statistical analysis. Additionally, face validity may be obtained by having the model reviewed and supported by an expert.

8. Experimentation-and-Analysis

   Experimentation involves developing the alternative model(s), executing the simulation runs, and statistically comparing the alternative(s) system performance with that of the real system.

9. Documentation-and-Implementation

   Documentation consists of the written report and/or presentation. The results and implications of the study are discussed. The best course of action is identified, recommended, and justified.

2.4.2.2 Decisions-for-Simulating

Simulation usually provides alternatives about a specific cases and it does not give an exact solution in priniciple since it only mimics the real system. Completing the required steps of a simulation study establishes the likelihood of the study's success but it does not guarante that the problem is solved. Although knowing the basic steps in the simulation study is important, it is equally important to realize that not every problem should be solved using simulation that requires cost benefit analysis. In the past, simulation required the specialized training of programmers and analysts dedicated to very large and complex projects. Now, due to the large number of software available, simulation at times is used inappropriately by individuals lacking the sufficient training and experience. When simulation is applied inappropriately, the study will not produce meaningful results. The failure to achieve the desired goals of the simulation study may induce blaming the simulation approach itself when in fact the cause of the failure lies in the inappropriate application of simulation [7].

It is advisable to consider some parametrs so as to check the benefit of applying the modeling and simulation method in order to solve a specific problem. The major factors that should be taken in to account to examine if the simulation is the right approach to solving a specific problem before carrying out the study are [7]:

1. Type of Problem
2. Availability of Resources
3. Costs
4. Availability of Data

1 Type of Problem: If a problem can be solved by common sense or analytically, the use of simulation is unnecessary. Additionally, using algorithms and mathematical equations may be faster and less expensive than simulating. Also, if the problem can be solved by performing direct experiments on the system to be evaluated, then conducting direct experiments may be more desirable than simulating. However, one factor to consider when performing directing experiments is the degree in which the real system will be disturbed. If a high degree of disruption to the real system will occur, then another approach may be necessary.The real system itself plays another factor in deciding to simulate. If the system is too complex, cannot be defined, and not understandable then simulation will not produce meaningful results. This situation often occurs when human behavior is involved.

2.Availability of Resources: People and time are the determining resources for conducting a simulation study. An experienced analyst is the most important resource since such a person has the ability and experience to determine both the model's appropriate level of detail and how to verify and validate the model. Without a trained simulator, the wrong model may be developed which produces unreliable results. Additionally, the allocation of time should not be so limited so as to force the simulator to take shortcuts in designing the model. The schedule should allow enough time for the implementation of any necessary changes and for verification and validation to take place if the results are to be meaningful.

3.Costs: Cost considerations should be given for each step in the simulation process, purchasing simulation software if not already available, and computer resources. Obviously if these costs exceed the potential savings in altering the current system, then simulation should not be pursued.

4.Availability of Data: The necessary data should be identified and located, and if the data does not exist, then the data should be collectible. If the data does not exist and cannot be collected, then continuing with the simulation study will eventually yield unreliable and useless results. The simulation output cannot be compared to the real system's performance, which is vital for verifying and validating the model.The basic steps and decisions for a simulation study are incorporated into a flowchart as shown in the figure (Fig 2.3) .

2.4.3 Simulation in Ship Building and Computer Integrated Manufacturing

Computer simulation has been applied mainly in ship design stage, especially in the initial planning and structural analysis at design stage, while it has not been widely implemented in production because ship production is very complicated and requires much experience. However, the introduction of production simulation is aimed at [8]:

(1) Quality improvement: to predict and estimate performance such as vessel speed, dead weight, strength and so on, in accordance with design demand.
(2) Shortening of lead times: to shorten the construction period and flow time from design to completion of a ship.
(3) Reduction of production cost: to decrease the costs, both material costs and personnel expenses, and to reduce the waste time during the manufacturing process.

In ship production, simulations may be applied in the following:

(1) Analysis and evaluation of the production process

(2) Planning and assisting of production

(3) Simulator for training of skilled work such as line heating, welding, and straightening.

(4) To confirm work safety

Computer Integrated Manufacturing (CIM) is the manufacturing approach of using computers to control the entire production process [9]. This integration allows individual processes to exchange information with each other and initiate actions. Through the integration of computers, manufacturing can be faster and less error-prone, although the main advantage is the ability to create automated manufacturing processes.

When Computer-Integrated Manufacturing (CIM) is applied, the functional areas of a manufacturing enterprise such as design, analysis, planning, purchasing, cost accounting, inventory control, and distribution are linked through the computer with the factory-floor functions such as materials handling and management; as result the CIM provides direct control and monitoring of all process operations. The CIM is most useful where a high level of information and communication technology (ICT) is used such as CAD/CAM systems, the availability of process planning, and its data. There are however few major challenges to development of a smoothly CIM operation: integration of components from different suppliers, data integrity, and process control (Yoram, 1983; Waldner, 1992; Singh, 1997).

Therefore in order to raise productivity, quality, and safety, which are three major elements in production, it becomes important to study the production procedure in advance using various computer simulations.

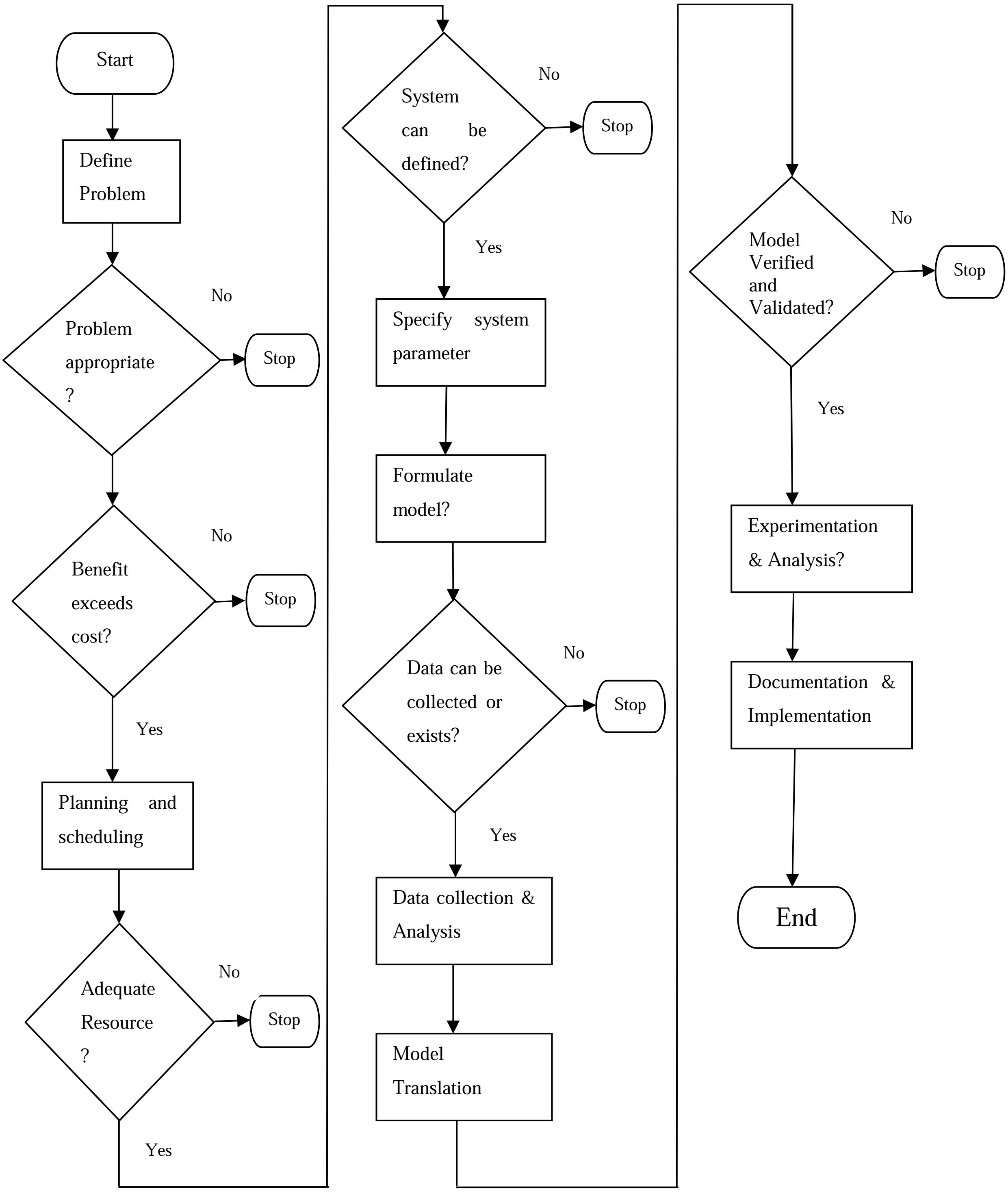


Figure 2.3 Steps and decisions for conducting a simulation study [7].

2.4.4 Computer Optimized Manufacturing

In the production field of shipbuilding, most of the works rely on the cooperation and integration of multiple workers. The simulation-based production allows [10]:

- ✓ Checking the feasibility of the construction procedure by using dynamic moving images,
- ✓ Confirming the interference both human and structures by compensating human errors and raising the integrity of the engineering, and
- ✓ Optimizing the construction process by providing common acknowledgment and cooperation to all related workers.

In order to carry out shipbuilding activities efficiently, effectively and safely, it is very important for all related workers to have a common acknowledgement and cooperation among themselves. Using the product model which is the core of the computer integrated manufacturing (CIM), design and production planning of the simulation base can be carried out, and the global optimization is obtained as shown in the figure (Fig 2.4) .

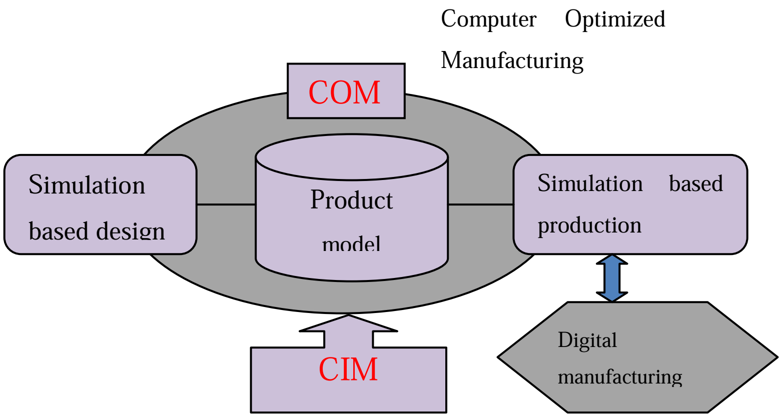


Figure 2.4 Concept of computer optimized manufacturing in shipbuilding [11]

2.5 Ship Building

2.5.1 The Ship Building Process

The ship building is an industry that produces products (ships, offshore structures, floating plants etc) for customers (private owners, companies, governments etc). In most cases, the product is built to order and customized to the specific requirements of the customer or purchasers. This applies even in cases where a similar series of ships is being built. The entire process is likely to vary somewhat depending on the customer involved, but generally involves a number of specific stages. These may be summarized as follows [12].

- Development of owners requirement
- Preliminary/ concept design
- Contract design
- Bidding/contracting

- Detail design and planning
- Construction

It is a common practice that the first stage in the ship building process is the formulation of the product requirements by the customers or buyers.

Examples

- ✓ A shipping line may forecast the demand for a transportation of 200,000 automobiles per year between two ports
- ✓ A company may want to transport 12 million tons of crude oil per year from one country to another
- ✓ A transportation agency may need to ferry 100,000 passengers per day across an inland water way over 10 routes averaging 30 trips per route.

In general, ship building can be viewed as a process that begins when an owner perceives a need to a vessel to perform some set of functions, that proceeds through a number of stages of paper works (design, contracting, planning etc) and that culminates in massive collection and joining of parts and components to manufacture the desired vessel. Productive ship building is highly dependent on careful consideration, control and performance in each of these stages.

2.5.2 Ship Building Terms and Definitions

Ship building is the construction of ships and a ship yard is the place where ships are built. Ship building is a construction industry which uses a wide variety of manufactured components in addition to basic construction materials. The process, therefore, has many of the characteristics of both construction and manufacturing [12]. It requires many workers having various skills, working within an established organizational structure at specific locations in which necessary facilities are available. The goal of a privately owned shipbuilding company is to earn a profit by building ships.

A ship, although a complex combination of things, can be most easily classified by its basic dimensions, its weight (displacement) and (or) load carrying capacity (dead weight) and its intended service. Fig 2.5 defines a number of basic ship dimensions as well as typical ship board regions. Some specific definitions are dependent on the vessel type or service, but in general, most dimensions are applicable for all ship types [12].

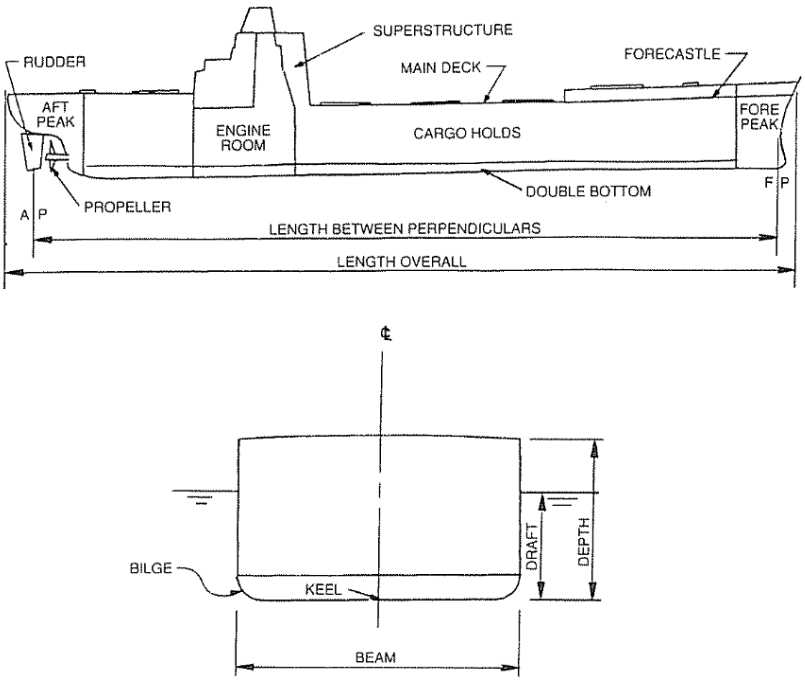


Figure 2.5 Basic ship dimensions and definitions [12]

2.5.3 Types of Ships

Ships can be divided into a number of classes based on their intended service and it inevitable that different scholars provide a number of classifications. The primary classes according to Richard Lee, Colin P, Howard m and Richard C Moore are

- Dry cargo ships
- Tankers
- Bulk carriers
- Passenger ships
- Fishing vessels
- Industrial vessels
- Combatant vessels
- Others

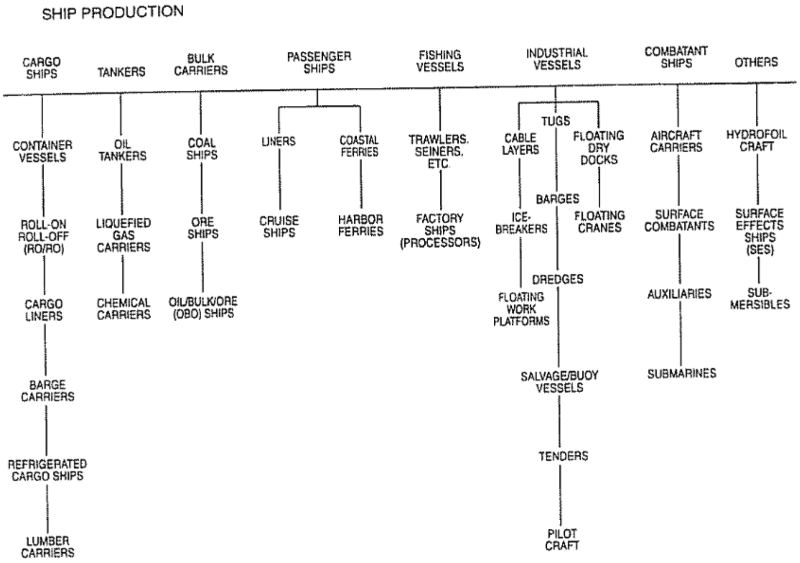


Figure 2.6 Ship types [12]

No simple classification of ships by type is likely to be all inclusive, but this general breakdown is sufficient to indicate general trends. The figure (Fig 2.6) shows typical in board profiles of the ship within each of these classes.

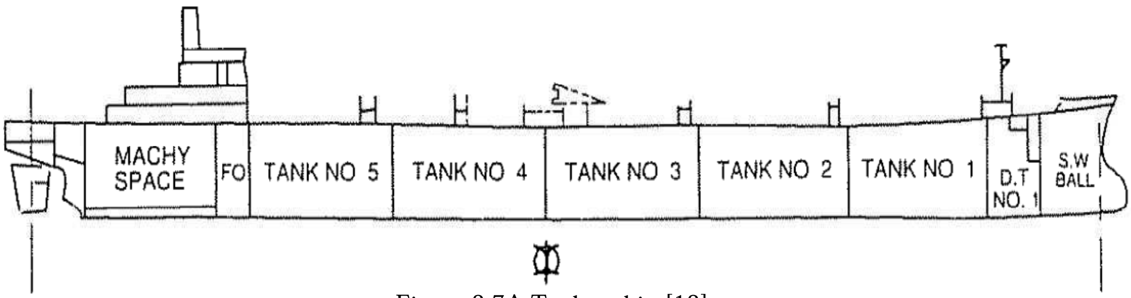


Figure 2.7A Tanker ship [12]

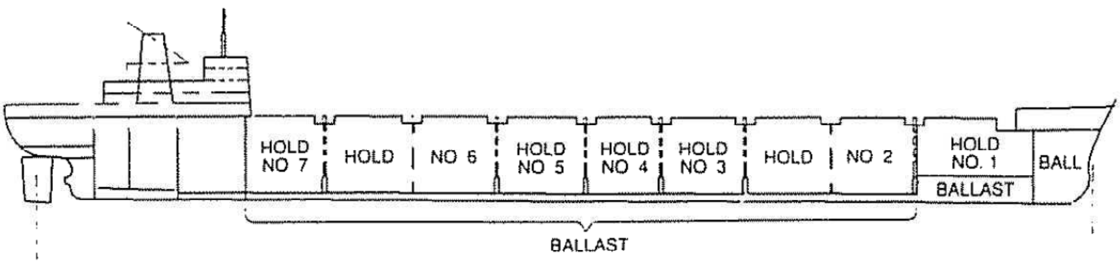


Figure 2.7B Bulk Carrier [12]

Figure 2.7C Container ship

(Source: California Publication of the National Oceanic & Atmospheric Administration (NOAA), USA: http://www.photolib.noaa.gov/coastline/line0534.htm)

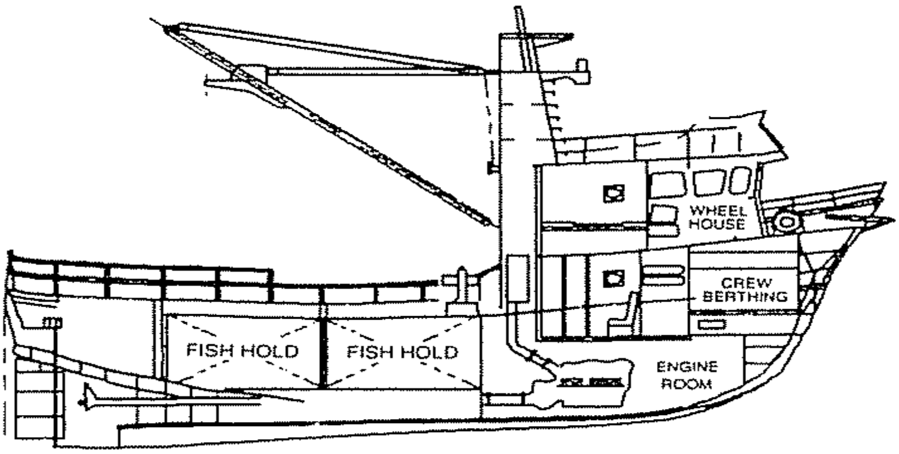


Figure 2.8D Fishing vessel [12]

2.5.4 Ship Yard Facilities

A ship yard generally contains several specific facilities laid out to facilitate the flow of the material and assemblies. There is no typical ship yard layout, partly because many shipyards were initially constructed in the ninetieth or early century. These yards have grown according to the availability of land and water front as well as in response to production requirements. Typical important features are listed below [12].

- ✓ A location on land for creating a ship, along with an associated means for getting the ship to the water, such as a graving dock, launching ways or floating dry dock.
- ✓ Piers for storing ships afloat to permit work to continue following launching

- ✓ Shops for performing various kinds of work, such as
  - Steel marking, cutting and forming shop
  - Steel assembly shop
  - Surface penetration and coating shop
  - Pipe shop
  - Sheet metal shop
- ✓ Storage, marshaling, outdoor work areas
- ✓ Offices and personnel support buildings (cafeteria, sick bay, etc)

Associated with each of these general types of facilities are specific pieces of equipment that are related to the work carried out in that location.

2.6 The Classification Societies and Regulatory Bodies

2.6.1 Classification Society

A classification society is a non-governmental organization that establishes and maintains technical standards for the construction and operation of ships and offshore structures. The society will also validate that construction is according to these standards and carry out regular surveys in service to ensure compliance with the standards.
The purpose of a Classification Society is to provide classification and statutory services and assistance to the maritime industry and regulatory bodies as regards maritime safety and pollution prevention, based on the accumulation of maritime knowledge and technology. The objective of ship classification is to verify the structural strength and integrity of essential parts of the ship's hull and its appendages, and the reliability and function of the propulsion and steering systems, power generation and those other features and auxiliary systems which have been built into the ship in order to maintain essential services on board. Classification Societies aim to achieve this objective through the development and application of their own Rules and by verifying compliance with international and/or national statutory regulations on behalf of flag Administrations. The vast majority of commercial ships are built to and surveyed for compliance with the standards laid down by Classification Societies. These standards are issued by the Society as published Rules [13].

Some of the major classification societies in the world are:-

- American Bureau of Shipping (ABS), USA
- *Lloyd's Register (LR), England*

- Bureau Veritas (BV), France
- Det Norske Veritas (DNV), Norway
- Germanischer Lloyd (GL), Germany
- Nippon Kaiji Kyokai (NNK), Japan
- Registro Italiano Navale (RINA), Italy

2.6.2 The International Association of Classification Societies (IACS)

The International Association of Classification Societies is an association established by a number of classification societies all over the world. Some classification societies are not members of the International Association of Classification Societies. Compliance with the IACS Quality System Certification Scheme (QSCS) is mandatory for IACS Membership. Dedicated to safe ships and clean seas, IACS makes a unique contribution to maritime safety and regulation through technical support, compliance verification and research and development. More than 90% of the world's cargo carrying tonnage is covered by the classification design, construction and through-life compliance Rules and standards set by the thirteen Member Societies of IACS. Classification Rules have been developed over many years by each Society through extensive research and development and service experience. In addition, certain Unified Requirements have been agreed by IACS Members and transposed into the individual Members' Rules [13].

2.7 Panel Line in Ship Building

The panel line is one of the most important production lines in the ship building and hence great care should be taken in to account since it affects the overall performance of the ship yards. It is imperative that the flow of activities in the ship yard varies one from another but the activities mentioned below are more or less the common practice in the ship yards.

- Grinding
- Chamfering
- Handling and storage
- Plate welding
- Grinding, cutting and marking
- Stiffening
- Framing
- Transport system

- o Bulk heads, pillars and hull plates
- o Automatic welding
- o Manual welding

In this project, the work stations that have been considered for modeling the panel line to examine the production line are:

- ✓ Plate welding (Automatic or Manual welding)
- ✓ Trimming, cutting, marking
- ✓ Profile (stiffener) mounting or setting
- ✓ Profile (stiffener) welding
- ✓ Completion

2.7.1 Plate Welding

In this work station, a number of plates will be welded together depending on the requirement for a specific section of the ship. The thickness of the plates determines the nature of the welding technique whether to weld them automatically or manually.

Figure 2.8 Plates after welding operations

2.7.2 Trimming, Marking and cutting

In this section, different types of activities will be carried out like trimming the edge parts of the welded plates based on the required dimensions described in the drawing for the specific section of the ship and different types of cut outs have also to be performed at this work station. The positions of the stiffeners will also be identified and marked at this work station so that in the next work station (which is the profile setting), the stiffeners would be placed easily and properly.

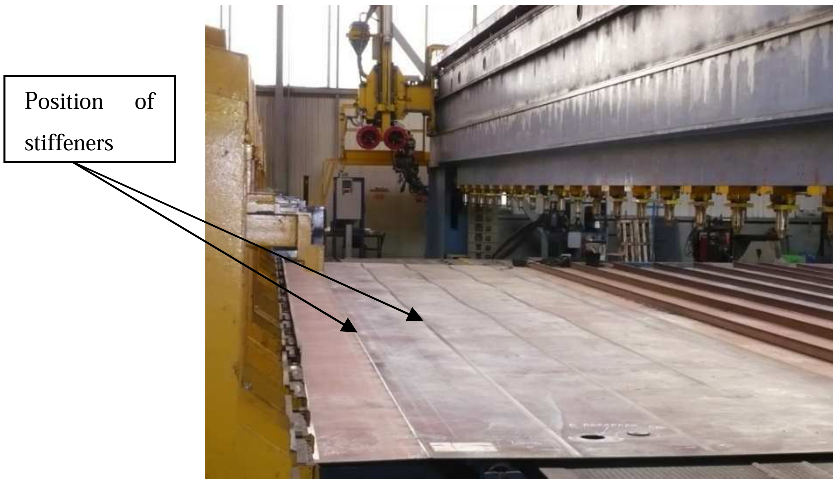


Figure 2.9 Marking for the position of the stiffeners

2.7.3 Stiffener (Profile) Setting

In order to properly weld the stiffeners on the plates which provide good structural strength to the ship, it is first necessary to properly place the stiffeners on their exact positions marked at the previous work station. Failure not to keep the exact location of the stiffeners as prescribed in main drawing from the design stage will ultimately affect the service period of the ship and it may even cause a structural distortion.

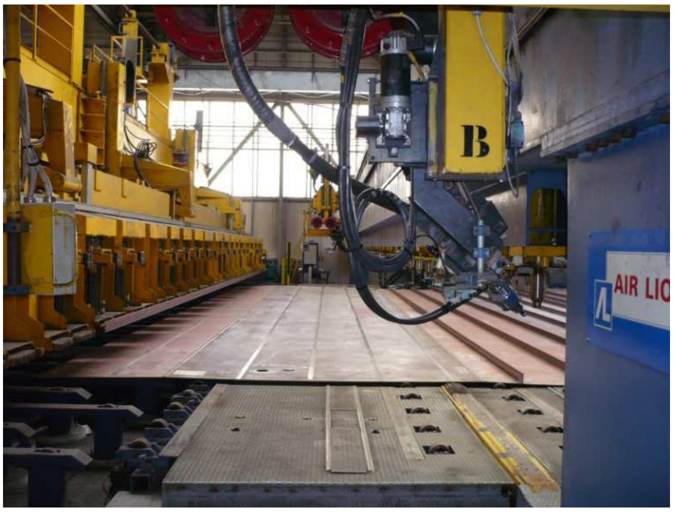


Figure 2.10 Placement of the stiffeners on the welded plates

2.7.4 Stiffener Welding

Once the stiffeners are properly placed on the welded plates, the next step is to weld the stiffeners to the plates. Depending on the requirement and the amount or length of stiffeners to be welded on the plates, one or two welding tools can be used along the length of the stiffener in order to reduce the time required for the welding of the stiffeners.

2.7.5 Completion Activities

This is the last work station considered in the model development for the panel line in ship building under this research. The activities performed in this section are different for each type of ship and some of the activities that would be performed in this work station are pre-outfitting activities, manual welding if necessary and some finishing activities before the stiffened panels are transported to another line in the ship yard.

2.8 Tecnomatix Plant Simulations 9.0

Plant Simulation is a discrete, event-oriented simulation program, i.e., it only inspects those points in time, at which events take place within the simulation model. The first procedure is to create an interface on the frame representing the input (Source), workstations and Output (Drain) relationship ships as indicated in the Sankey diagram with appropriate connectors.In order to model the panel line in the ship building, Tecnomatix Plant Simulation 9.0 has been utilized. Simulation technology is an important tool for planning, implementing, and operating complex technical systems. Several trends in the economy such as [14]

- ✓ increasing product complexity and variety
- ✓ increasing quality demands in connection with high cost pressure
- ✓ increasing demands regarding flexibility
- ✓ shorter product life cycles
- ✓ shrinking lot sizes
- ✓ increasing competitive pressure

lead to shorter planning cycles. Simulation has found its place where simpler methods no longer provide useful results. Steffen Bangsow (2010) suggested that simulation can be applied during planning, implementation, and operation of equipment.

2.8.1 Definitions Used in the Simulation

Simulation (source: VDI 3633)
Simulation is the reproduction of a real system with its dynamic processes in a model. The aim is to reach transferable findings for the reality. In a wider sense, simulation means preparing, implementing, and evaluating specific experiments with a simulation model.

System: (VDI 3633)
A system is defined as a separate set of components which are related to each other.

Model: (VDI 3633)

A model is a simplified replica of a planned or real system with its processes in another system. It differs in important properties only within specified tolerance from the original.

Simulation run: (source: VDI 3633)

A simulation run is the image of the behavior of the system in the simulation model within a specified period.

Experiment: (source: VDI 3633)

An experiment is a targeted empirical study of the behavior of a model by repeated simulation runs with systematic variation of arguments.

2.8.2 Standard Classes in Plant Simulation

In general, only a limited selection of objects is available for representing the real installation. Hierarchically structured system models are best designed top-down. In this way, the real system will be decomposed into separate functional units (subsystems) [14]. If we are not able to model sufficiently precise with the available model objects, we should continue to decompose, etc. Each object must be described precisely: The individual objects and the operations within the objects are linked to an overall process. This creates a Frame and with the objects and the Frame various logistical systems can be modelled considering the input, failures and output parameters as depicted in the figure (Fig 2.11).

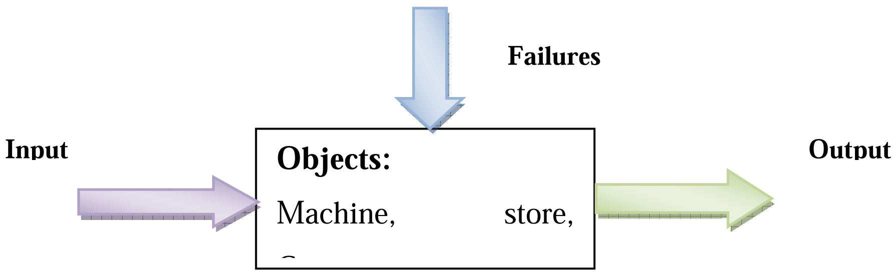


Figure 2.11 Input output relationship in modeling the system [14]

The standard classes used in the Tecnomatix Plant simulation 9.0 can be classified into six categories:

1. Material flow objects
2. Resources
3. General objects
4. Mobile objects
5. Lists and tables
6. Display objects

While using the software, due attention has to be given for the definitions of the terms used in the software because sometimes the meaning may be a little bit different from the definitions used in other applications. One of the most important parameters used in the software is time and the definitions for each time have been given below.

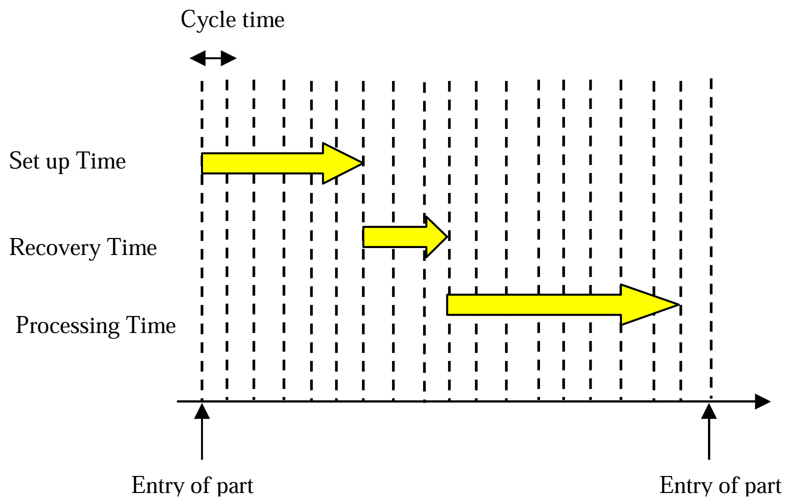


Figure 2.12 The processing duration of the part on a station [14]

Set up time: The Setup Time is the time which is required to set up a basic object for processing another type. The type is determined by the name of a MU (MUs with the same name have the same type). You can also use a setup time after a certain number of parts have been set up, for example, for regular tool changes.

Recovery time: At the entrance of a basic object, there is a gate, which closes for a specified time after an MU entered. This way you model robots, which require a certain time to insert parts into the machine.

Processing time: The processing time determines how long an MU stays on the object after the setup time, before Plant Simulation tries to move the MU to a succeeding object.

Cycle time: Cycle times can be used for synchronizing productions. They specify in which interval or in which integral multiple of an interval entering the workstation is possible (e.g., every 20 seconds). The gate opens every 20 seconds. A new MU can only enter after the end of the previous processing and the next opening of the gate.

It is also important to consider the distribution of the material from one work station to the next station and there should be a method on how to distribute the parts to the successive station which is considered as Exit strategy.

Exit strategy: This is a strategy that defines how the material will leave one station after being processed and some of them are listed below:

- To move the parts cyclically to the next successor in line, select Cyclic.
- To cyclically move the part to the successor according to the sequence of successors, which you entered into the list, select Cyclic Sequence.

- To move the parts to the successor that has been waiting the longest for an MU, select Least Recent Demand.
- To move the parts to the successor in a linear fashion, according to the sequence of successors, which you entered into the list, select Linear Sequence.
- To move the parts to the successor with the longest processing time, select Maximum Processing Time.
- To move the parts to the successor with the longest set-up time, select Maximum Set-up Time.
- To move the parts to the successor that received the smallest number of MUs, select Minimum Number In.
- To move the parts to the successor with the shortest processing time, select Minimum Processing Time.
- To move the parts to the successors according to a percentage distribution, select Percentage.

In modeling and simulation, we usual want to have a result for a specific period of time probably per year, per month etc and this can be done by making use of the Event controller in the plant simulation software.

EventController: - coordinates and synchronizes the different events taking place during a simulation run.

Chart: - The **Chart** graphically displays the data sets that Plant Simulation recorded during a simulation run

2.9 Verification and Validation in Simulation (V & V)

It is imperative that simulation results provides only options to the decision making process and if the results obtained from the simulation process are not concrete and reliable enough the decision made could have a catastrophic effect on the overall process. It is highly recommended to verify and validate the system at each stage in particular and the whole system in general. The process of verification and validation in simulation is a broad concept and different authors developed a number of procedure model on how to carry out the V & V analyses.

Simulation is an established analysis method for production and logistic purposes. It is frequently used when decisions with high risks have to be taken, and the consequences of such decisions are not directly visible, or no suitable analytical solutions are available. This, however, implies that correctness and suitability of the simulation results are of utmost importance. Wrong simulation results, translated into wrong decision proposals which are then implemented, can cause cost that are by orders of magnitude higher than the total cost of the simulation study. This illustrates the relevance of verification and validation (V&V) within simulation studies in this application domain [15].

The figure (Fig 2.13) depicts the procedure model of simulation with verification and validation developed by authors (Rabe, Spiekermann and Wenzel, 2009) based on a guideline of the German Engineers' Association, VDI (VDI 2009). Starting from the Sponsor Needs, this procedure model considers only tasks that normally occur after the acceptance of the task and cost plan for a simulation study, not distinguishing between external and internal service providers. Therefore, the proposed procedure starts with the Task Definition, which is considered to be the first analysis step within a simulation study.
According to these authors, verification and validation is not at all a task that is conducted at the end of a project. Especially, it should never be considered as a procedure that is iterated after the implementation until the model seems to operate correctly in contrast V & V has to accompany the simulation project from the start until the very end, and specific V & V activities are indispensable within each single phase of the modeling process.

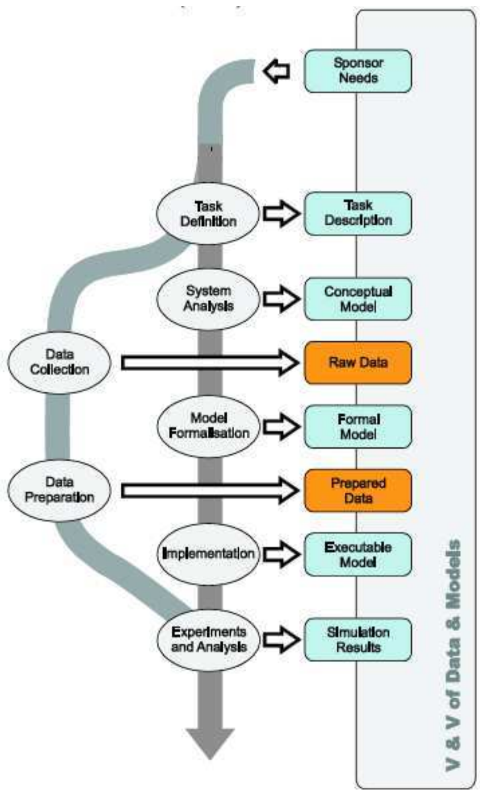


Figure 2.13 Procedure model for simulation including V&V (cp. Rabe et al. 2008b)

CHAPTER 3 DATA COLLECTION AND PREPARATION

3.1 INTRODUCTION

This chapter deals with the collection of the relevant data and preparing them in such a way that the data will be used in the model developed in the next chapter where different scenario analysis have to be carried out for the panel line in the ship building. Great care should be taken in to account while collecting the data or making them ready for the simulation process since failure to consider all the necessary parameter will result in making unreliable decisions based on the results that will be obtained from the modeling and simulation process. Two types of ships (Container and Tanker) have been considered in order to model the panel line and some of the data are already prepared to be sued directly in the model developed and others are to be collected from the drawing (Tanker ship) and synthesized so as to be used in the simulation process.

3.2 Methodology of the Whole Process

It is clear that people usually apply different methodology or procedure in order to carry out a research depending on the nature of the problem to be addressed. The figure (Fig 3.1) represents the procedure followed in order to carry out the modeling and simulation of panel line in the ship building process and a short explanation has also been provided for each steps.

Step 1 Start

This is the first procedure in the flow chart and it is assumed that all the problems and objectives are already set in advance. The purpose of this research is to make use of the simulation software (Tecnomatix plant simulation 9.0) in order to examine and optimize the panel line in the ship building.

Step 2 data collection and synthesis

At this stage the question is whether the data available are good enough to be used in the simulation process or not. Since there are two types of ships which will be considered in the research and it was found out that the data with regard to the container ship is already synthesized in the research center and can be used directly in simulation process. But in case of the Tanker ship, the only available information is drawings and the data has been directly obtained from the drawing which required further preparation by applying some mathematical manipulations.

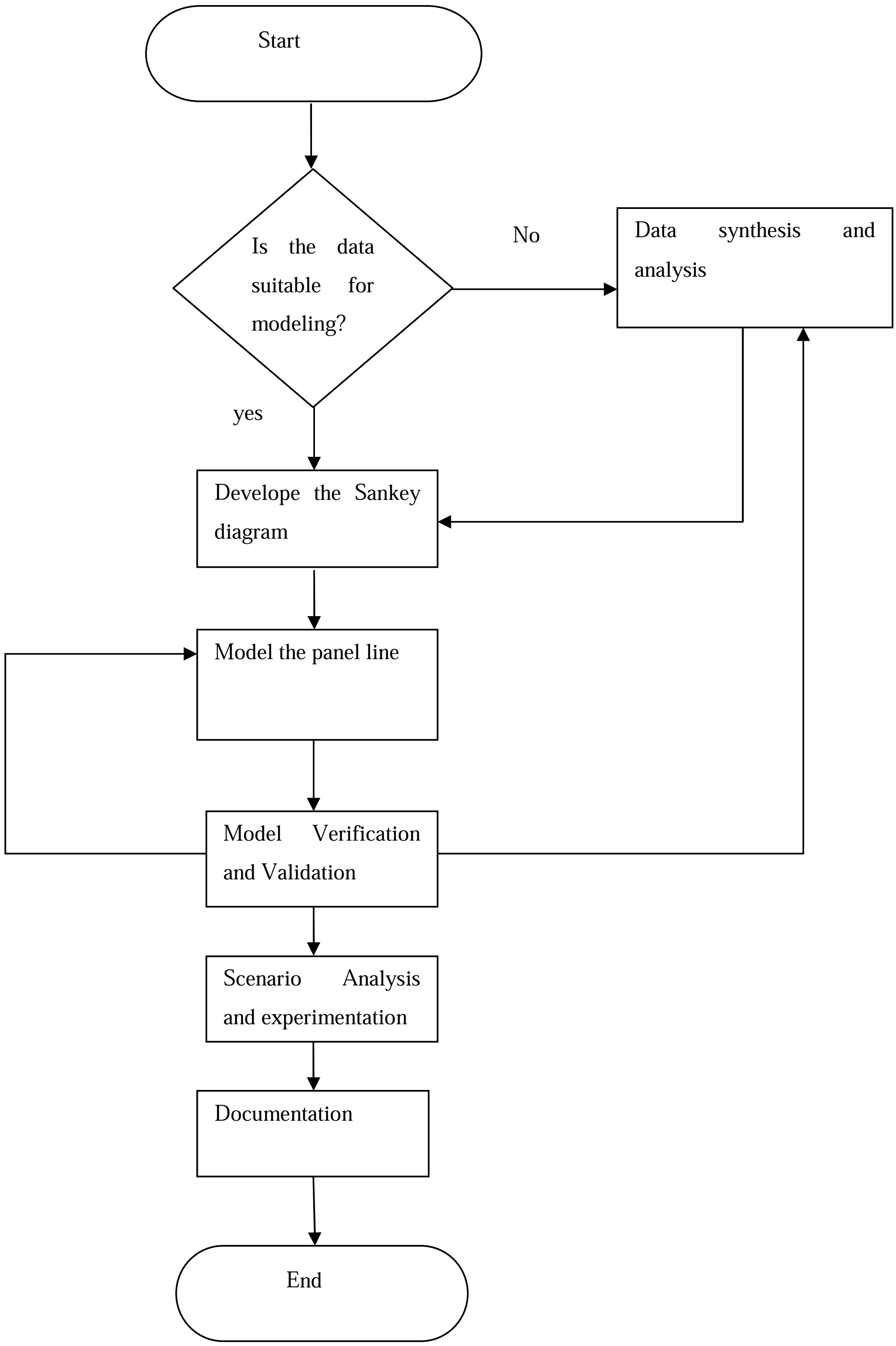


Figure 3.1 Flow chart of the activities to model and simulate the panel line

Step 3 Develop the Sankey diagram

Once we have all the necessary data for the modeling and simulation process, the next step is to exactly identify the flow of the material along the panel line. It provides information about the predecessors and successors relationships which is very important in developing the model. The exit strategy in the model development is highly affected by the Sankey diagram and it has a profound effect on the overall result of the production in the panel line.

Step 4 Model development

This part is all about the model development which is the important step because it is believed to provide the solution to the problem stated in the problem description and satisfy the objective requirements. If the model does not contain all the necessary information along the panel line including the product and machinery information, it may not provide good results and great care should be taken while developing the model.

Step 5 Model verification and Validation

At this stage careful assessment has to be carried out if the model has all the necessary information about the overall production process or not. A simulation test can also be performed in order to see the result or how the model is performing. Model verification and validation is a process of increasing the confidence about the work to be done not about ensuring the model is correct. A check list has been developed for the sake of verification and validation for this specific model and presented in next chapter.

Step 6 scenario analysis and experimentation

This step involves performing different scenarios and experimentation in order to have alternatives about the simulation results which provide an alternative that is very helpful for the decision making process. This is one of the advantages of modeling and simulation for it provides different options on how to solve the problem in question which has to be checked against the conditions of the company.

Step 7 Documentation

This is the last step and is very important because the results obtained from the simulation process should be documented so that it could be presented to the decision making management where all the explanations and benefits are incorporated.

3.3 Data Collection and Analysis

The data that will be necessary for the modeling and simulation process are parameters related to each work stations like processing time, set up time, waiting time, machine availability, Mean time to repair (MTTR) etc. some assumptions have been made and mentioned in the next chapter about availability and MTTR.

3.3.1 Container Ship

Container ship is one of the ship types where the panel line is used to produce stiffened panels that are sections of the entire ship. The cycle time for each work station is considered for analyzing the panel line and these data along with the Sankey diagram in the panel line are already available in the research center research (obtained from P & S ship yard for container ship) and will be used in the model development.
There are 6 stations in the panel line and the activities that will be performed in each section have been mentioned below.

1. Station 1 (S1): This is the station where two sides welding are performed for the plates with a considerable plate thickness manually.
2. Station 2 (S2): This is the station where one side welding is performed for the plates applying automatic welding techniques.
3. Station 3 (S3) : This is the station where activities like marking, trimming, cutting etc are carried on the plates.
4. Station 4 (S4): This is the station where placements of stiffeners are preformed.
5. Station 5 (S5): This is the station where stiffeners are being welded on the plates.
6. Station 6 (S6): This is the final workstation for the completion of the panel line represented in the figure (Fig 3.2).

Cycle time: The time elapsed when a part enters and leaves a certain workstation after being processed in the same work station. Sometimes it is referred as the work station time. The cycle time of the production line is the maximum station time along the production line and it also depends on the Sankey diagram of the flow line.
Takt time: This is the time related to the demand of the customer about a specific product and usually expressed in terms of the available time in the production system to quantity of the products requested by a customer (net time available for production/customer demand) [16].

Cycle time is an important parameter for the purpose of simulation because it gives an insight on how to determine the total manufacturing time for a certain product in the production line so that comparison will be made with the demand of the customer. The cycle time for each workstation is given in the table below (Table 3.1)

Table 3.1 Cycle time for each work station for the container ship case

Station	Description	Cycle Time, minute/plate
1	Manual welding	87.5
2	Automatic welding	96.8
3	Trimming, marking etc	138.8
4	Profile setting	54.4
5	Profile Welding	82
6	Completion	73

The Sankey diagram in figure (Fig 3.2) depicts the flow of materials in the panel line along with their percentage distributions.

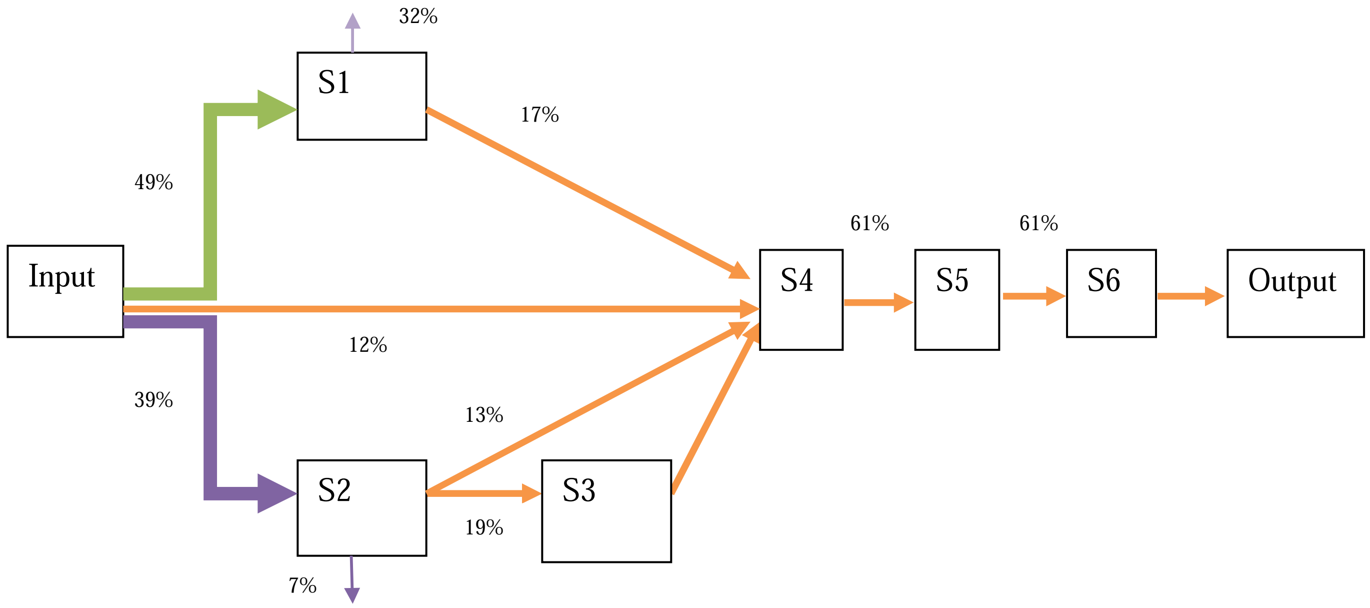


Figure 3.2 The flow of material along the panel line for the Container ship

The input for the above panel line is the plates after being properly processed to be welded and stiffened in the panel line. The final result of the above panel line is stiffened panel with appropriate dimensions which will be used for the next step in the ship building that is the fixing of frames on the stiffened panels.

The following illustrates the Cycle time and Takt time for a container ship for which the demand per year is considered to be 8100 sheets per year including the panel line and other production lines.

Production capacity:

- ✓ Available time: 22.1 hours per day and 250 days per year
- ✓ Cycle time for each work station (given in Table 3.1)
- ✓ Material flow (given in Fig 3.2)

Takt time= $\frac{Available\ time}{Customer\ demand}$=$\frac{22.1*250*60\ minutes}{8100\ sheets}$= 40.93 minutes per sheet

= **40.93 minutes per sheet**

It indicates that there should be exactly one sheet every 40.93 minutes in order to satisfy the demand of the customer which is 8100 sheets per year. Considering this as a reference, takt time for each work station can be computed taking the Sankey diagram in to account so that comparison will be made at each work station between the cycle time (Capacity) and the takt time (Demand).Referring to the Sankey diagram given in figure (Fig3.2), the percentage of material flow to station 1 is 49% then the takt time for this specific work station will be:

Takt time (S1)= $\frac{Available\ time}{Customer\ demand*flow\ percentage} = \frac{22.1*250*60}{8100*0.49}$

= 83.5 minutes per sheet

Since the work station has a capacity of producing one sheet every 87.5 minutes (cycle time) which is greater than takt time (83.5 minutes), it will not satisfy the requirement of the customer demand and the table below shows the comparison for each work station and the negative difference indicates that the work station will not satisfy the customer demand. The maximum negative difference between the cycle time and takt time of a work station indicates the bottleneck of the production line and in this case the profile welding station is the bottleneck.

Table 3.2 Comparison of cycle time and takt time for each work station

Station	Description	Cycle Time minute	Flow Percentage	Takt Time minute	Difference minute
1	Manual welding	87,5	0,49	83,5	-4,0
2	Automatic welding	96,8	0,39	104,9	8,1
3	Trimming, Cutting, marking etc	138,8	0,19	215,4	76,6
4	Profile setting	54,4	0,61	67,1	12,7
5	Profile Welding	82	0,61	67,1	-14,9
6	Completion	73	0,61	67,1	-5,9

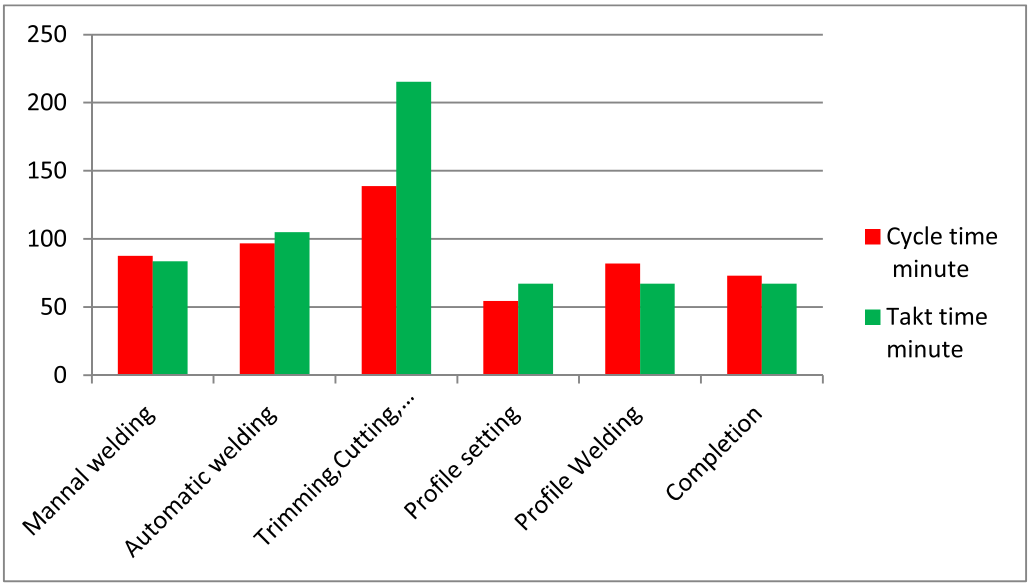


Figure 3.3 Comparison of cycle time and takt time for each work station

3.3.2 Tanker Ship

The only available information about the tanker ship is the drawings and relevant data have been collected by referring directly to the sections of the ship in the drawing. The figure below represents the main drawing of the tanker ship three views: Top, side and front. All the necessary dimensions are also included in the drawing like the frame spacing, number of stiffeners, plate thickness etc which are very useful for the determination of the cycle time for each work stations along the panel line.

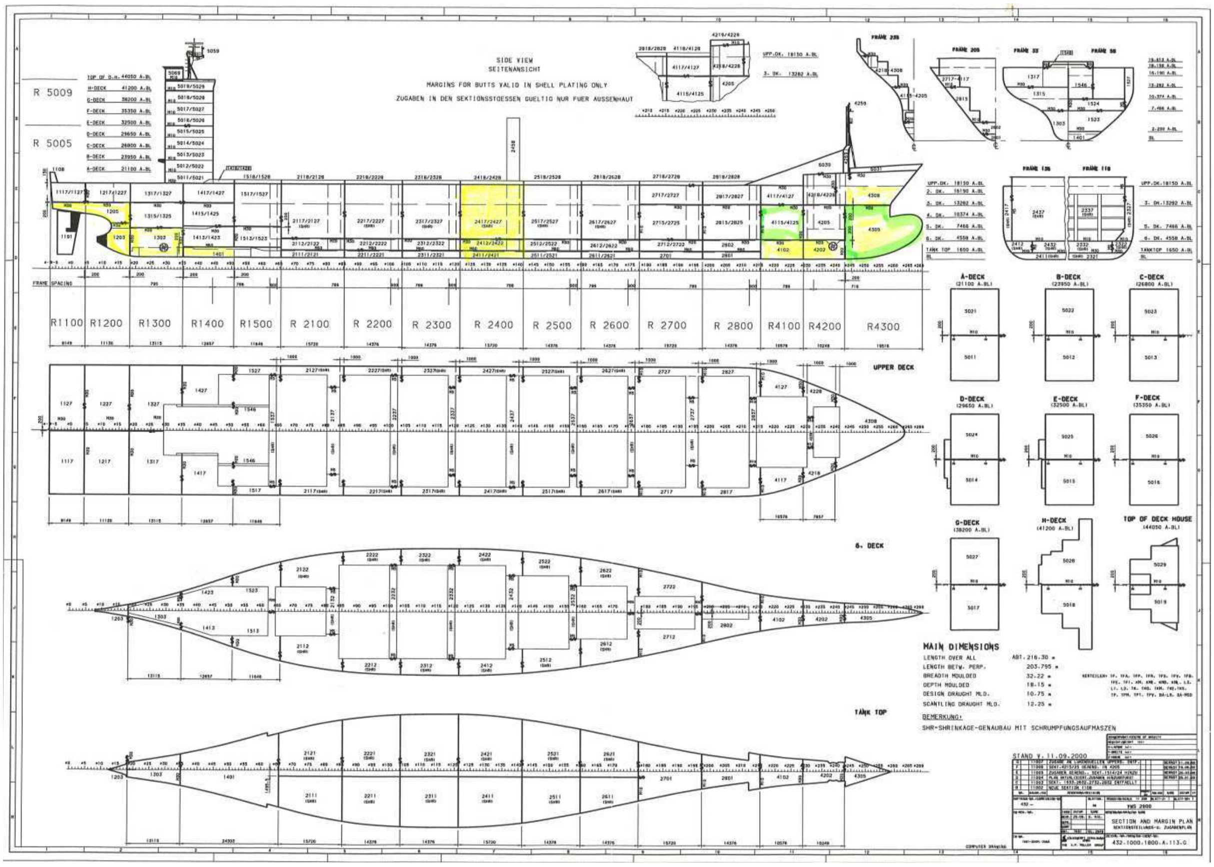


Figure 3.4 The main drawings of the tanker ship

Since there are no real data on the processing time, set up time, and cycle time for each work station in the panel line referring the tanker ship, computation of these parameters have been done by considering the drawing and identifying the possible plates, panels and stiffeners from the drawing. An attempt has been made to identify those panels that will pass through the panel line excluding the curved and other panels and the results are depicted in the table (Table 3.3).

Table 3.3 Number of plates, stiffeners, panels, and the average plate thickness identified for a specific section from the drawing

Panel No	Section	Parameters		Plate Thickness
		Stiffener	Plate	Average,mm
1	AV 2412-inner	4	2	12
2	AV 2412- outer	4	2	17
3	AV 2412- A	3	1	12,5
4	AV 2417 -Inner shell	15	6	16
5	AV 2417 -A	2	1	12
6	AV 2417 -B	2	1	12

7	AV 2417 -C	2	1	12
8	AV 2411-Inner	9	5	15
9	AV 2411-A	2	1	13
10	AV 2411-B	2	1	12
11	AV 2411-C	2	1	12
	Total Number of Plates=		22	
Total Number of plates to be welded=			15	
Average number of plates or sheets per panel are				2

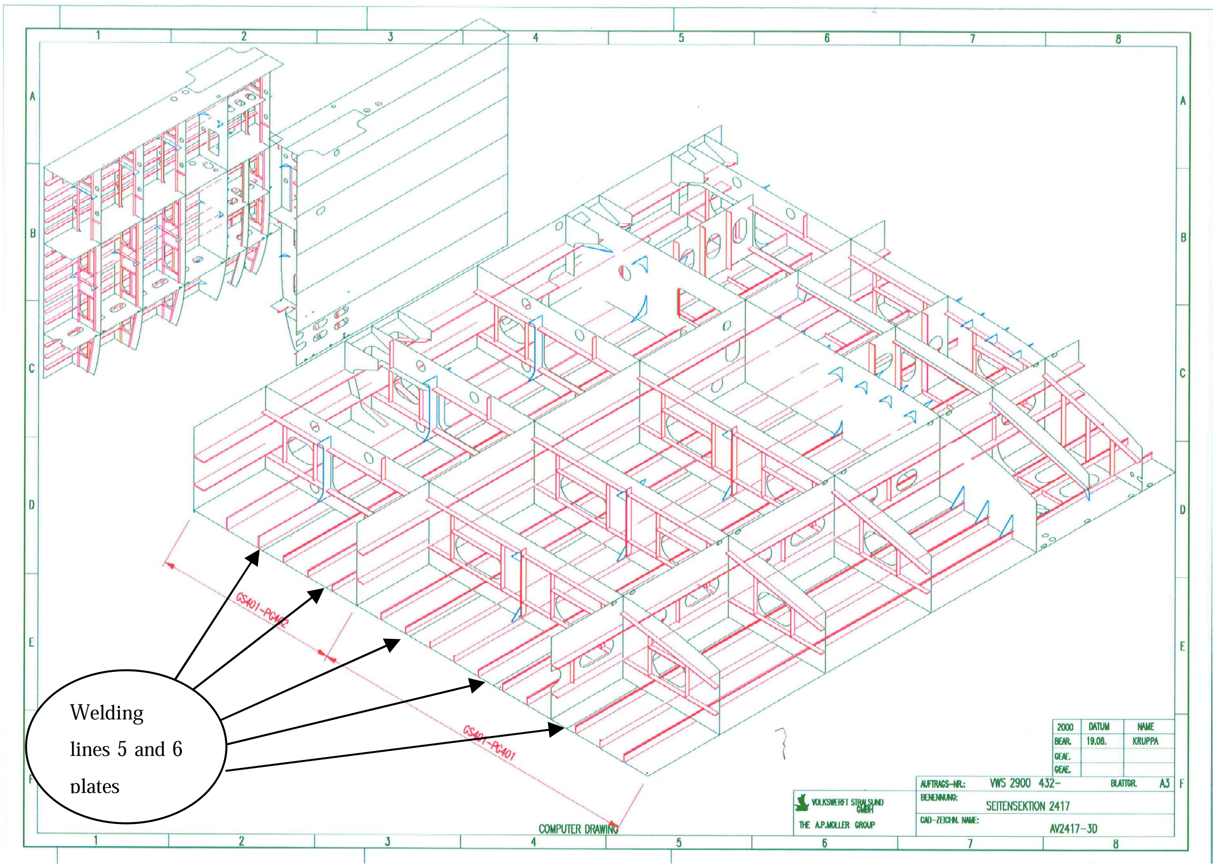


Figure 3.5 The detailed drawings of the tanker ship for section AV 2417

From the above figure, considering the bottom part of the stiffened panel it is clear that there are five welding lines longitudinally where the 6 plates will be welded together and counting the number of stiffeners to be placed on the bottom part containing the 6 plates gives 15 stiffeners. The thickness of the plate is important parameters while choosing the speed of the welding device and the thickness of each plate is given in the figure (Fig 3.5) where the average thickness of the plates is considered for further computation of the cycle time.

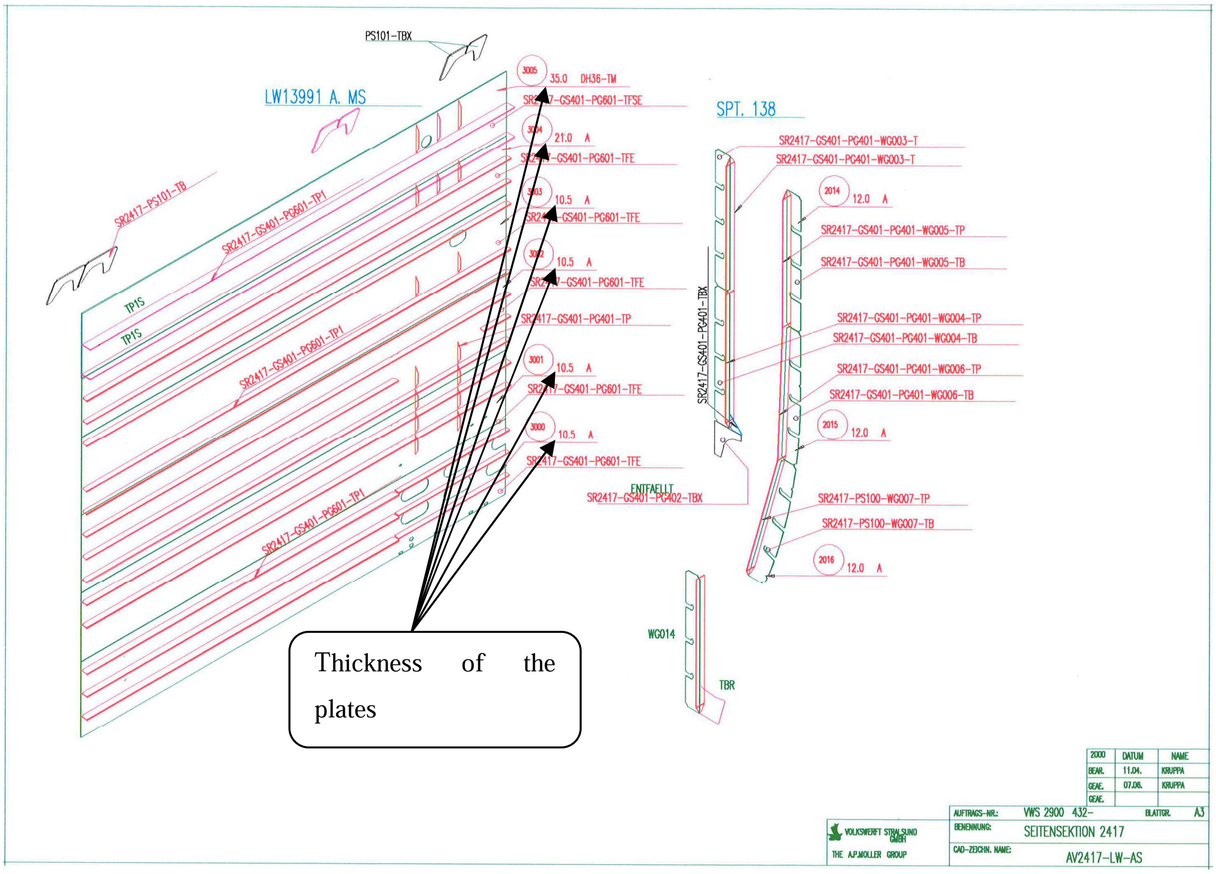


Figure 3.6 The detailed drawings of the tanker ship for section AV 2417 showing the thickness of the 6 plates

While selecting the proper sections from the main and the detailed drawing of the tanker ship, a great care has been taken in to account in order not to include the parts that have a curved geometry which has no effect on the panel line. Stiffened panels with curved geometry will be produced in a different line not in a panel line. The figure (Fig 3.7) depicts a curved stiffened panel that will not be produced along the panel line.

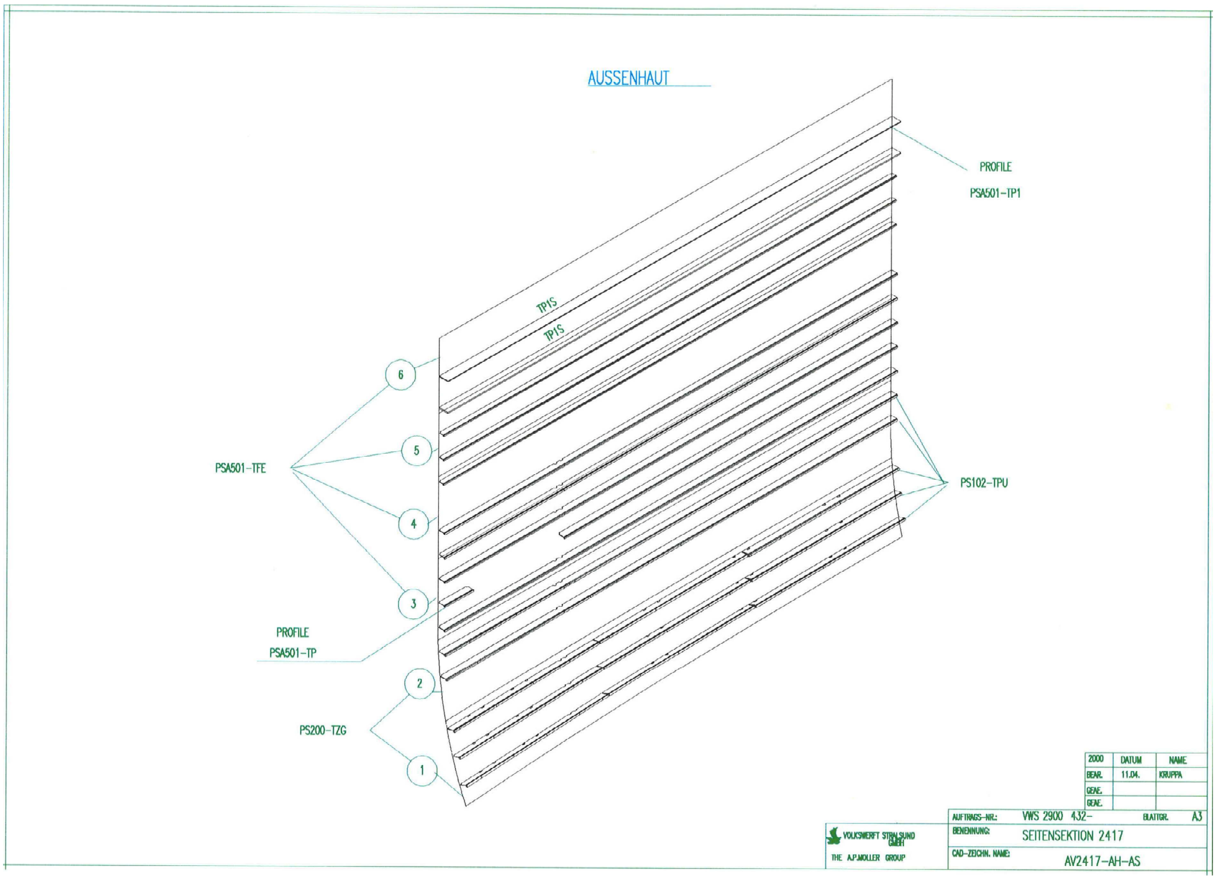


Figure 3.7 The detailed drawings of the tanker ship showing the curved geometry

Considering the parameters (Table 3.2) as the reference section of the tanker ship for which we can compute the cycle time for each section and the thickness of the plate determines whether to carry out the manual or automatic welding operation. If the plate thickness is greater than 30 mm, it requires the double side welding and it has to be done on the manual welding operation and hence the Sankey diagram depicts the flow of the material along the panel line with the percentages mentioned below. Panels with only one plate will directly be transferred to the profile setting station without visiting the plate welding.

Referring to the table (Table 3.2), there are 15 plates to be welded in the plate welding work station and the rest (7 plates) would pass on to the stiffener setting work station bypassing the plate welding station and this is very helpful in developing the Sankey diagram that indicates the flow of the plates along the panel line.

Percentage of plates to the plate welding= number of plates to be welded/total number of plates

Percentage of plates to the plate welding=15/22*100%

=68,2 %

The rest (31,8%) will be transferred directly to the stiffener setting work station and the flow has been represented below.

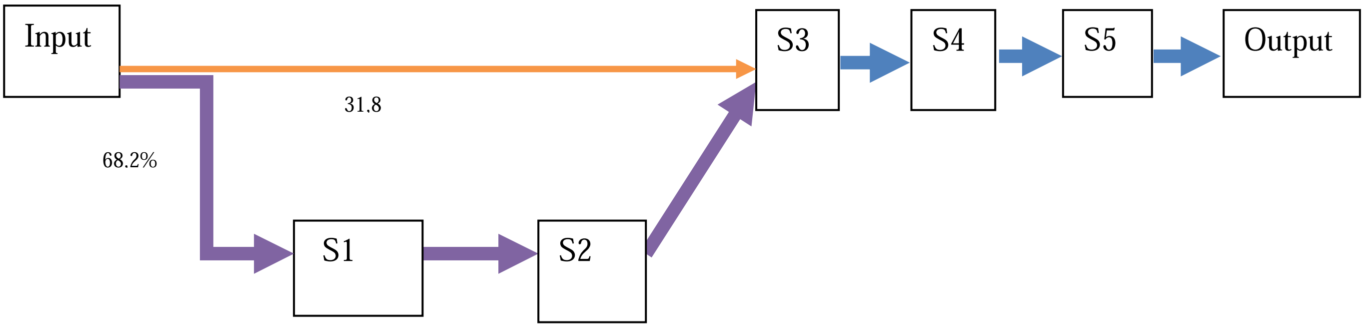


Figure 3.8 The flow of material along the panel line for the Tanker ship

After properly identifying the stiffened panels that would be produced in the panel line excluding the curved sections of the stiffened panels, the next step is to determine the cycle time for each work stations and presented in the next section.

3.3.2.1 Determination of the Cycle Time for Automatic Welding Work Station

In order to determine the cycle time for this work station, the following parameters have been taken in to account:

- The speed of the welding machine
- The length of the plates
- The number of runs per panel
- Processing time account for 15% of the cycle time

NS:- Number of stiffeners

NP:-Number of plates

FS:-Frame spacing

NF:-Number of frames

Table 3.4 Determination of the cycle time for Automatic welding station

Panel No	Section	Parameters		Plate Thickness Average ,mm	welding					No. Of Run	Cycle Time,m
		NS	NP		Speed cm/min	FS	NF	Length	Time, in min Per run		
1	AV 2412-inner	4	2	12	92,4	786	20	15720	17,0	1,0	113,4
2	AV 2412- outer	4	2	17	83,4	786	20	15720	18,8	1,0	125,7
3	AV 2412- A	3	1	12,5	91,5	786	20	15720	17,2		
4	AV 2417 -Inner	15	6	16	85,2	786	20	15720	18,5	5,0	615,0
5	AV 2417 -A	2	1	12	91,4	786	20	15720	17,0		
6	AV 2417 -B	2	1	12	92,4	786	20	15720	17,0		
7	AV 2417 -C	2	1	12	92,4	786	20	15720	17,0		
8	AV 2411-Inner	9	5	15	87	786	20	15720	18,1	4,0	481,8
9	AV 2411-A	2	1	13	90,6	786	20	15720	17,4		
10	AV 2411-B	2	1	12	92,4	786	20	15720	17,0		
11	AV 2411-C	2	1	12	92,4	786	20	15720	17,0		
	Total Number of plates=		22				Total Cycle time =				1335,9
Total Number of plates to be welded=				15	Cycle time per plate =						89,1
Average number of plates per panel are =					2						

Example for panel 1

Average plate thickness 12 mm

Number of plates 2

Frame spacing 786 mm

Number of frame 20

Plate Welding length= frame spacing * number of frames

= 786mm * 20

=15720 mm

The welding speed depends up on the thickness of the plate and interpolation has been utilized so as to get the welding speed by considering the reference given in the figure 3.8 and referring to the first alternative in the figure where the welding speeds for plate thickness of 5 and 30 mm are 105 and 60 cm per minute respectively, it is possible to interpolate using these two parameters so as to get the approximated welding speed for the plate thickness of 12 mm.

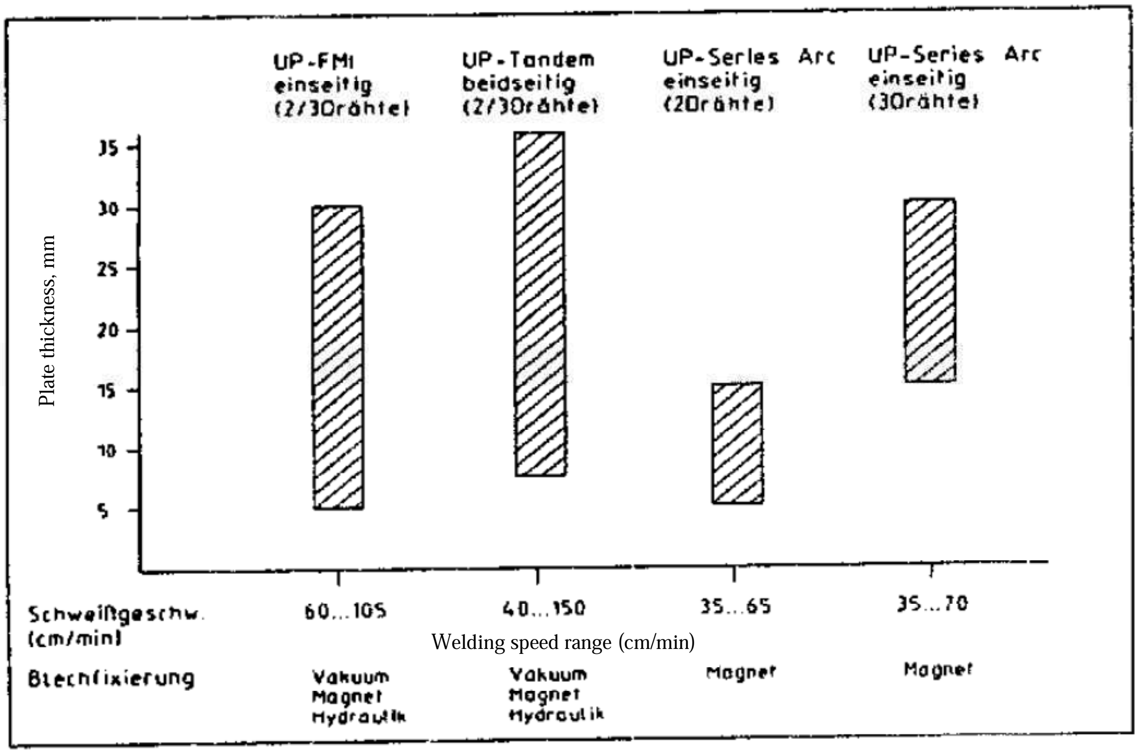


Figure 3.9 Welding speed (cm/minute) ranges for different plate thickness [17]

Thickness (mm)	speed (cm/minutes)
5	105
12	?
30	60

Welding speed for plate thickness 12 mm = 60 + (105-60)*(30-12)/(30-5)

= 92.4 cm/minute

Processing time = welding length / speed of welding

= 15720 mm/92.4 cm/minute

=17.02 minutes

Since there are only two plates in this panel, the number of running (welding frequency) will only be one time. Then the cycle time for the panel can be computed as follows

Note: Processing time account for 15% of the cycle time

Cycle time = Processing time * frequency of welding /0.15

= 17.02 minutes *1/0.15

=113.4 minutes

The same procedure has been followed for each panel and finally the cycle time per plate is computed by dividing the total cycle time to the number of plated being welded.

Cycle time per plate= Total cycle times * total number of plates welded

= 1335.9/15

=89.1 minutes

3.3.2.2 Determination of the Cycle Time for Trimming, Cutting and Marking Work Station

In order to determine the cycle time for this work station, trimming and cutting operations are considered separately and summed up finally. The following parameters have been take in to account for the trimming operation

- The speed of the machine (consider speed 700 mm/minute)
- The length and width of the panel
- Processing time account for 55% of the cycle time

Table 3.5 Determination of the cycle time for trimming operation

Section	Length	Width	Speed, mm/min	Processing time, minute
AV 2412-inner	15720	6681	700	64,00
AV 2412- outer	15720	4716	700	58,39
AV 2417 -inner	15720	13362	700	83,09
AV 2411 -inner	15720	1572	700	49,41
Number of plates	15		Total time=	254,89
			Cycle time=	463,43
	Cycle time per Plate is		30,90	minutes

The following parameters have been take in to account for the cutting out operation

- The speed of the machine (consider speed 1000 mm/minute)
- The dimensions of the cutout
- Set up time 1 minute per cut out
- Cycle time is the summation of the processing time and the set up time

Table 3.6 Determination of the cycle time for cutting operation

Section	Length mm	Width mm	Number of cutouts	Speed, mm/min	Processing time	setting up, m/cut out	Cycle time
AV 2417	943,20	314,40	5,00	1000,00	12,58	1,00	17,58
AV 2417	628,80	314,40	1,00	1000,00	1,89	1,00	2,89
AV 2417	314,40	314,40	1,00	1000,00	1,26	1,00	2,26
AV 2417	157,20	157,20	7	1000,00	4,40	1,00	11,40
AV 2411	501,70	1003,40	6,00	1000,00	18,06	1,00	24,06
AV 2411	334,47	668,94	20,00	1000,00	40,14	1,00	60,14
AV 2411	167,23	167,23	26,00	1000,00	17,39	1,00	43,39
Number of plates with cut outs			11			Cycle time=	161,71
				Cycle time per Sheet=		14,70	Minute

The cycle time for the trimming and cutting work station is the summation of the trimming and the cutting cycle times that is 30.9+ 14.7 = 45.6 minutes

3.3.2.3 Determination of the Cycle Time for Profile Setting Work Station

The following parameters have been take in to account for the cutting out operation

- The speed of the machine (Average speed 4500 mm/minute)
- The number of stiffeners and the number of the plates
- Processing time accounts for 25% of the cycle time

Table 3.7 Determination of the cycle time for profile setting station

SN	Section	Parameters			Speed mm/min	Processing Time , minute	Cycle Time, minute
		NS	NP	Length mm			
1,00	AV 2412-inner	4,00	2,00	15720,00	4500,00	13,97	55,89
2,00	AV 2412- outer	4,00	2,00	15720,00	4500,00	13,97	55,89
3,00	AV 2412- A	3,00	1,00	15720,00	4500,00	10,48	41,92
4,00	AV 2417 -inner	15,00	6,00	15720,00	4500,00	52,40	209,60
5,00	AV 2417 -A	2,00	1,00	15720,00	4500,00	6,99	27,95
6,00	AV 2417 -B	2,00	1,00	15720,00	4500,00	6,99	27,95
7,00	AV 2417 -C	2,00	1,00	15720,00	4500,00	6,99	27,95
8,00	AV 2411-	9,00	5,00	15720,00	4500,00	31,44	125,76
9,00	AV 2411-A	2,00	1,00	15720,00	4500,00	6,99	27,95
10,00	AV 2411-B	2,00	1,00	15720,00	4500,00	6,99	27,95
11,00	AV 2411-C	2,00	1,00	15720,00	4500,00	6,99	27,95
	Total Number of plates=		22,00		Total cycle time =		656,75
	Number of plates to be welded=		15,00	Cycle time per Plate is		29,85	minutes

3.3.2.4 Determination of the Cycle Time for Profile Welding Work Station

The following parameters have been take in to account for the cutting out operation

- The speed of the machine (Average speed 700 mm/minute)
- The number of stiffeners and the number of the plates
- Processing time accounts for 75% of the cycle time

Table 3.8 Determination of the cycle time for profile welding station

SN	Section	Plates and stiffeners				Processing	Cycle
		NS	NP	Length mm	Speed mm/min	Time, minute	Time minute
1	AV 2412-inner	4,00	2,00	15720,00	700,00	89,83	119,77
2	AV 2412- outer	4,00	2,00	15720,00	700,00	89,83	119,77
3	AV 2412- A	3,00	1,00	15720,00	700,00	67,37	89,83
4	AV 2417 -inner	15,00	6,00	15720,00	700,00	336,86	449,14
5	AV 2417 -A	2,00	1,00	15720,00	700,00	44,91	59,89
6	AV 2417 -B	2,00	1,00	15720,00	700,00	44,91	59,89
7	AV 2417 -C	2,00	1,00	15720,00	700,00	44,91	59,89
8	AV 2411-	9,00	5,00	15720,00	700,00	202,11	269,49
9	AV 2411-A	2,00	1,00	15720,00	700,00	44,91	59,89
10	AV 2411-B	2,00	1,00	15720,00	700,00	44,91	59,89
11	AV 2411-C	2,00	1,00	15720,00	700,00	44,91	59,89
	Total Number of plates=		22,00				**1407,31**
	Number of plates to be welded=		15,00	Cycle time per Plate is		63,97	minutes

3.3.2.5 Determination of the Cycle Time for the Completion Work Station

The completion work station involves a number of activities like pre-outfitting, some manual welding activities and others. Since it is not know exactly at this point what activities are carried out in the completion work station which makes the determination of the cycle time very difficult, the cycle times used for the container ship can be used as a reference in order to interpolate the cycle time for the tanker ship.

Work station	Container	Tanker
Profile welding	82	64
Completion	73	?

The completion time for Tanker case = 64*73/82

=57 minutes

The table below summarizes the cycle time for each work station along the panel line.

Table 3.9 Cycle time for each work station of the panel line

Station	Description	Cycle Time, minute/plate
1	Automatic welding	89.1
2	Trimming, cutting, marking etc	45.6
3	Profile setting	29.9
4	Profile Welding	64
5	Completion	57

CHAPTER 4 MODEL DEVELOPMENT AND SCENARIO ANALYSIS

Since there are two types ships (namely Container and Tanker ship) considered in this thesis, two models have been developed separately following to the data collection and synthesis carried out in the previous chapter. This chapter contains information regarding the model development and scenario analysis for each type of ship along the panel line in the ship building industry. The Sankey diagram that provides about the flow of the material along the panel line has been taken in to account while developing the model and a number of experiments are carried out to examine and find out the optimal cycle time for some work stations that will maximize the overall production line.

4.1 Model Development and Scenario Analysis for Container Ship

It is clear that the Sankey diagram provides an insight what percentage to use in the exit strategy dialogue box. The first procedure so as to carry out the simulation analysis is to represent all the workstations along with their interactions with each other starting from the source until the final result in the plant simulation frame. The figure below depicts the representation of the workstations in the plant simulation interface.

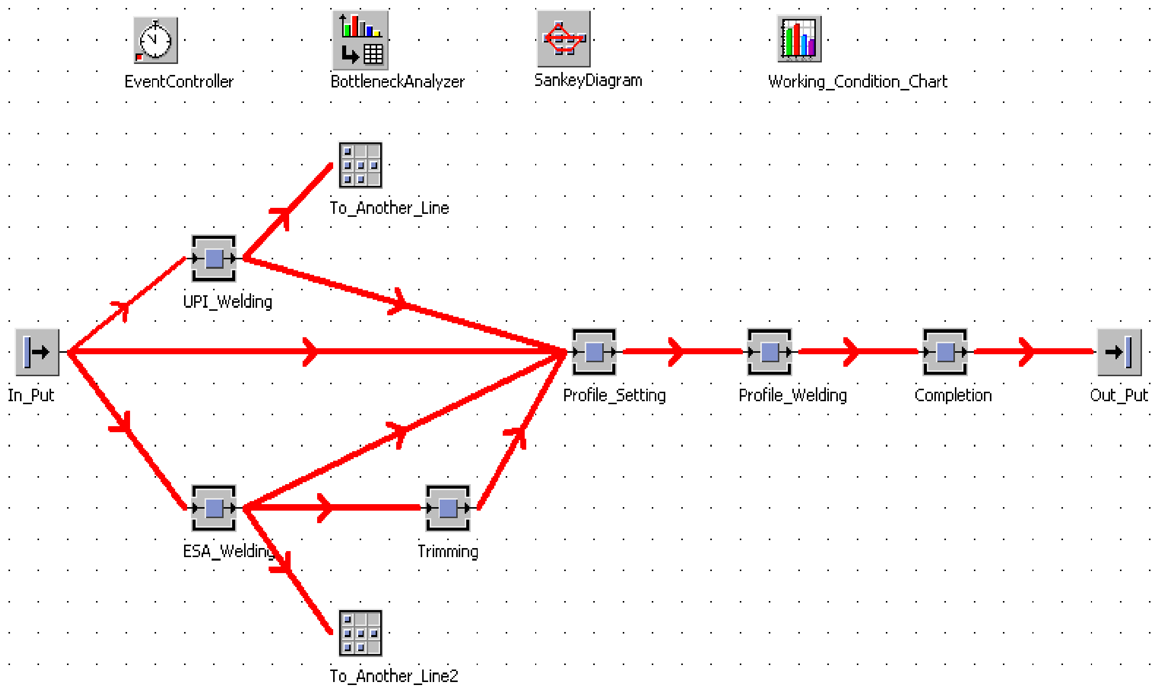


Figure 4.1 Representation of the panel line in the simulation frame for Container ship

The above model is developed based on the information presented in the figure (Fig 3.2) that indicates the flow of the plates along the panel line and all the product parameters like cycle time. It is advisable to check the model (verification and validation) at each stage in order to avoid cumulative errors at the end of the simulation process. The most important thing while developing the model is to check whether the model would provide all the necessary answers set as an objective in advance taking in to account the problem descriptions. It is also possible to run a test simulation and look for the sample results before going further to scenario analysis. The check lists below are used to check the importance of the model for the overall analysis and applied in both cases (Container and Tanker).

- Is the model developed in such a way that it will provide information about the utilization at each work station?
- Will the model help in decision making process with regard to production planning and control?
- Are the results easy to understand and interpret?
- Will the result indicate the effect of each work station on the overall panel line?
- Is it possible to see the effect of the addition of new work station to the existing panel line?

The model has been cross checked against the above checklists and positive results have been obtained in both cases. Considering the sankey diagram and the cycle time for each work stations given in table 3.1, the dominant cycle time will be the station time for the profile welding which is 82 minutes per sheet. Hence the theoretical production rate without considering the failure in the production line will be

Production rate = available time /cycle time

= 331200 minutes/82 minutes/sheet

=4039 sheets per year

This result has also been used to check the results from the simulation where the failure along the production line is taken in to account.

4.1.1 Scenario One for Container Ship

This is the first case considered to see the simulation result in the Panel line based on the cycle time given in the table (Table 3.1). It is recommended to select one of the key performance measures to compare the results of different scenarios and in this case annual throughout (annual production rate) has been considered for the sake of comparing the results of the different cases. Due attention should be given when providing the simulation run parameters because it is this value that will be considered in the overall simulation run.

Working days per year = 250 days

Working hours per day = 22.1 hrs

In order to give an input of one year running time for the simulation, the time has to be converted in to real working days.

Real working days per year= 250*22.1/24= 230 days

This will be used in the EventController in the plant simulation software as the simulation run time.

Assumptions

- 99% availability of resources
- Mean time to repair (MTTR) is 2 minutes

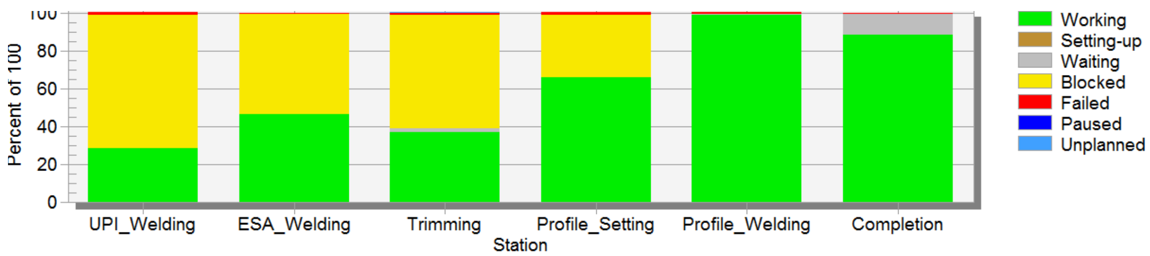


Figure 4.2 Performance characteristics of each workstation for scenario one (container)

Total Throughput= 3996 sheets (Note: Theoretical production rate is 4039 sheets)

The bottleneck station is profile welding

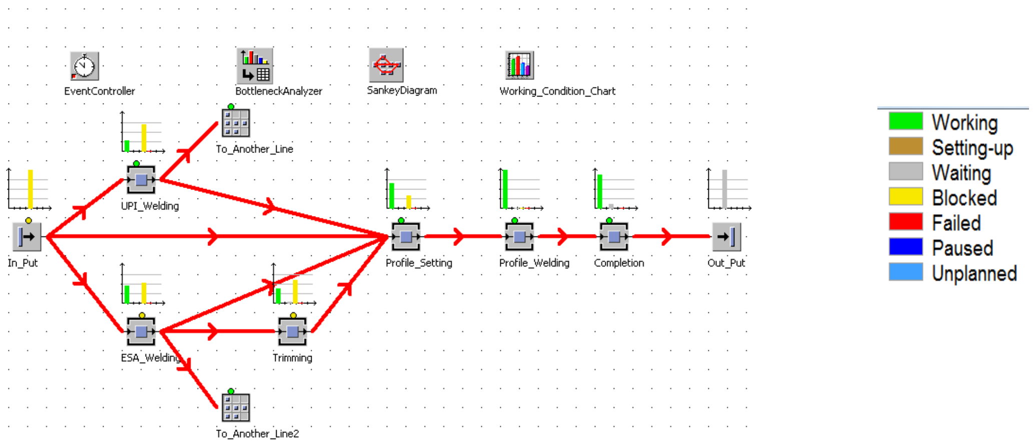


Figure 4.3 The standard statistics of the material flow objects for scenario one (container)

The bottleneck analyzer gives statistical information about each work station which is relevant to clearly identify how each work station is performing in the production line.

Referring to the figure (Fig 4.3), most of the time, the workstations plate welding and trimming are blocked that reduced the productivity of the panel line.

4.1.2 Scenario Two for Container Ship

In the previous section, it has been found out that the bottleneck section is the profile welding work station and in this section an attempt has been made to find out the optimal cycle time using the Experimental manger that runs experiments with simulation model. In order to carry out the optimization analysis with the experimental manager, the lower bound, the upper bound and the increment (Design experiment) have to be selected and presented in the table below. Three simulation runs have also been considered for each experiment which means three results will be taken in to account for each input value that gives rise to 33 experiments with 99 simulation runs.

Table 4.1 Design table of the experiment for the profile welding work station

Input values	Cycle Time, minutes/plate
Lower bound	50
Upper bound	82
Increment	1

Table 4.2 Output for each experiment of the profile welding workstation for scenario one

Experiment	**Cycle time , Minute**	**Output**	**Experiment**	**Cycle time , Minute**	**Output**
1	50	4489	18	67	4488
2	51	4489	19	68	4487
3	52	4489	20	69	4485
4	53	4489	21	70	4482
5	54	4489	22	71	4475
6	55	4489	23	72	4466
7	56	4489	24	73	4451
8	57	4489	25	74	4406
9	58	4489	26	75	4356
10	59	4489	27	76	4304
11	60	4489	28	77	4251
12	61	4489	29	78	4198
13	62	4489	30	79	4146
14	63	4489	31	80	4094
15	64	4489	32	81	4044
16	65	4488	33	82	3995
17	66	4488			

The plant simulation software also provides graphical representation of the result which is good for visualization and it is part of the report that will be created automatically when it finished the optimization process.

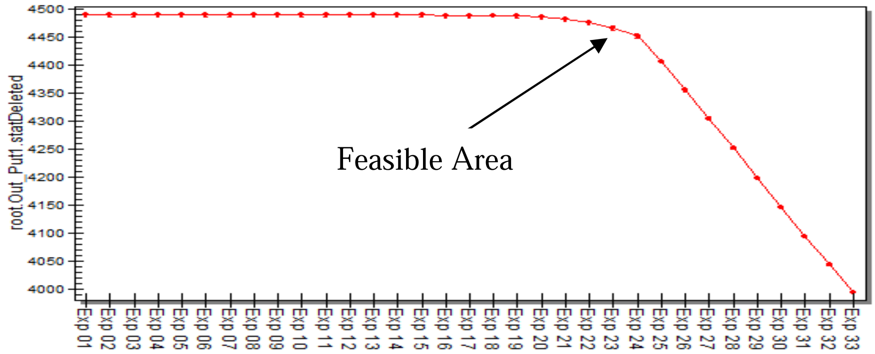


Figure 4.4 The total throughput from the experimental manager considering the profile welding work station (container)

Since there are three simulations run for each experiment, the above output values represent the average value for each experiment and a confidence level interval of 95% which is reasonable for scientific analysis has been taken into account in the experimental manager.

Referring to figure 4.4, it is clear that the total output is exactly the same for the first 15 experiments and it starts to decline afterwards. Examining how the output declines, it is from experiment 24 to 25 where high decline in output has been observed and experiment 24 (73 minutes) can be considered as an optimal solution.

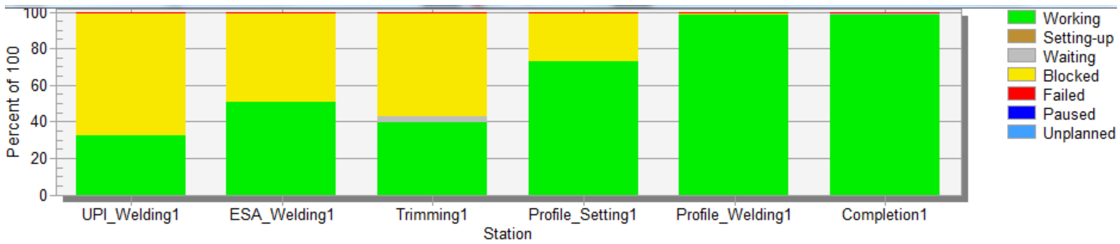


Figure 4.5 Optimal results for profile welding

The total output in this case is 4451 sheets and the percentage improvement will be

= (4451-3996)/3996*100%

=11,4 % improvement

In order to get the above percentage improvement in productivity, it requires a cost benefit analysis on the work station because one or more of the followings have to be engaged to realize the gain.

- Additional man power hiring in the profile welding work station
- Improving the technology involved in the work station
- Future demand has also to be taken to account

4.1.3 Scenario Three for Container Ship

The specific purpose of this scenario is to see if it is possible to optimize further by combining the profile welding and the completion work stations.

Table 4.3 Design table of the experiment for the profile welding and completion work stations

Input Values	**Profile Welding , Cycle time, minute/plate**	**Completion , Cycle Time minute/plate**
Lower bound	50	50
Upper bound	82	73
Increment	1	1

A total of 792 experiments with 1584 simulation runs and the results are displayed below which shows the statistical distribution of the results for the combination of profile welding and completion.

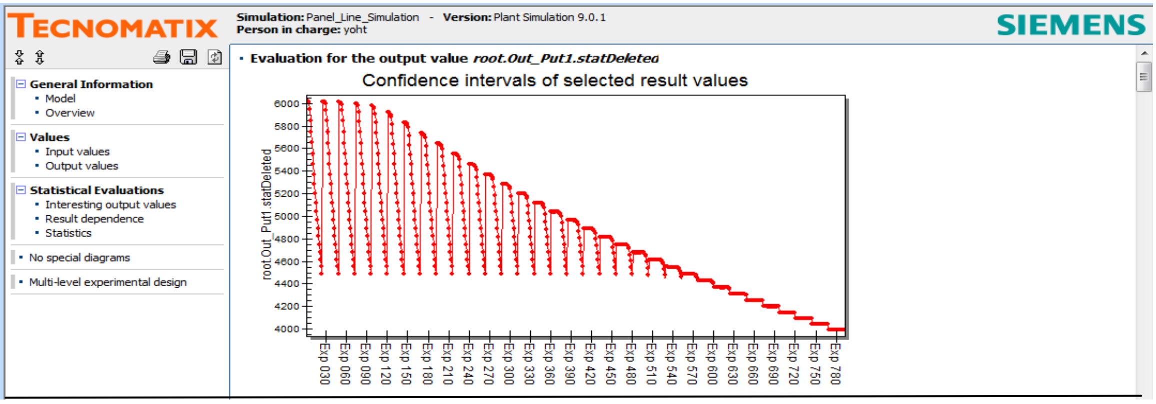


Figure 4.6 The total throughput from the experimental manager considering the profile welding and completion work stations (container)

The results depicted in the figure 4.6 shows that the output is similar for some experiments (every 24 experiments) and this is due to the difference in lower and upper bound for the profile welding and the completion work stations. But it gives interesting information on how to choose the best combination of the cycle times for both work stations taking in to account the demand forecast. If it is required that there should be an output of 5041 sheets, we can consider the experiments listed in the table (Table 4.4) below.

Table 4.4 design experiments that provide the same output of 5041 sheets

Experiment	Profile welding Minute	Completion Minute	Output Sheets
16	50	65	5041
40	51	65	5041
64	52	65	5041
88	53	65	5041
112	54	65	5041
136	55	65	5041
160	56	65	5041
184	57	65	5041
208	58	65	5041

Even though the results are the same for the total output in the table 4.4, experiment 208 gives optimal combination of the cycle times for the profile welding and the completion workstations. Therefore the total output in this case is 5041 sheets and the percentage improvement will be

= (5041-3996)/3996*100%

=26.2 % improvement

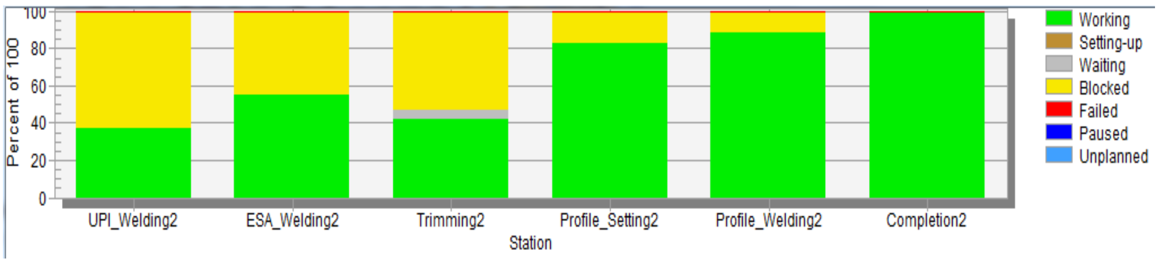


Figure 4.7 Optimal results for profile welding and completion workstations (container)

4.1.4 Optimization using The Genetic algorithm (GA)

In the previous sections , an optimization analysis has been performed using the experimental manager tool from the tecnomatix plant simulation software and here an attempt has been made how to apply the generic algorithm method in order to find out the best optimal solution considering the workstations where improvement could be possible by reducing the station time. Genetic algorithm helps to find out an optimal solution based on a stochastic approach and GA starts with an initial solution set, which contains individuals created randomly .This is called initial population [18]. The initial step can mightily improve the efficiency of the algorithm, thus a new start strategy can be momentous. The new population is always generated from the actual population's participants by the genetic operators. The generation of new populations is continued until a predefined stop criterion is satisfied. The figure below depicts the life cycle of genetic algorithms.

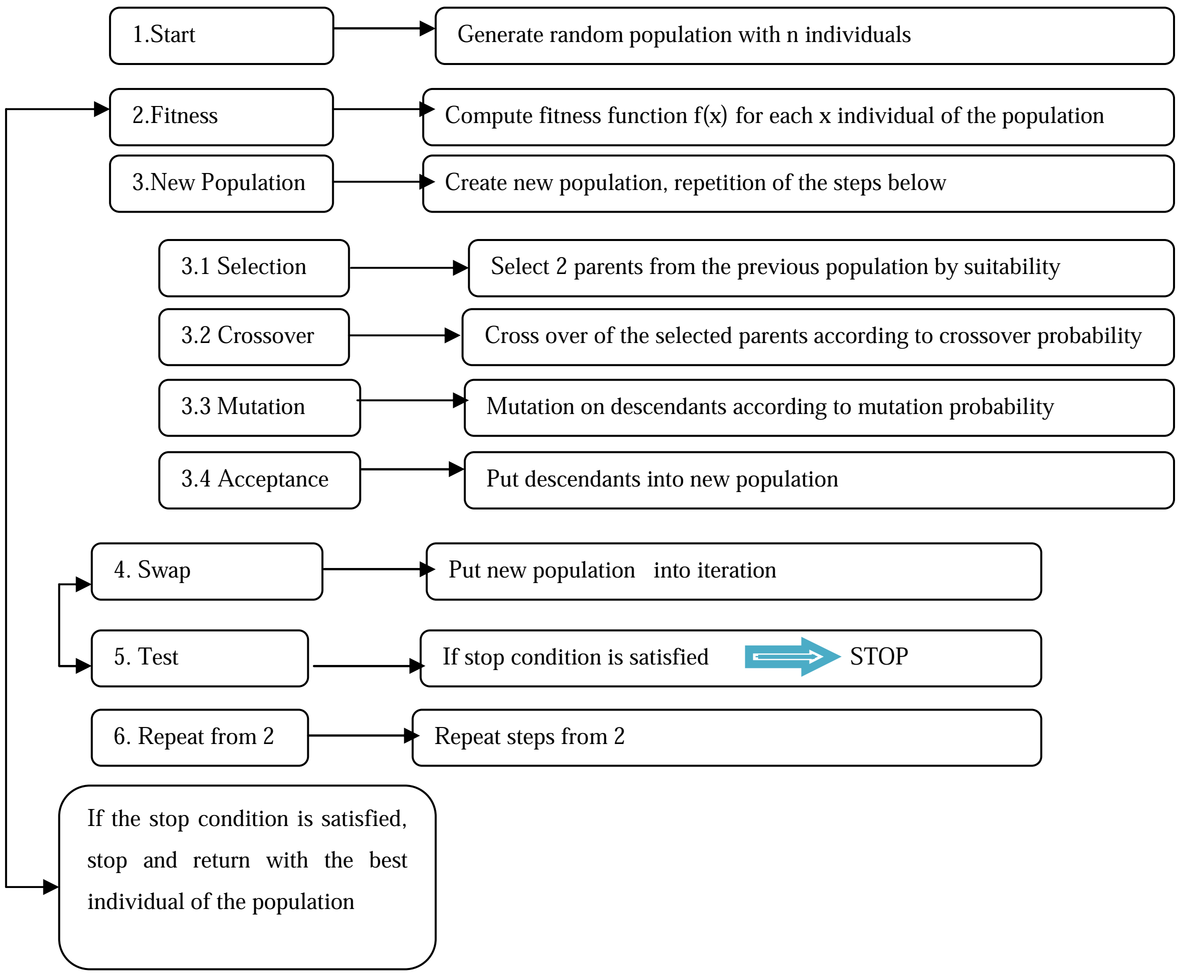


Figure 4.8 The life cycle of generic algorithm [18]

In order to carry out the optimization analysis, parameters should be selected from different stations for which the optimization would be performed by varying these values so as to maximize or minimize the objective function. Genetic algorithm allows multiple objective optimizations with weight percentage but in this case there exists only one objective function and that is the production rate along the panel line. Looking at the performance characteristics of the workstation in scenario one, the work stations profile setting, profile welding and completion are selected in which the processing time is the parameter for optimization.

Table 4.5 Optimization parameters of GA for the container ship

Input values	Profile setting, minute/plate	Profile welding, minute/plate	Completion, minute/plate
Lower bound	30	50	50
Upper bound	54.4	82	73
Increment	1	1	1

The objective function is to maximize the production rate along the panel line considering the following optimization parameters

$$30<=X1<=54.4$$

$$50<=X2<=82$$

$$50<=X3<=73$$

Where

X1-The processing time per sheet for profile setting work station in minute

X2- The processing time per sheet for profile welding work station in minute

X3- The processing time per sheet for Completion work station in minute

Number of generations (Iterations):= 20

Size of the generation (population size):= 20

Initially 20 initials solutions (population) are selected from the optimization parameters and evaluated based on their fitness by the fitness function where the two parents have to be selected. The distribution of the initial solution of the first generation is depicted in the figure below and the rest are placed at annex part of the report. Iteration continues until the end of the last 20 generations by computing the best and the worst solutions on each generation from which the best solution will be fitted in to the optimization parameters that would provide the maximum production rate along the production line.

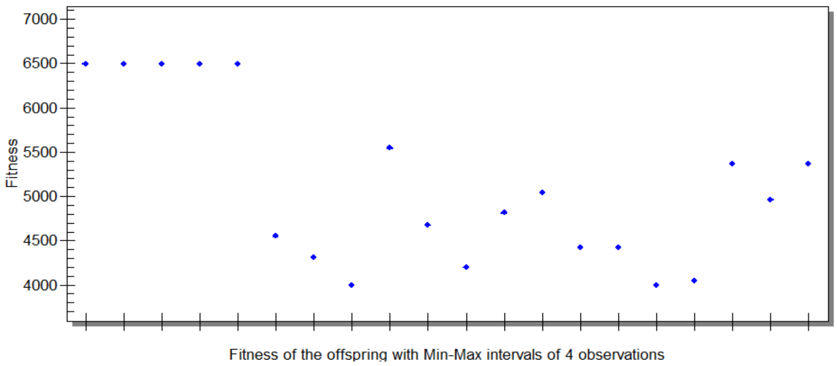


Figure 4.9 The initial solution of the optimization process

For each iteration, the best, the worst and the average fitness (solutions) are computed and the results are represented in the figure below for the whole generations considered in the optimization process.

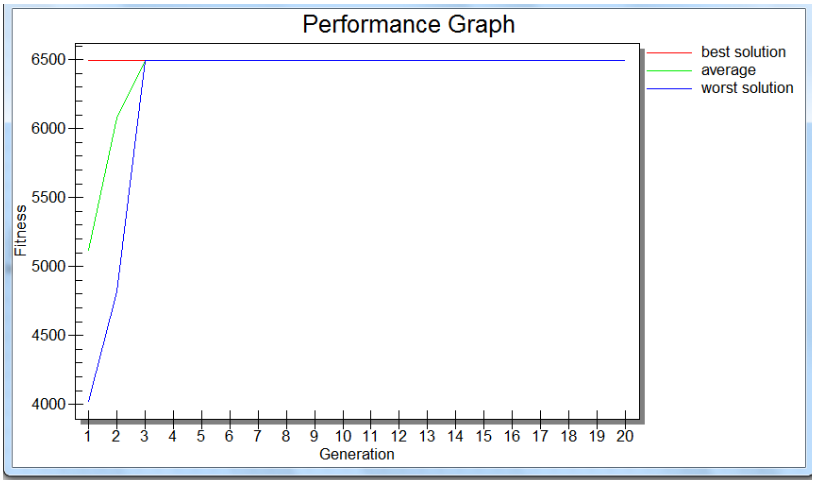


Figure 4.10 The performance graph of the 20 generations

Referring to the above performance graph, the worst and the best fitness coincides to each other indicating the optimal solution resulting in the production rate of 6497 sheets per year for which the best fit for optimization parameters profile setting, profile welding and completion are 33,50 and 50 minutes respectively. One of the basic differences between the experimental manager and the genetic algorithm is that experimental manager considers one input at a time but GA considers a number of inputs as a population and selects the best fit from the population. In order to benefit more from the genetic algorithm, cost constraint should be incorporated so that an optimal solution that could be justified by cost-benefit analysis would be obtained along the production line.

4.1.5 Scenario four for Container Ship

In this section an attempt has been made to see the effect of adding a new workstation to the panel line where the PVPs will be welded on the stiffeners in order to improve the strength of the ship thereby reducing the catastrophic effects during collision and grounding. One of the most important parameter for testing the effect of the PVPs work station is the cycle time and since the project is still undergoing, the following assumptions have been considered for the sake of checking its effect on the panel line production.

Assumption

i. Ten points will be selected for proper placement of the PVPS (0,5 minute each)

ii. Robot welding will be applied in order to weld the PVPS on the panel

Speed , V=0,0083 m/s

Distance, L=2,8 m

Time= L/V= 2,8/0,0083=337,5 sec or 5,62 minutes

Considering 4 runs to entirely weld the PVPS

Total time for welding= 4*5,62= 22,5 minutes

Table 4.6 Determination of cycle time for PVPs work station

S.N	Activity	Time, minute
1	Estimated time to transport one PVPs to the stiffened panel	1
2	Estimated time to weld parts of the PVPs on the panel for proper placement of the PVPs	5
3	Average time to weld the PVPs on the stiffened panel	22,5
	Estimated time to work with the PVPs on the panel line	**28,5**

	Time per PVPs=	**28,5**	**minutes**
Panel	**PVPs**	**Time per panel, minute**	**Cycle time ,min /sheet**
1	3	85,5	38,00
1	4	114	50,67
1	5	142,5	63,33
1	6	171	76,00
1	7	199,5	88,67
1	8	228	101,33
1	9	256,5	114,00
1	10	285	126,67
1	11	313,5	139,33
1	12	342	152,00

Considering the number of PVPs per panel to be 6 and the number of sheets per panel to be 2.25, the simulation analysis gives the following results.

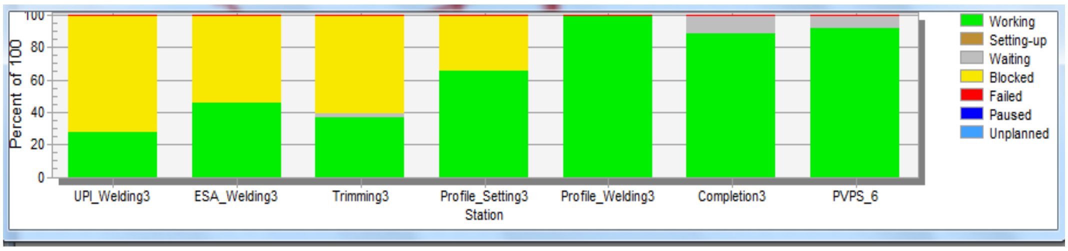


Figure 4.11 Performance behaviors in each work station under scenario four (Container)

The total output for the above simulation is 3994 sheets and compared to the first result (3996 sheets), it is clear that the PVPs workstation has no significant effect on the panel line under this condition where the cycle time for the PVPs work station 76 minutes and hence still the bottleneck is the profile welding.

If we consider the number of PVPs per panel to be 7 for which the cycle time for the PVPs work station will be 88. 67 minutes, the addition of the new work station becomes a new bottleneck and resulted in the total output of 3695 sheets per year.

Percentage of reduction in productivity along the panel line due to the addition of the new work station (PVPs) can be computed by comparing the new result with the output obtained from the existing panel line

= (3695-3996)/3996*100%

=-7.5 %

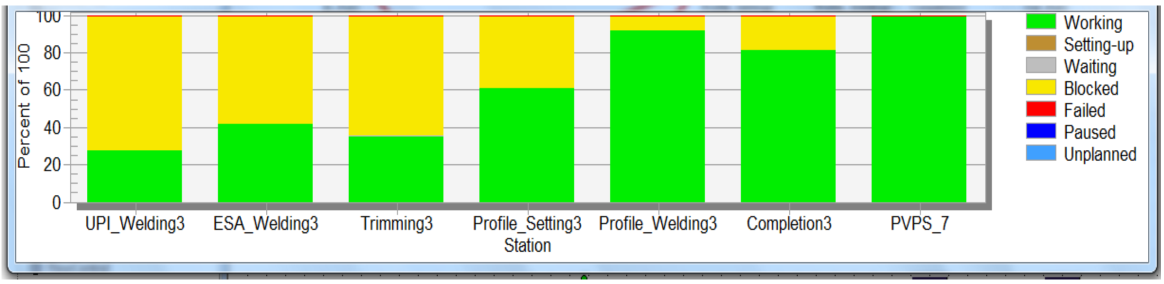


Figure 4.12 Performance behaviors in each work station considering 7 PVPs per panel

The above analysis provides an insight on how to visualize the effect of adding a new work station in to the existing panel line and it is inevitable that as the number of PVPs exceeds 6 per panel the profile welding is no more a bottleneck along the panel line since its cycle time is less than the new work station (PVPs) work station which gives rise to the reduction of the production rate along the panel line. Since the requirement for the number of PVPs per panel also depends on the structural analysis, the work station can have sub stations so that the number of PVPs can exceed 6 per panel without affecting the panel line where the PVPs work station has less cycle time than the profile welding station.

4.1.6 Scenario Five for Container Ship

The purpose of this section is to use the experimental manager in order to find out the optimal cycle time for the PVPs work station in such a way that the total throughput will be maximized. The design parameters are selected considering the number of PVPs in a panel (assume 3 to 7 PVPs in a panel) and hence the range of the cycle time is depicted in the table below with upper and lower bound.

Table 4.7 Design table of the experiment for the PVPs work station

Input values	**Cycle time, minutes/plate**
Lower bound	38
Upper bound	90
Increment	2

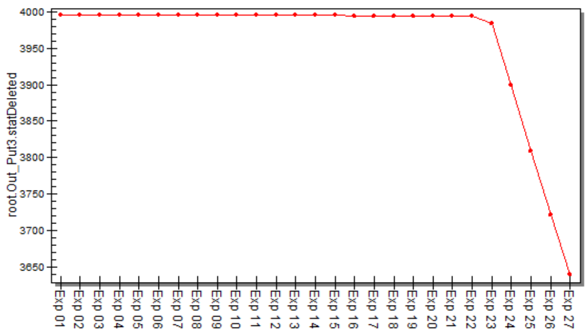


Figure 4.13 The total throughput from the experimental manager considering the PVPs work station

Referring to the results obtained from the experimental manager, the total output is more or less similar for the first 22 (until cycle time=82 minutes) experiments and the numbers of sheets produced are almost the same with the first scenario and this indicates that the profile welding is the work station that is affecting the panel line. It is clear that an attempt to reduce the cycle time in the PVPs work station does not have any effect on the overall performance of the panel line unless the cycle time for the profile welding is also taken in to consideration during the optimization.

4.2 Model Development and Scenario Analysis for Tanker Ship

In the previous section a simulation analysis has been carried out for a container ship and in this part the same analysis will be performed for a tanker ship in order to examine the effect of the ship type on the panel line and the influence of the PVPs work station to the panel line. Since there are no real data on the processing time, set up time, and cycle time for each work station in the panel line referring the tanker ship, computation of these parameters have been done by considering the drawing and identifying the possible number of plates, panels and stiffeners from the drawing.

In order to model the panel line for the stiffened panels that will be used for the construction of the Tanker ship, the Sankey diagram represented in the figure (Fig 3.7) has been taken in to account so as to identify the flow of the materials along the panel line and cycle time for each work station presented in the table (Table 3.8). The figure below depicts the representation of the workstations in the plant simulation interface.

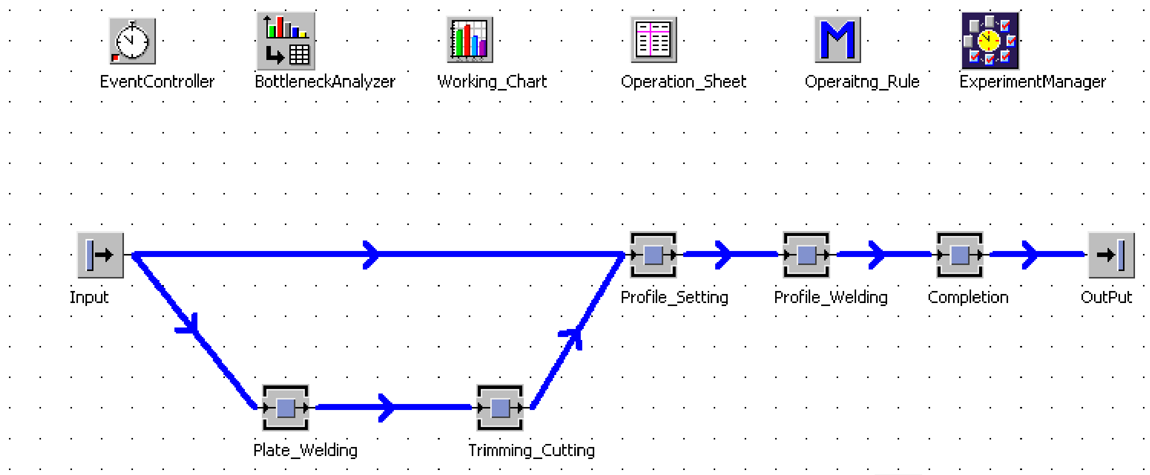
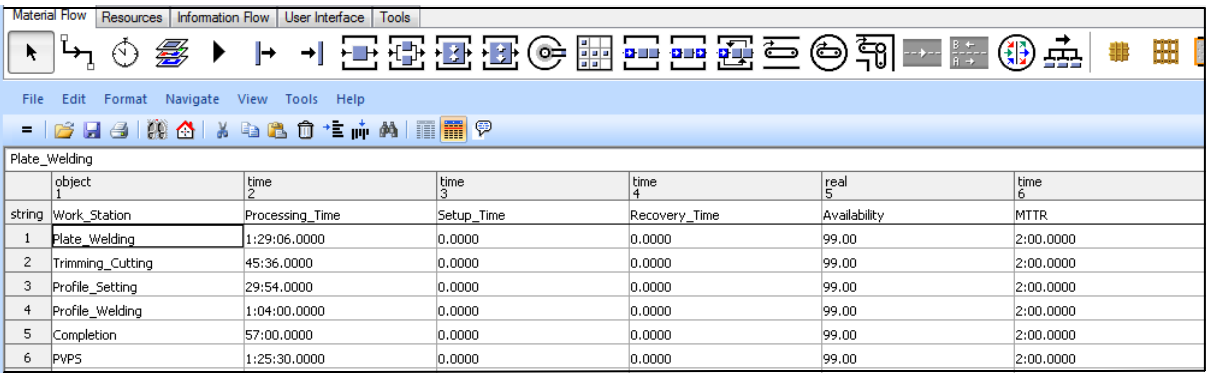


Figure 4.14 Representation of the panel line in the simulation frame for Tanker ship

In the above frame, a table (Operation_sheet) and a method (Operating_Rule) have also been incorporated that will facilitate the modeling and the simulation process. Instead of assigning all the parameters for each work station, it is recommended to use a table that stores all the information about the processing unit (machine or work station) and then use **Method** object, in which we program how to extract the data from the table to be used in each processing unit. The table below describes all the information about each work station and whenever needed it is possible to edit the data and run program so that all the information will be updated without going through each work station.



	object 1	time 2	time 3	time 4	real 5	time 6
string	Work_Station	Processing_Time	Setup_Time	Recovery_Time	Availability	MTTR
1	Plate_Welding	1:29:06.0000	0.0000	0.0000	99.00	2:00.0000
2	Trimming_Cutting	45:36.0000	0.0000	0.0000	99.00	2:00.0000
3	Profile_Setting	29:54.0000	0.0000	0.0000	99.00	2:00.0000
4	Profile_Welding	1:04:00.0000	0.0000	0.0000	99.00	2:00.0000
5	Completion	57:00.0000	0.0000	0.0000	99.00	2:00.0000
6	PVPS	1:25:30.0000	0.0000	0.0000	99.00	2:00.0000

Figure 4.15 Table containing all the parameters for each work station

The following code has been used in the Method object in order to retrieve the data from the table and pass on to the processing unit in the panel line.

```
********************************************************
is
        workstation: object;
        i: integer ;
do
         for i:= 1 to Operation_Sheet.yDim loop
                workstation:= Operation_Sheet["Work_Station", i];
                workstation.procTime:= Operation_Sheet["Processing_Time",i] ;
                workstation.setupTime:= Operation_Sheet ["Setup_Time",i];
                workstation.recoveryTime:= Operation_Sheet ["Recovery_Time",i];
                workstation.failures.failure1.availability:= Operation_Sheet ["availability",i];
                workstation.failures.failure1.MTTR:= Operation_Sheet ["MTTR",i];
                next;
end;
**************************************************************
```

4.2.1 Scenario One for Tanker Ship

This is the first case considered to see the simulation result in the Panel line based on the cycle time given in the table (Table 3.8). It is recommended to select one of the key performance measures to compare the results of different scenarios and in this case annual throughout (annual production rate) has been considered for the sake of comparing the results of the different cases. Due attention should be given when providing the simulation run parameters because it is this value that will be considered in the overall simulation run.

Working days per year = 250 days

Working hours per day = 22.1 hrs

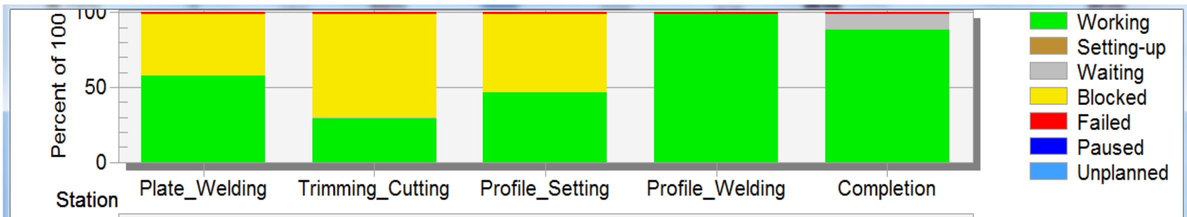
In order to give an input of one year running time for the simulation, the time has to be converted in to real working days.

Real working days per year= 250*22.1/24= 230 days

This will be used in the EventController in the plant simulation software as the simulation run time.

Assumptions

- 99% availability of resources
- Mean time to repair (MTTR) is 2 minutes



	Plate_Welding	Trimming_Cutting	Profile_Setting	Profile_Welding	Completion
Working	57,30%	29,31%	46,20%	98,87%	88,04%
Setting-up	0,00%	0,00%	0,00%	0,00%	0,00%
Waiting	0,00%	0,03%	0,00%	0,03%	10,95%
Blocked	41,78%	69,70%	52,81%	0,04%	0,00%
Failed	0,92%	0,95%	0,98%	1,06%	1,01%
Paused	0,00%	0,00%	0,00%	0,00%	0,00%
Unplanned	0,00%	0,00%	0,00%	0,00%	0,00%

Figure 4.16 Performance characteristics of each workstation for scenario one (Tanker)

Results obtained from the simulation

- Total throughput 5115 plates per year
- The bottleneck is the profile welding

4.2.2 Scenario Two for Tanker Ship

In the previous section, it has been found out that the bottleneck section is the profile welding work station and in this section an attempt has been made to find out the optimal cycle time using the Experimental manger that runs experiments with simulation model. In order to carry out the optimization analysis with the experimental manager, the lower bound, the upper bound and the increment (Design experiment) have to be selected and presented in the table below. Three simulation runs have also been considered for each experiment which means two results will be taken in to account for each input value that gives rise to 35 experiments with 70 simulation runs.

Table 4.8 Design table of the experiment for the profile welding work station

Input values	Cycle time, minutes/plate
Lower bound	30
Upper bound	64
Increment	1

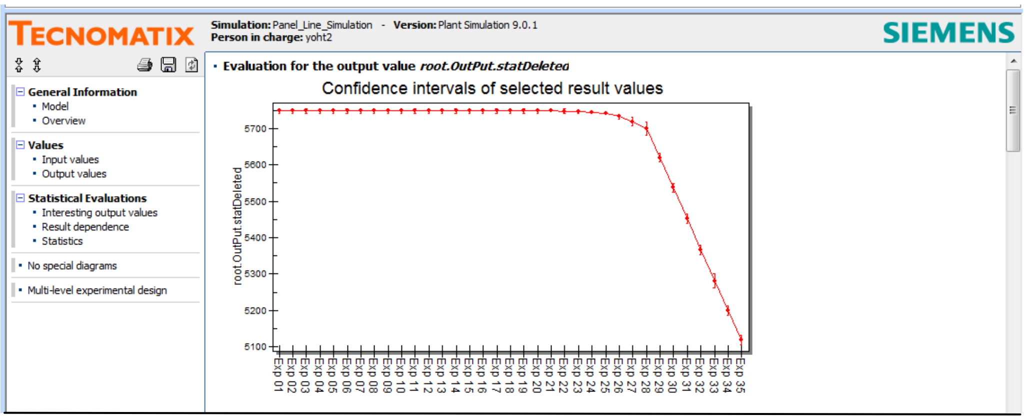


Figure 4.17 The total throughput from the experimental manager considering the profile welding work station (Tanker)

Since there are two simulations run for each experiment, the above output values represent the average value for each experiment and a confidence level interval of 95% which is reasonable for scientific analysis has been taken into account in the experimental manager.

Referring to figure (Fig 4.17), it is clear that the total output is exactly the same for the first 21 experiments and it starts to decline afterwards. Examining how the output declines, it is from experiment 28 to 29 where high decline in output has been observed and experiment 28 (57 minutes) can be considered as an optimal solution.

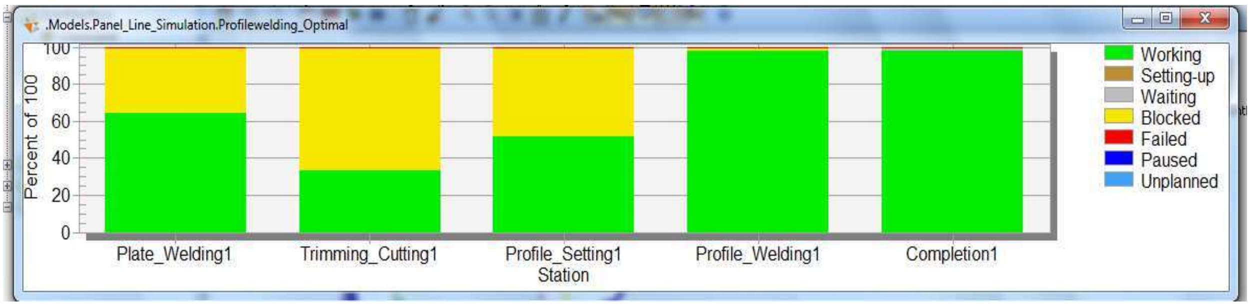


Figure 4.18 Optimal results for profile welding (Tanker)

The total output in this case is 5699 sheets and the percentage improvement will be

= (5699-5115)/5115*100%

=11,4 % improvement

In order to get the above percentage improvement in productivity, it requires a cost benefit analysis on the work station because one or more of the followings have to be engaged to realize the gain.

- Additional man power hiring in the profile welding work station
- Improving the technology involved in the work station
- Future demand has also to be taken to account

4.2.3 Scenario Three for Tanker Ship

The specific purpose of this scenario is to see if it is possible to optimize further by combining the profile welding and the completion work stations.

Table 4.9 Design table of the experiment for the profile welding and completion work stations

Input values	**Profile Welding , Cycle Time**	**Completion , Cycle Time , minute/plate**
Lower bound	30	30
Upper bound	64	57
Increment	1	1

A total of 980 experiments with 1960 simulation runs and the results are displayed below which shows the statistical distribution of the results for the combination of profile welding and completion.

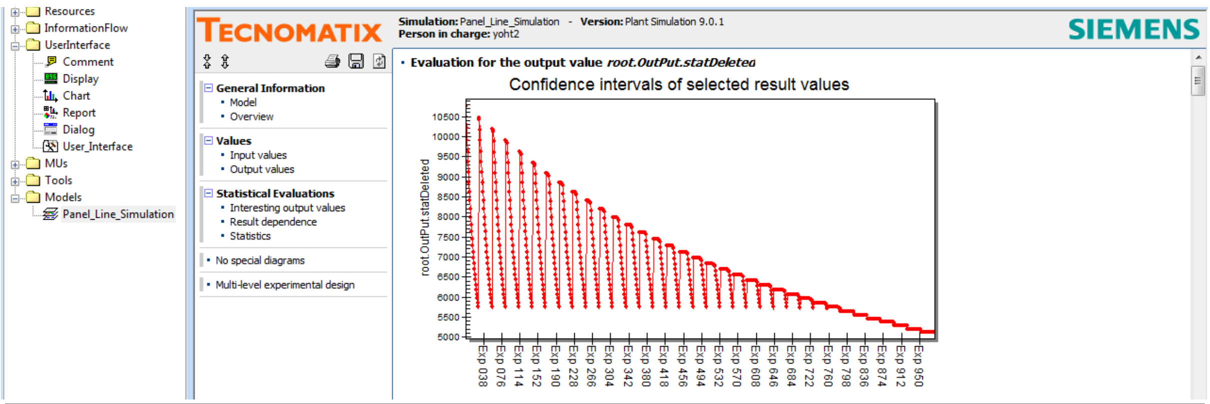


Figure 4.19 The total throughput from the experimental manager considering the profile welding and completion work stations (Tanker)

The above figure depicts the total throughput per year for different combinations of the cycle time for the profile welding and completion work stations. The results are very important in order to make a capacity planning decision based on the customer demand (forecasted or Known) and it provides an insight on how to plan the panel line to satisfy the customer demand by delivering the product in time. For example if the expected numbers of sheets to be produced are 6552, we can consider the experiments listed in the table below.

Table 4.10 design experiments that provide the same output of 6552 sheets

Experiment	Profile Welding Minute	Completion Minute	Output Sheets
21	30	50	6552
49	31	50	6552
77	32	50	6552
105	33	50	6552
133	34	50	6552
161	35	50	6552
189	36	50	6552
217	37	50	6552
245	38	50	6552
273	39	50	6552
301	40	50	6552
329	41	50	6552
357	42	50	6552
385	43	50	6552
413	44	50	6552

Even though the results are the same for the total output in the table 4.10, experiment 413 gives optimal combination of the cycle times for the profile welding and the completion workstations. Therefore the total output in this case is 6522 sheets and the percentage improvement will be

= (6552-5115)/5115*100%

=28.1 % improvement

4.2.4 Optimization Using the Genetic Algorithm (GA)

In order to carry out the optimization analysis similar to the case in Container ship, parameters should be selected from different stations for which the optimization would be performed by varying these values so as to maximize or minimize the objective function. Genetic algorithm allows multiple objective optimizations with weight percentage but in this case there exists only one objective function and that is the production rate along the panel line. Looking at the performance characteristics of the workstation in scenario one, the work stations profile welding and completion are selected in which the processing time is the parameter for optimization.

Table 4.11 Optimization parameters of GA for the Tanker ship

Input values	**Profile welding, minute/plate**	**Completion, minute/plate**
Lower bound	40	40
Upper bound	64	57
Increment	1	1

The objective function is to maximize the production rate along the panel line considering the following optimization parameters

$$40<=X1<=64$$
$$40<=X2<=57$$

Where

X1- The processing time per sheet for profile welding work station in minute

X2- The processing time per sheet for Completion work station in minute

Number of generations (Iterations):= 20

Size of the generation (population size):= 20

Initially 20 initials solutions (population) are selected from the optimization parameters and evaluated based on their fitness by the fitness function where the two parents have to be selected. The distribution of the initial solution of the first generation is depicted in the figure below and the rest are placed at annex part of the report. Iteration continues until the end of the last 20 generations by computing the best and the worst solutions on each generation from which the best solution will be fitted in to the optimization parameters that would provide the maximum production rate along the production line.

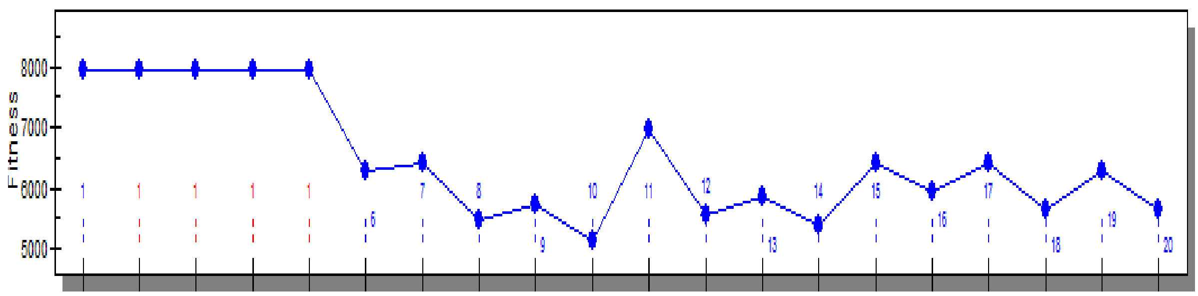


Figure 4.20 The initial solution of the optimization process

In each iteration, the best, the worst and the average fitness (solutions) are computed and the results are represented in the figure below for the whole generations considered in the optimization process.

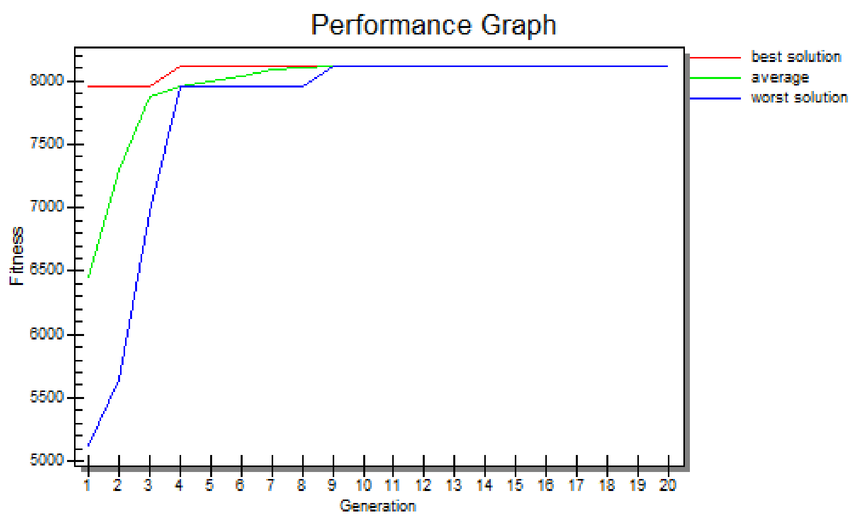


Figure 4.21 The performance graph of the 20 generations

Referring to the above performance graph, the worst and the best fitness coincides to each other starting from generation 9 indicating the optimal solution resulting in the production rate of 8120 sheets per year for which the best fit for optimization parameter profile welding and completion is 40 minutes. One of the basic differences between the experimental manager and the genetic algorithm is experimental manager considers one input at a time but Genetic Algorithm consider a number of inputs as a population and selects the best fit from the population.

4.2.5 Scenario Four for Tanker Ship

In this section an attempt has been made to see the effect of adding a new workstation to the panel line where the PVPs will be welded on the stiffeners in order to improve the strength of the ship thereby reducing the catastrophic effects during collision. One of the most important parameter to for testing the effect of the PVPs work station is the cycle and since the project is still undergoing, the following assumptions have been considered for the sake of checking its effect on the panel line production.

Assumption

i. Ten points will be selected for proper placement of the PVPs (0,5 minute each)

ii. Robot welding will be applied in order to weld the PVPs on the panel

Speed , V=0,0083 m/s

Distance, L=2,8 m

Time= L/V= 2,8/0,0083=337,5 sec or 5,62 minutes

Considering 4 runs to entirely weld the PVPs

Total time for welding= 4*5,62= 22,5 minutes

Table 4.12 Determination of cycle time for PVPs work station (Tanker)

S.N	Activity	Time, minute
1	Estimated time to transport one PVPs to the stiffened panel	1
2	Estimated time to weld parts of the PVPs on the panel for proper placement of the PVPs	5
3	Average time to weld the PVPs on the stiffened panel	22,5
	Estimated time to work with the PVPs on the panel line	**28,5**

		Plates per Panel=	2
	Time per PVPs=	**28,5**	**Minute**
Panel	**PVPs**	**Time per panel,min**	**Cycle time ,min /sheet**
1	3	85,5	42,75
1	4	114	57,00
1	5	142,5	71,25
1	6	171	85,50
1	7	199,5	99,75
1	8	228	114,00
1	9	256,5	128,25
1	10	285	142,50
1	11	313,5	156,75
1	12	342	171,00

Considering the number of PVPs per panel to be 6 and the number of sheets per panel to be 2.0, the simulation gives the following results.

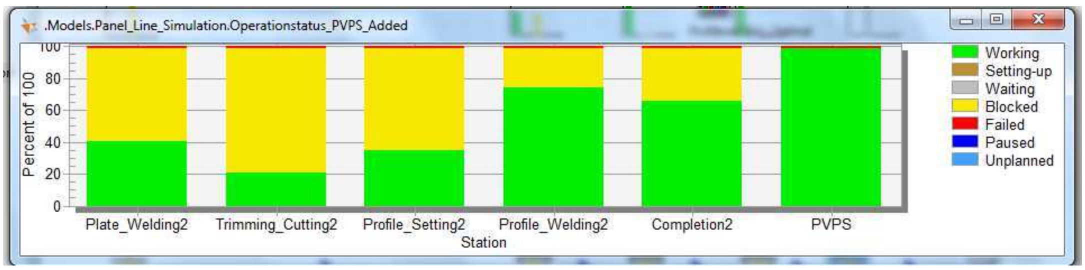


Figure 4.22 Optimal results for PVPs work station (Tanker)

Results obtained from the simulation

- Total throughput 3832 plates per year
- The bottleneck is the PVPs work station

The percentage of decline due to the addition of the work station (PVPs)

= (3832-5115)/5115*100%

=-25.1 % (reduction in productivity due to the PVPs work station)

4.2.6 Scenario Four for Tanker Ship

The purpose of this section is to use the experimental manager in order to find out the optimal cycle time for the PVPs work station in such a way that the total throughput will be maximized. The design parameters are selected considering the number of PVPs in a panel (assume 3 to 7 PVPs in a panel) and hence the range of the cycle time is depicted in the table below with upper and lower bound.

Table 4.13 Design table of the experiment for the PVPs work station

Input values	**Cycle Time, minutes per plate**
Lower bound	40
Upper bound	100
Increment	1

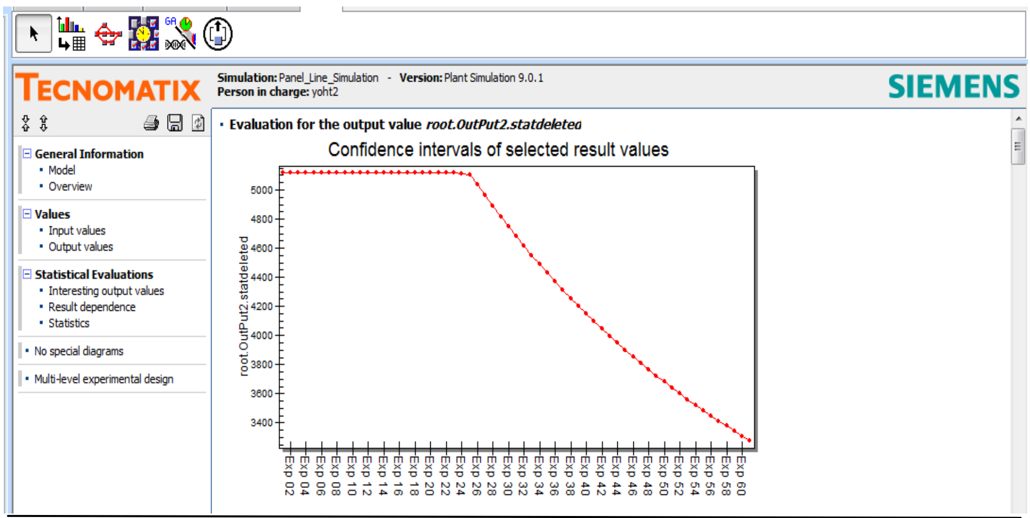


Figure 4.23 The total throughput from the experimental manager considering the PVPs work station

Referring to the results obtained from the experimental manager, the total output is more or less similar for the first 25 (until cycle time=64 minutes that is similar to the cycle time of profile welding) experiments. If the cycle time for PVPs work station is greater than 64 minutes, it will be a bottleneck and care has to be taken when incorporating the PVPs workstation to the existing panel line. The results of the simulation by changing the cycle time of the PVPs workstation to 64 minutes is presented in the figure (Fig. 4.24).

Figure 4.24 Optimal results for profile PVPs workstation (Tanker)

It is clear from the above figure that the completion workstation is under the state of blocked and waiting as well since the cycle time for this work station is less than both the profile welding and the PVPs work stations. (The cycle time for completion work station is 57 minutes and the cycle time for the profile welding and PVPs work stations is 64 minutes). Therefore the maximum number of PVPs per panel should be 4 for the case of Tanker ship so that the existing panel line will not be affected. Since the requirement for the number of PVPs per panel also depends on the structural analysis, the work station can have sub stations so that the number of PVPs can exceed 4 per panel without affecting the panel line where the PVPs work station has less cycle time than the profile welding station.

4.3 Integrating Ms Access and Ms Excel in the Simulation Process

In the previous sections a simulation analysis has been performed for a Tanker and Container ship using the available data and in this section an attempt has been made to integrate the Ms Access where the data for the workstations will be stored and Ms excel where the result will be exported. The advantage of using the Microsoft applications (Access and Excel) is to facilitate the overall simulation process there by helping the users who are not familiar with the simulation software to work with the data. It also gives more time to the simulation expert to focus and work with the development of the models than changing the work stations' parameters that can be accessed directly from the database system.

4.3.1 The Working Procedure

It is first important to properly identify the number of workstations and all the information that are relevant to each station along the production line (Processing time, set up time, Availability, etc) and the flow of the material along the panel line. After proper identification of all the necessary parameters, we can develop the database in the Microsoft Access and great care should be taken in to account about the type of the data to be used in the database keeping in mind that the same data will be used in the plant simulation software otherwise incompatibility will be experienced that will affect the simulation analysis. For example:

Description	MS access	Simulation Software
Processing Time	Data type: integer (in seconds)	Data type: time
Set up time	Data type: integer (in seconds)	Data type: time
Cycle time	Data type: integer (in seconds)	Data type: time
Recovery time	Data type: integer (in seconds)	Data type: time
Availability	Data type: Number (Double)	Data type: Real
MTTR	Data type: integer (in seconds)	Data type: time

The figure below depicts the input output relationship in the simulation analysis.

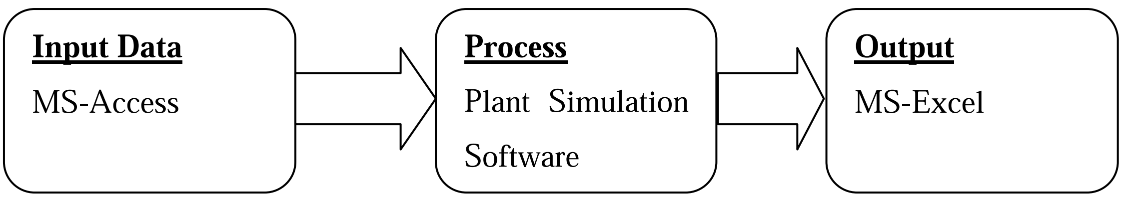


Figure 4.25 Input output relationship

In order to give more flexibility to the modeling and simulation process the plant simulation software has been linked with the Microsoft access where the database is saved and to Microsoft excel where the final results will be exported. The Microsoft access and Microsoft excel files have been placed on the frame in order to easily access the files at the same time.

The section below provides a short summary how the process works.

- The first procedure is to link the Microsoft access where all the necessary data for the simulation analysis have been saved with the plant simulation software applying the Object Database Connectivity procedure (ODBC).
- The second procedure is to write a programming code (Method, init) to initialize the connectivity and make a request for appropriate data acquisition from the database (example tables) which will be used as an input for the simulation analysis. In order to be used by the simulation software, all the data should be copied and saved in a table with appropriate data reformatting within the plant simulation software.
- The third procedure is to pass all the data to the objects (in this case work stations) making use of the same initialization code. Examples of the data are processing time, Availability, MTTR etc. at this stage we are ready to simulate the panel line and a question will prompt to ask the user how long the simulation time will be and care should be taken at this point that the input should be in seconds.
- The fourth procedure is to export the result to Microsoft excel which is easy for further manipulation. All the results will be first saved in a table within the simulation software and finally exported to Microsoft excel with a programming code (Method, Endsim) at the end of the simulation. A report has also been incorporated within the frame interface to see the results at the end of the simulation run.

4.3.2 Times and Distributions

Time is the most important parameter both in terms of the simulation time and the time as product characteristics in each work station along the production time. In order to give more of the realistic nature to the modeling and simulation process, it is advisable to take in to account the variability of the time (for example processing time, setup time, etc) instead of considering only average time which is constant and not always true in reality. *Plant Simulation* is a discrete simulation system and it is based on a variety of different times, such as processing times, machine down times, etc. It allows true to life modeling with fixed times as well as with statistically distributed times. *Plant Simulation* provides these statistical distributions: Beta, Binomial, Constant Erlang, Gamma, Geom, Hypergeo, Lognormal, Normal, Negexp, Poisson, Triangular, Uniform, and Weibull. The most commonly used distribution in science and engineering is Normal Distribution and this has been utilized while developing the database for the input parameters of processing time, cycle time, recovery time and setup time.

The figure below shows the detailed flow procedure for the input output relationship.

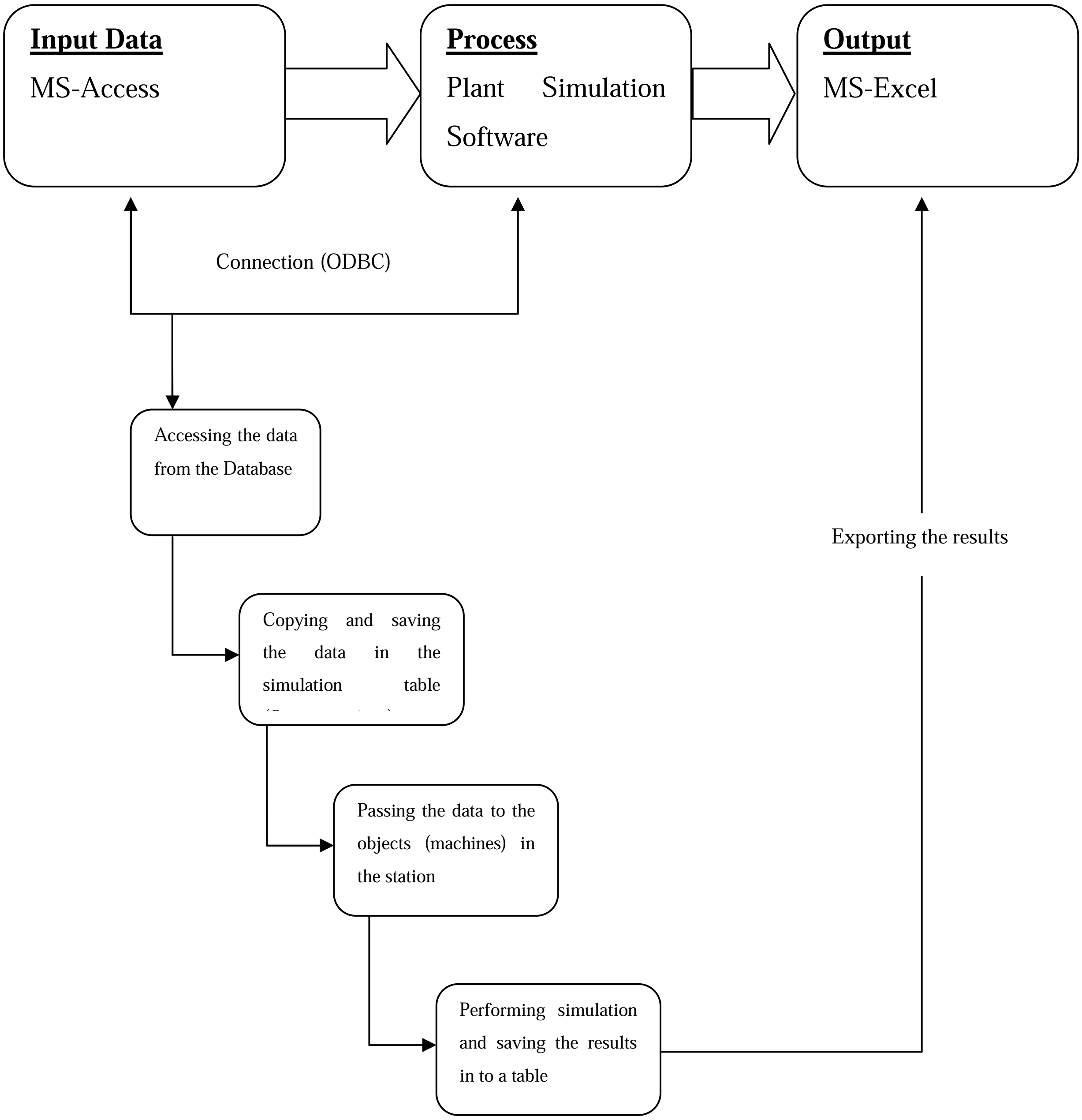


Figure 4.26 The work flow in the input output relation ship

4.3.3 Normal Statistical Distribution

The normal distribution is the most important one in all of the probability and statistics. Many numerical populations have distributions that can be fit very closely by an appropriate normal curve. "A continuous random variable X is said to have a normal distribution with parameters mean (μ) and standard deviation (σ) or (μ and σ^2), where $-\infty < \mu < \infty$ and $0 < \sigma$, if the probability density function of X is [19]"

$$f(x;\mu,\sigma)=\frac{1}{\sqrt{2\pi}\sigma}e^{\frac{-(x-\mu)^2}{2\sigma^2}}$$

e- The base of the natural logarithm function (e is approximately equal to 2.718)

μ-the mean of the values (Data type: Real)

σ–the standard deviation of the results (Data type: Real)

The normal distribution with mean,μ=0 and standard deviation, σ=1 ισ is called a standard normal distribution.

If the population distribution of a variable is (approximately) normal, then

- Roughly 68% of the values are within 1 SD (standard deviation) of the mean
- Roughly 95% of the values are within 2 SDs (standard deviation) of the mean
- Roughly 99.7% of the values are within 3 SDs (standard deviation) of the mean

It is indeed unusual to observe a value from a normal population that is much farther than 2 SDs (standard deviations) from the mean value and If X has a normal distribution with mean μ and standard deviation σ, then the standard normal random variable is given by [19]:

$$Z=\frac{X-\mu}{\sigma}$$

The normal distribution is considered as one of the most prominent probability distribution in statistics and there are several reasons for this .First, the normal distribution is very tractable analytically, that is, a large number of results involving this distribution can be derived in explicit form. Second, the normal distribution arises as the outcome of the central limit theorem, which states that under mild conditions the sum of a large number of random variables is distributed approximately normally. Finally, the "bell" shape of the normal distribution makes it a convenient choice for modeling a large variety of random variables encountered in practice [20].

in order to make use of the probability distribution in the plant simulation, there should be a method containing arguments at least the type of the distribution (data type string) and additional arguments (like mean, standard deviation, stream number, upper and lower bound etc) depending on the nature of the distribution to be used in the simulation process at each work stations.

For normal distribution, the user defined method should include the following parameters:

Setparam(“Normal”, stream,mean,standard deviation,lower bound,upper bound) or

Setparam("Normal", stream,mean,standard deviation)

The function for normal distribution is denoted by z_normal(s,μ, σ) where

s- The random variable stream (data type: Integer)

μ-the mean of the values (Data type: Real)

σ–the standard deviation of the results (Data type: real)

The random variable stream is used by the plant simulation software so as to produce the real random numbers (between 0 and 1) and the standard deviation can never be zero. While writing the code (Method) to retrieve the data from Ms Access, two options have been considered for the time assignment (Constant or Normal distribution).

For example: Processing time

Processing_Time_Mean (μ)

Processing_Time_Stream (s)

Processing_Time_Sigma (σ)

If the processing time is assumed to be distributed normally with the above parameters (μ and σ), the values (mean, stream and sigma) will be directly retrieved from the database and passed on to the stations or else only the Processing_Mean_Time will be used as a constant processing time. The following example illustrates how the program selects the appropriate distribution of the processing time for plate_welding_Mannual and plate_welding_Automatic by checking the input data given in the database. Refering to the values given in the database, the processing time for the plate_welding_Mannual will have a normal distribution pattern but for plate_welding_Automatic the processing time is constant since the stream number (Processing_Time_Stream) is assigned to zero.

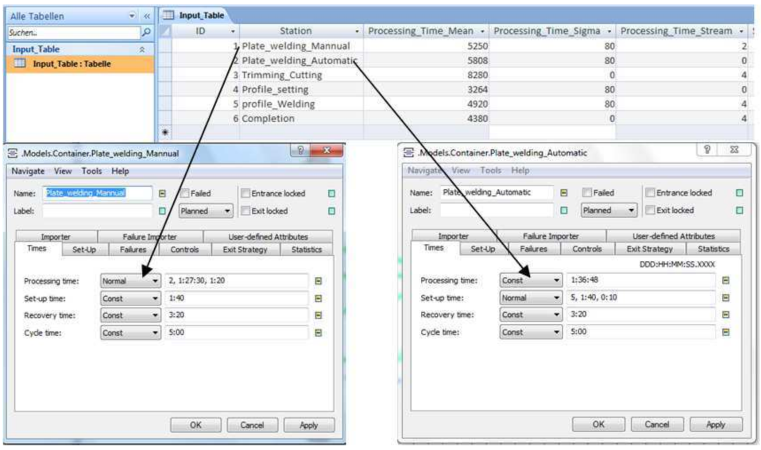


Figure 4.27 Constant and normally distributed processing Times for work stations

CHAPTER 5 CONCLUSION

Plant simulation software is an important tool in modelling and simulating the panel line without carrying out the actual work and it gives an insight about the effect of each work station along the production line by clearly identifying the influence of one station on the overall panel line. It also provides a scenario analysis where optimized options could be obtained for one or more work stations thereby improving the productivity of the panel line. The results obtained from the modelling and simulation analysis can be used as an input to the production planning and control scheme that highly influence the overall business of the company where decisions can be made in advance based on the outputs from the simulation experiments in order to meet customer demands in time (delivery time) without compromising the quality of the product. The results could also facilitate the process of preparing bidding documents for it gives how long it will require producing the required number of stiffened panels per ship.

The overall analysis carried out in this project for two types of ships namely Container and Tanker ships revealed that the profile welding is the bottleneck that is affecting the productivity of the panel line. It was also found out that the addition of new work station (Namely PVPs work station) may affect the production rate of the existing panel line depending on the number of the PVPs per panel and different results have been obtained for the two types of ships (Container and Tanker ship). Based on the simulation Analysis carried out to examine the effect of introducing new work station in to the existing panel line, the maximum number of PVPs per panel for the container and Tanker ships are 6 and 4 respectively so that the existing panel line will not be affected. But this can of course be overcome by dividing the PVPs work station in to substation so that the cycle time for PVPs work station will be reduced.

Finally the researcher strongly recommends the cost benefit analysis to be carried out for future work that plays a vital role in decision making process in order to benefit from the modelling and simulation analysis using tecnomatix plant simulation 9.0 especially in case of generic algorithm optimization for it provides the optimal solution for multiple objectives where the cost component can be incorporated as an additional objective term in the equation.

ACKNOWLEDGEMENT

First and foremost I would like to thank the almighty God for giving me the courage to start and complete this program. My special appreciation goes to my father, who had been very supportive, passionate and lovely since the time I could remember.

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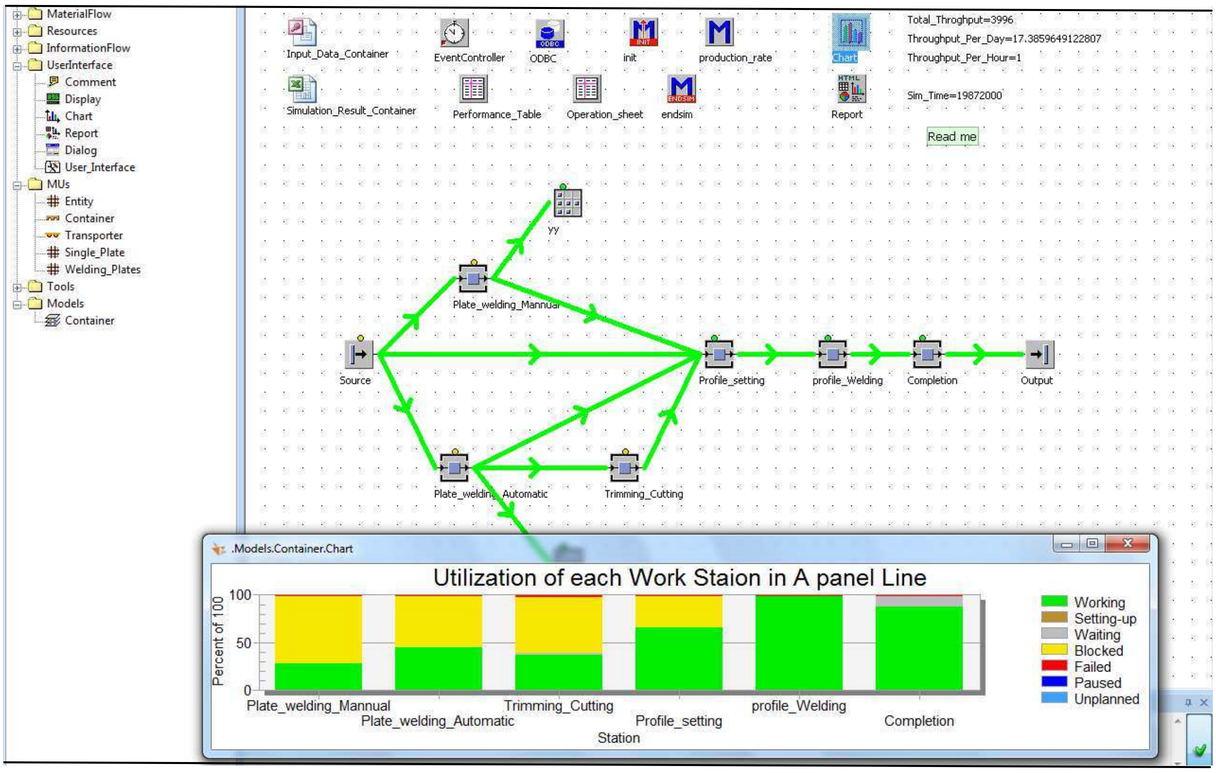
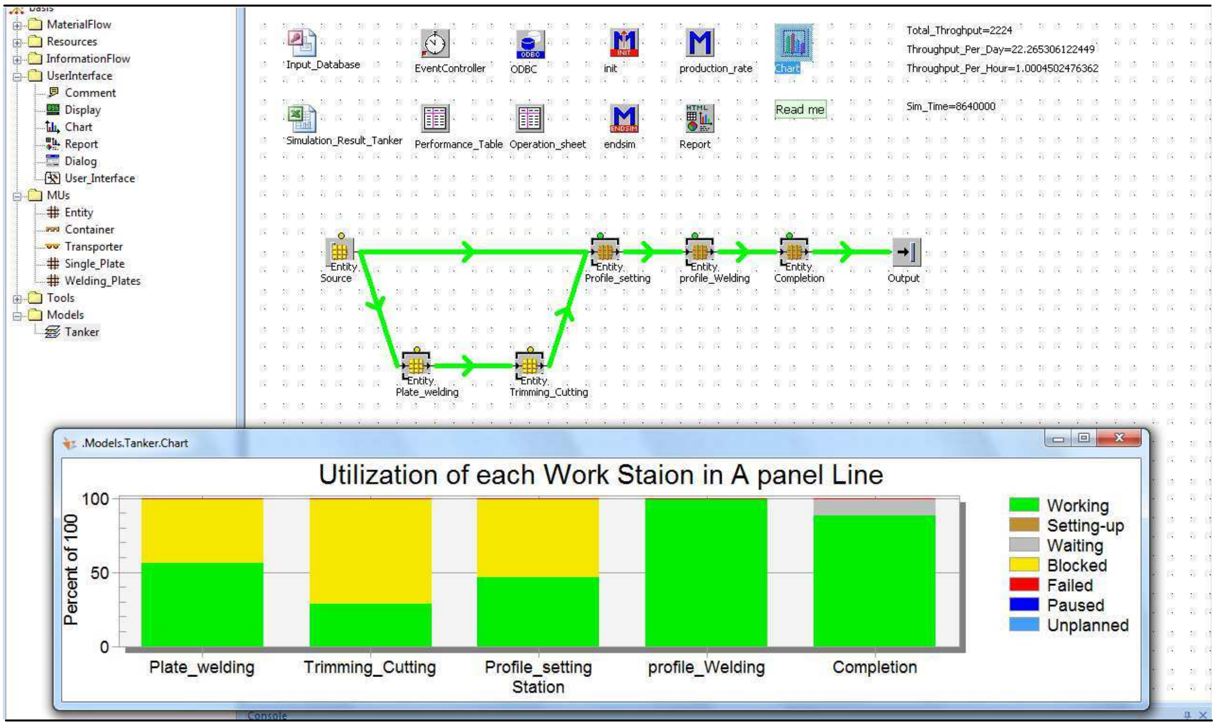
APPENDIXES

A1. Interface of the Model Developed for the Container Ship



A2. Interface of the Model Developed for the Tanker Ship



A3.Results from the Genetic Algorithm Iterations for the Container Ship

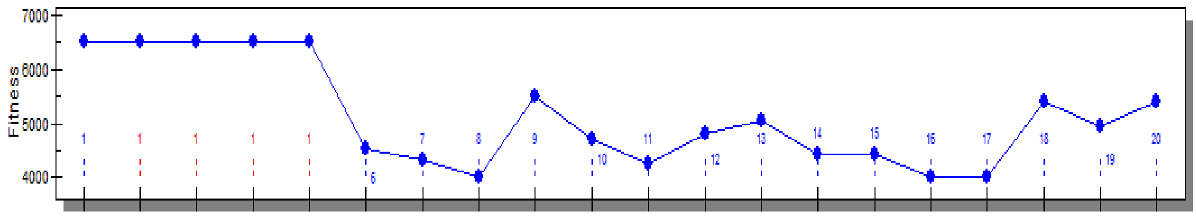
Number of multiple generated individuals: 663

Number of evaluated individuals: 117

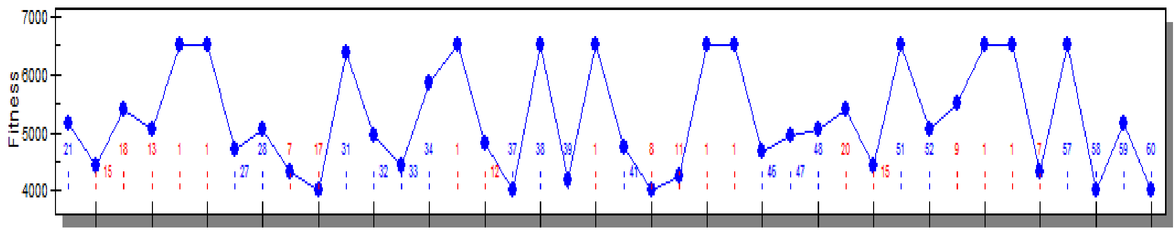
Observations per individual: 4

468 simulation runs are performed

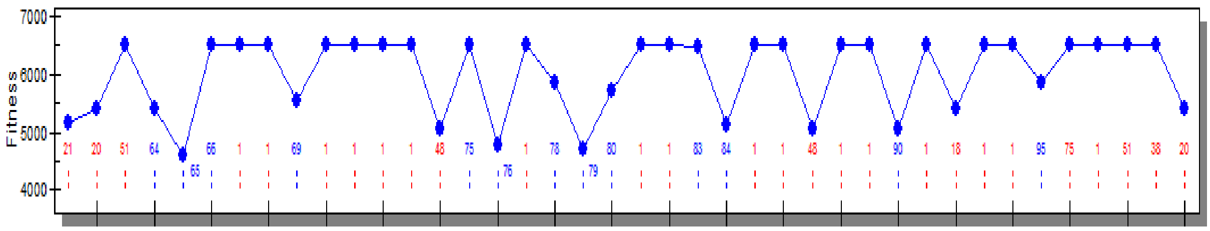
Children of generation 1 with 16 new evaluated individuals



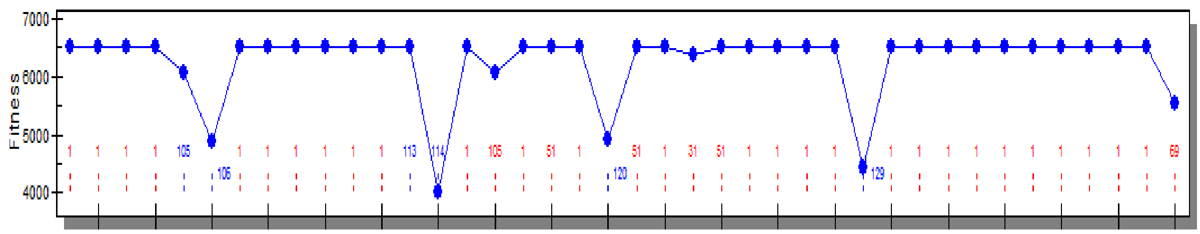
Children of generation 2 with 20 new evaluated individuals



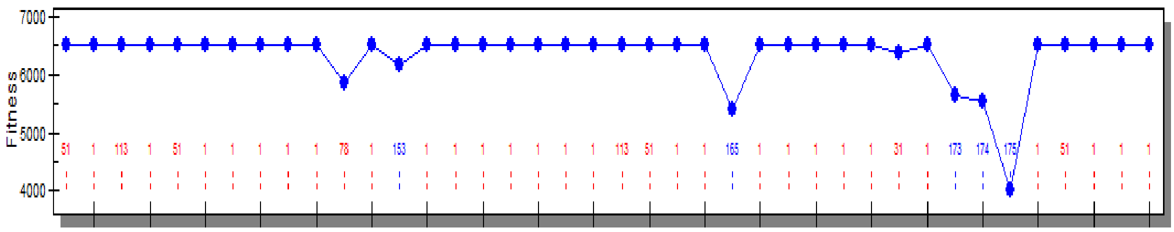
Children of generation 3 with 13 new evaluated individuals



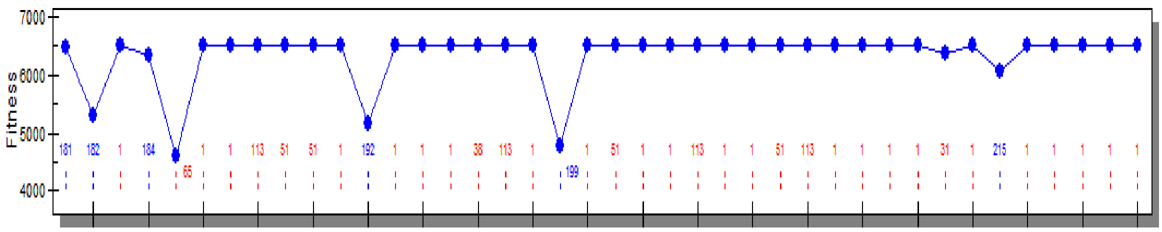
Children of generation 4 with 6 new evaluated individuals



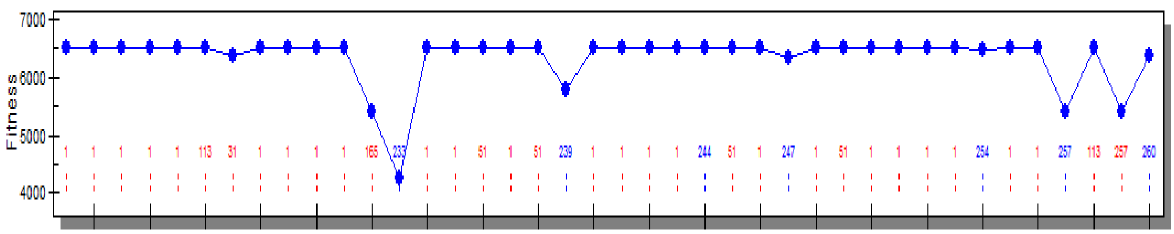
Children of generation 5 with 5 new evaluated individuals



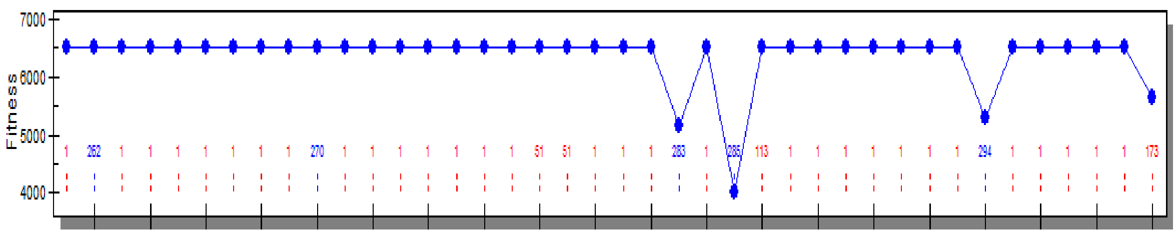
Children of generation 6 with 6 new evaluated individuals



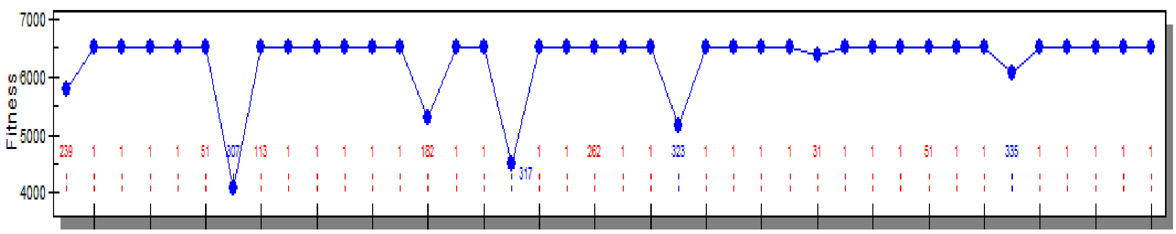
Children of generation 7 with 7 new evaluated individuals



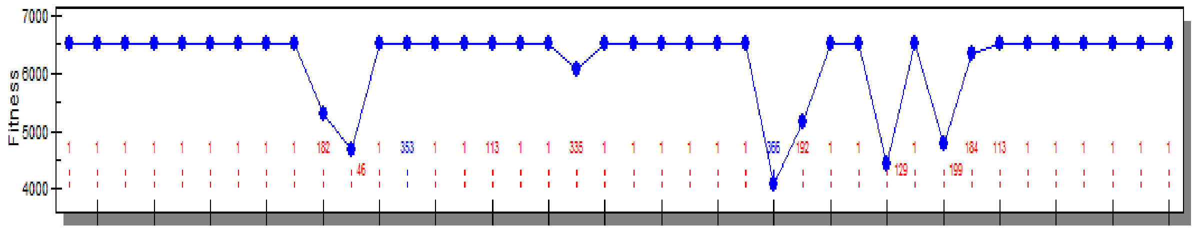
Children of generation 8 with 5 new evaluated individuals



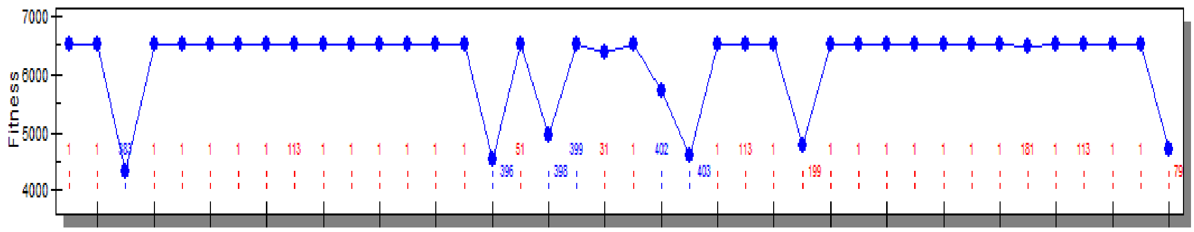
Children of generation 9 with 4 new evaluated individuals



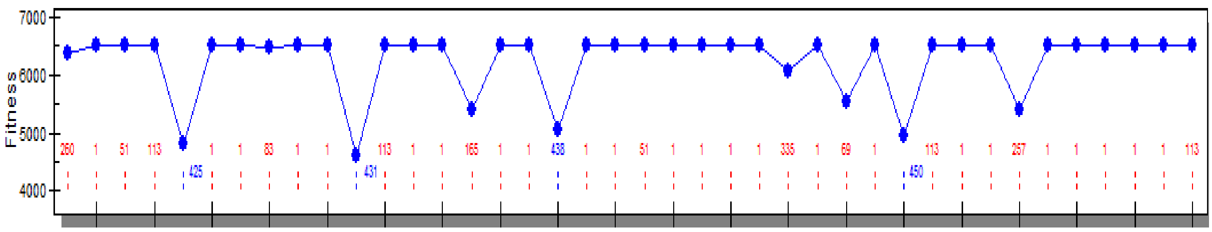
Children of generation 10 with 2 new evaluated individuals



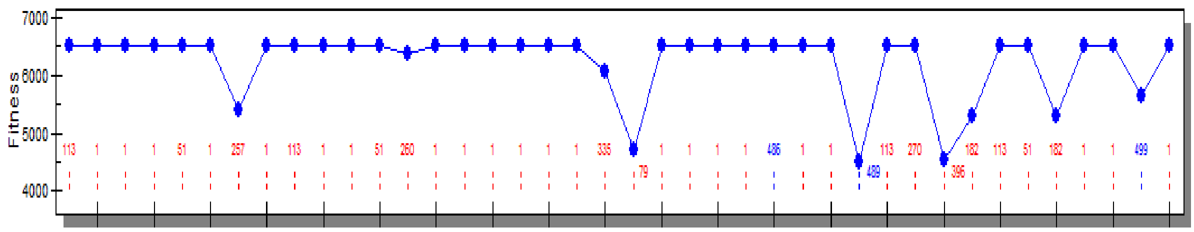
Children of generation 11 with 6 new evaluated individuals



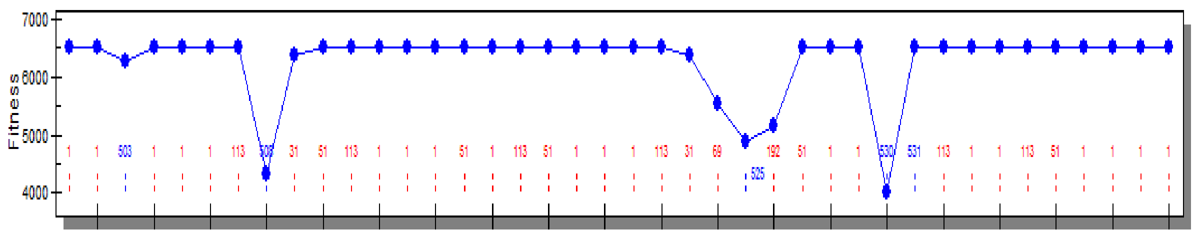
Children of generation 12 with 4 new evaluated individuals



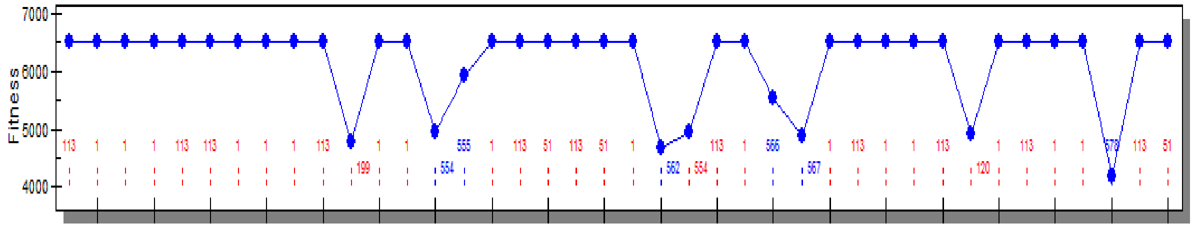
Children of generation 13 with 3 new evaluated individuals



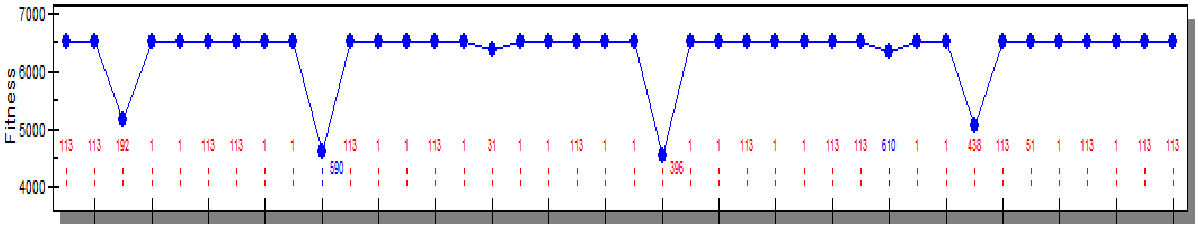
Children of generation 14 with 5 new evaluated individuals



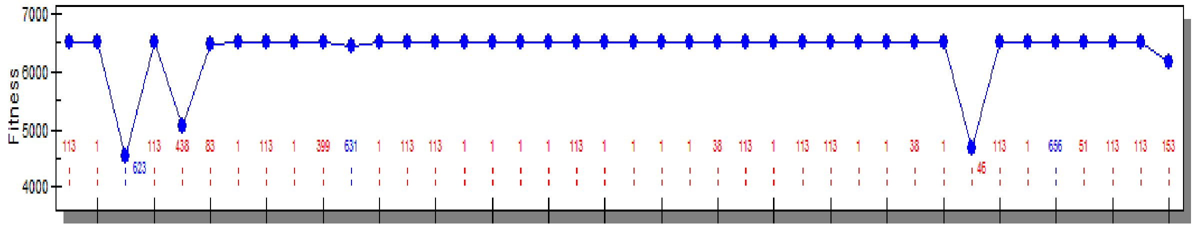
Children of generation 15 with 6 new evaluated individuals



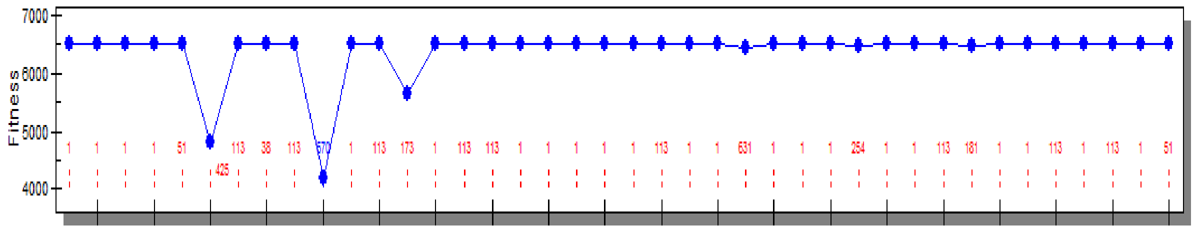
Children of generation 16 with 2 new evaluated individuals



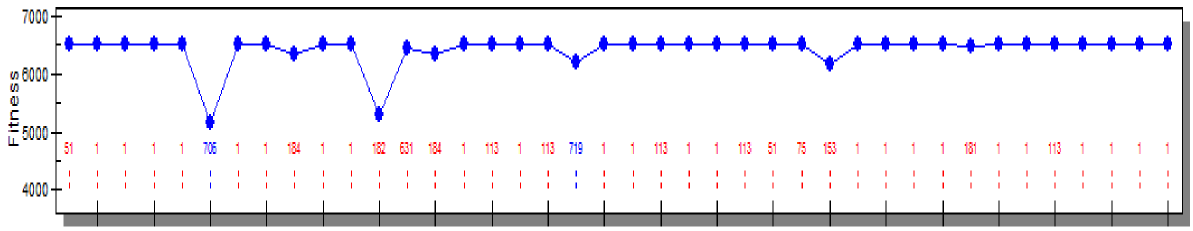
Children of generation 17 with 3 new evaluated individuals

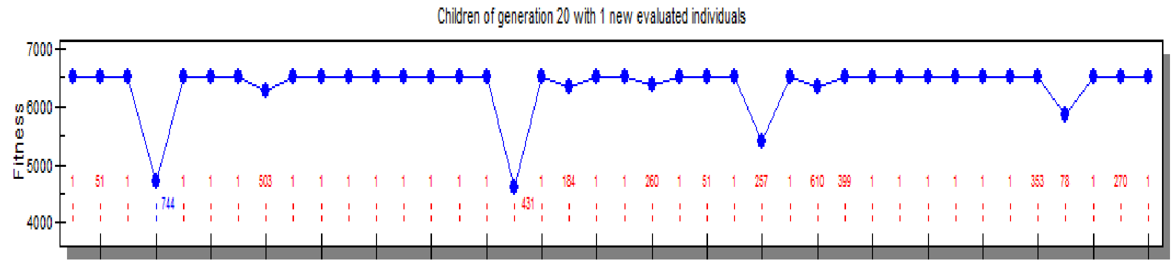


Children of generation 18 with 1 new evaluated individuals



Children of generation 19 with 2 new evaluated individuals





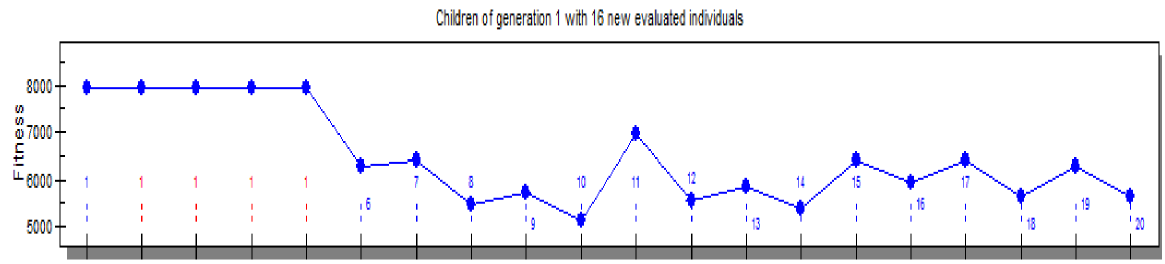
A4. Results from the Genetic Algorithm Iterations for the Tanker Ship

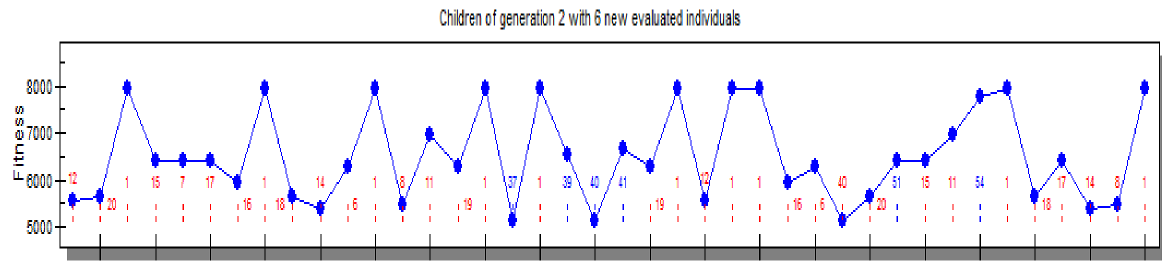
Number of multiple generated individuals: 1486

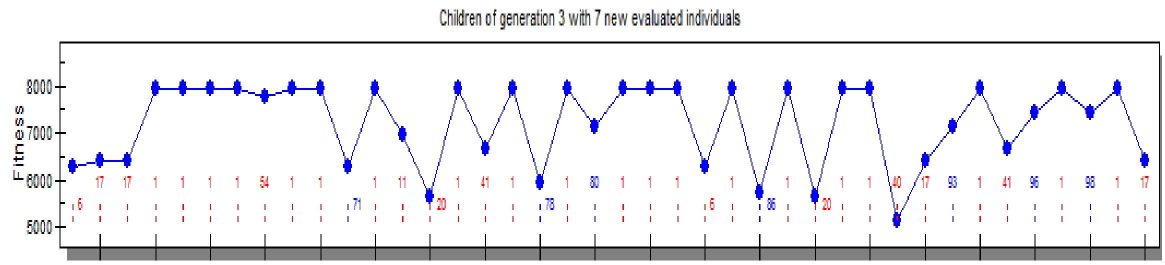
Number of evaluated individuals: 74

Observations per individual: 4

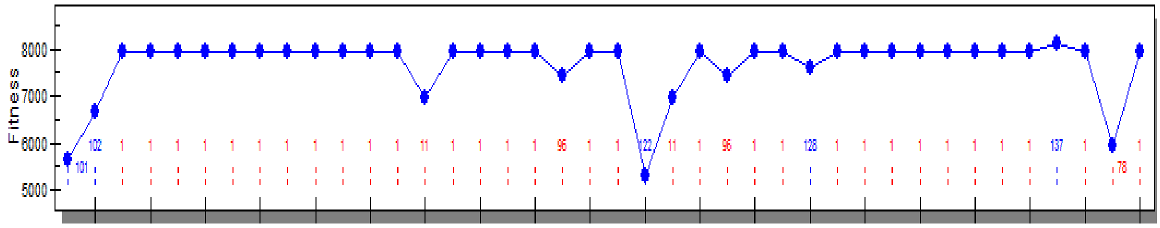
296 simulation runs are performed



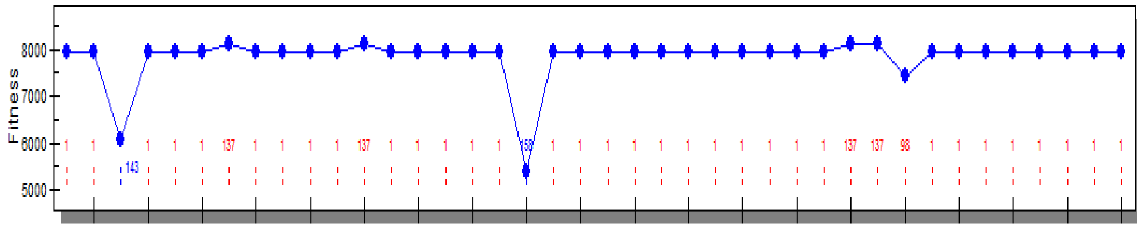




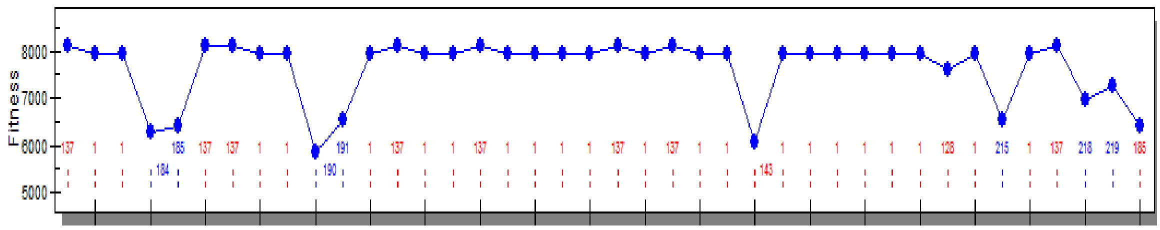
Children of generation 4 with 5 new evaluated individuals



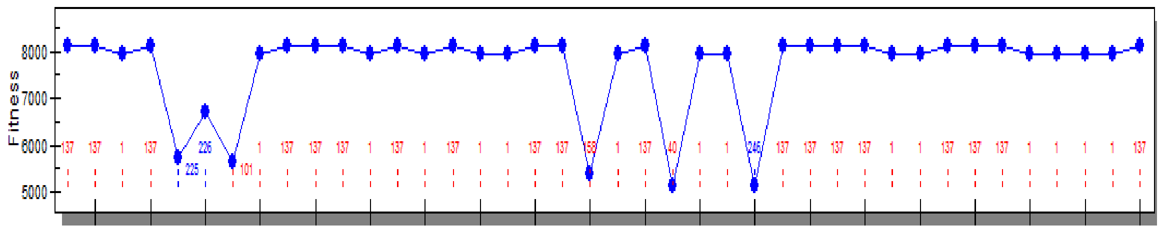
Children of generation 5 with 2 new evaluated individuals



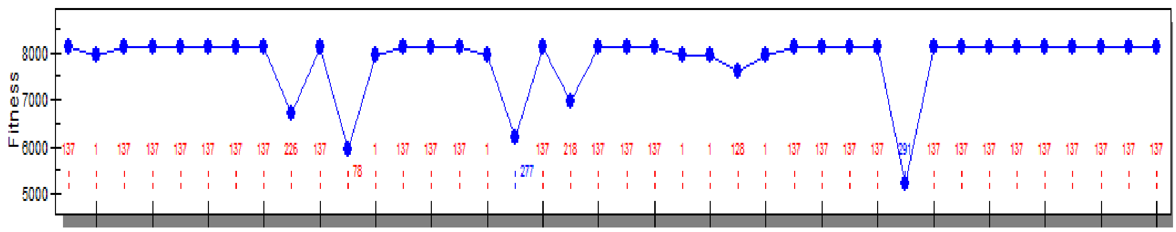
Children of generation 6 with 7 new evaluated individuals



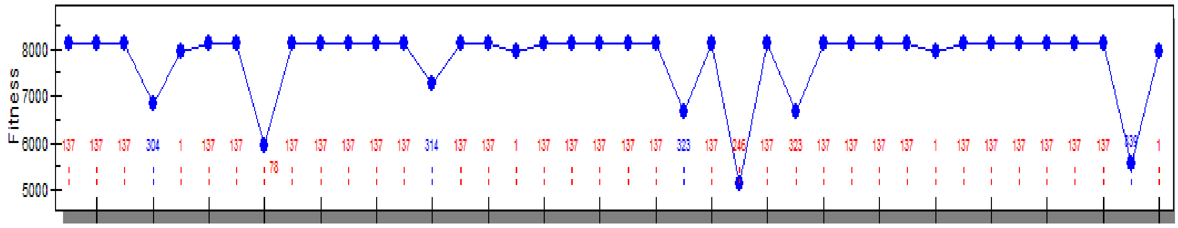
Children of generation 7 with 3 new evaluated individuals



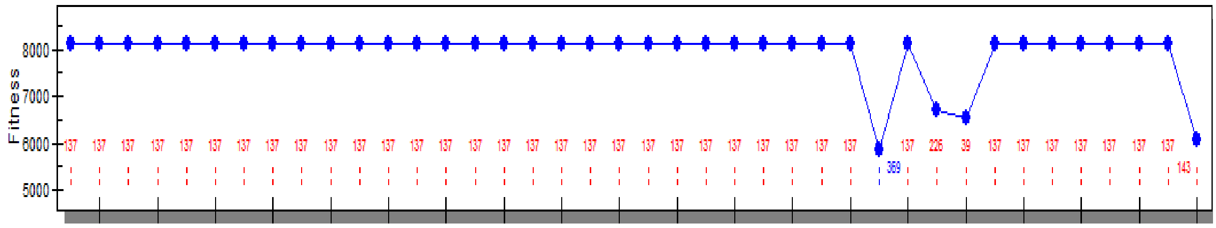
Children of generation 8 with 2 new evaluated individuals



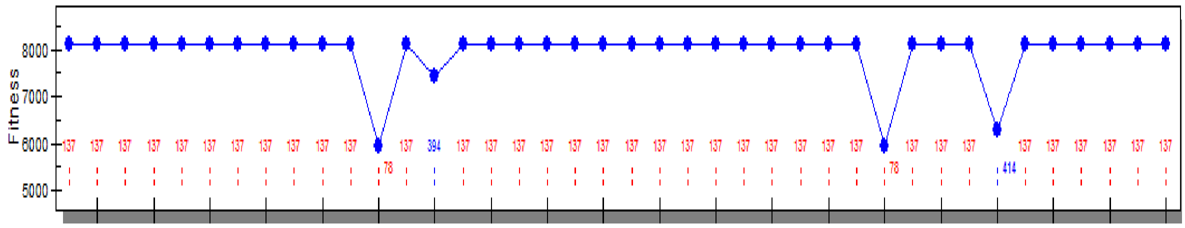
Children of generation 9 with 4 new evaluated individuals



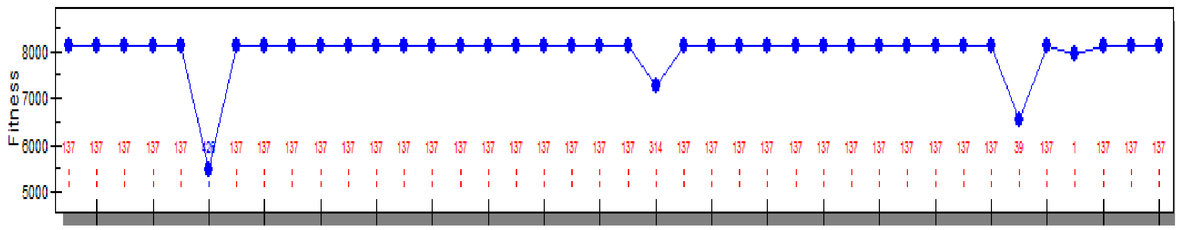
Children of generation 10 with 1 new evaluated individuals



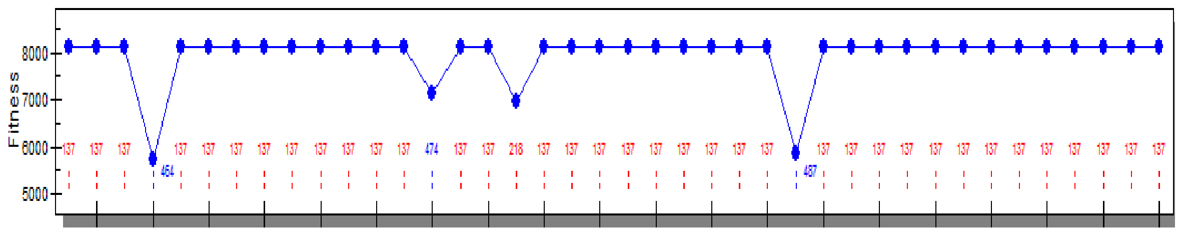
Children of generation 11 with 2 new evaluated individuals

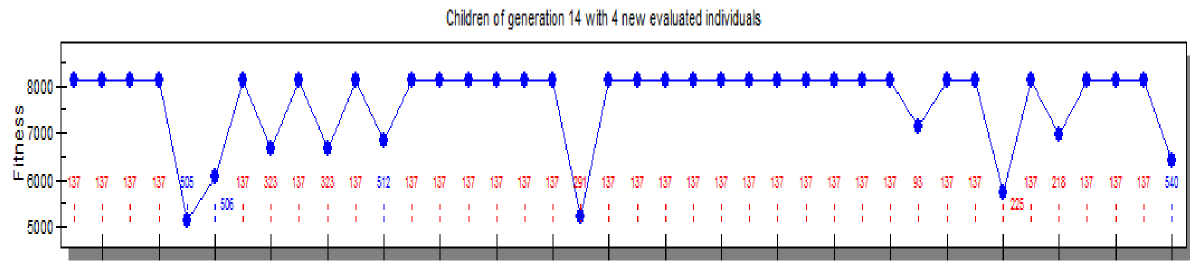


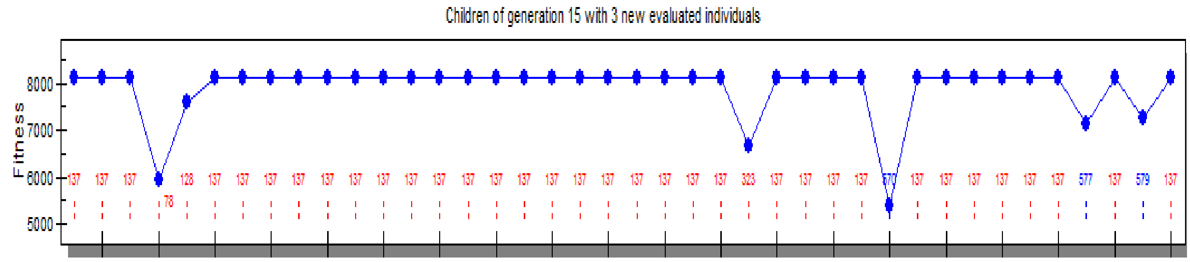
Children of generation 12 with 1 new evaluated individuals

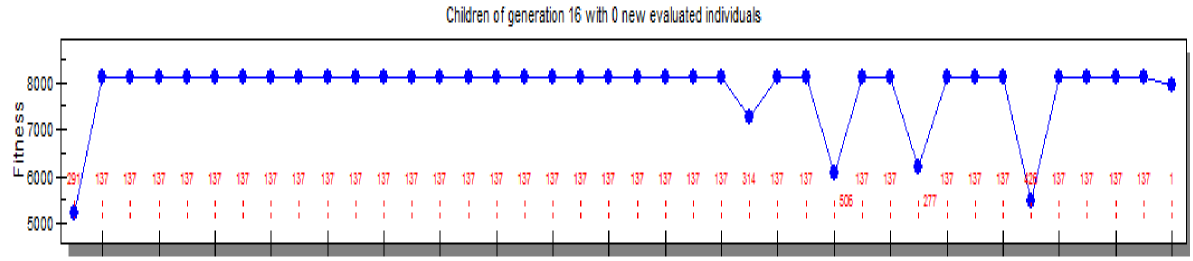


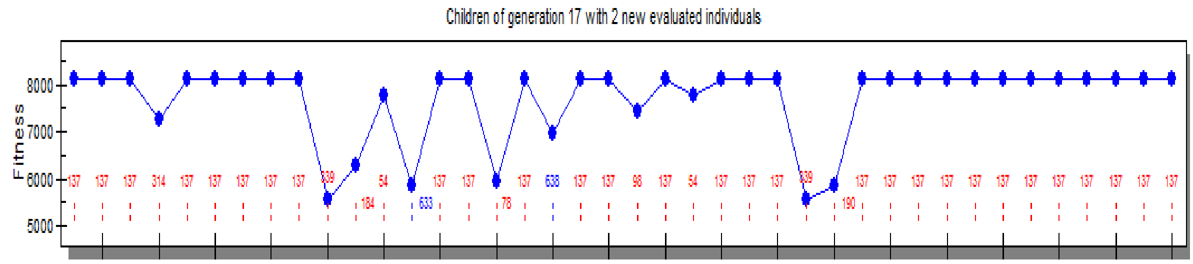
Children of generation 13 with 3 new evaluated individuals

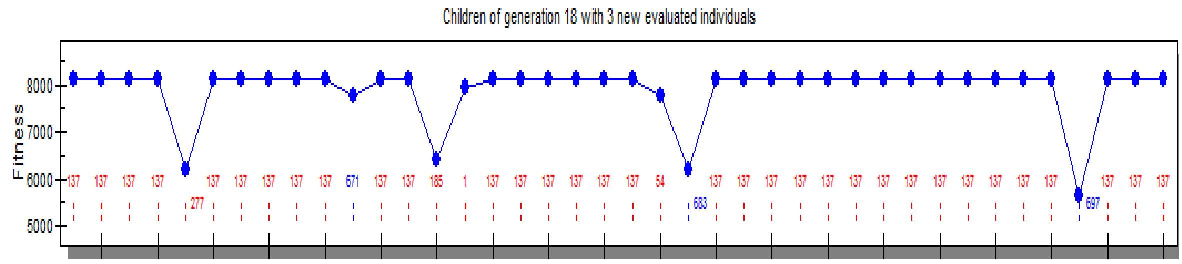


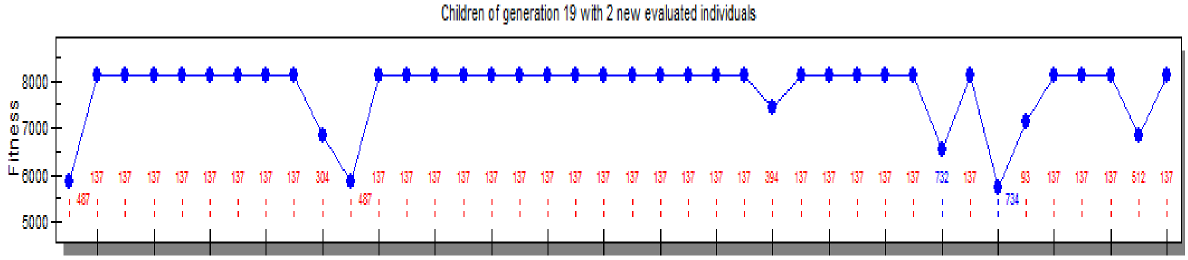

Children of generation 14 with 4 new evaluated individuals
Fitness
8000
7000
6000
5000

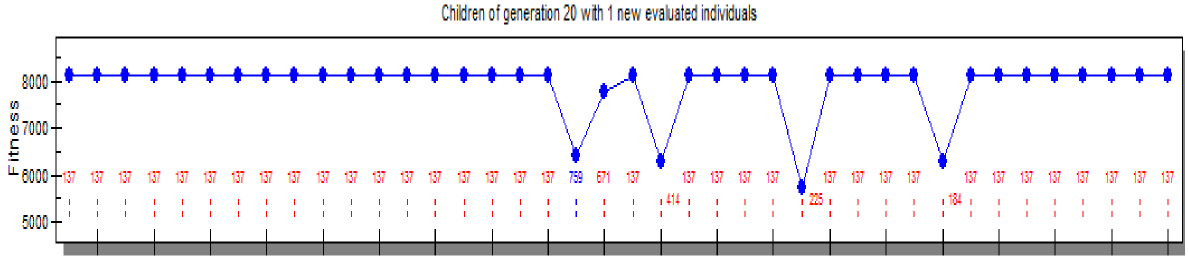

Children of generation 15 with 3 new evaluated individuals
Fitness
8000
7000
6000
5000


Children of generation 16 with 0 new evaluated individuals
Fitness
8000
7000
6000
5000


Children of generation 17 with 2 new evaluated individuals
Fitness
8000
7000
6000
5000


Children of generation 18 with 3 new evaluated individuals
Fitness
8000
7000
6000
5000


Children of generation 19 with 2 new evaluated individuals
Fitness
8000
7000
6000
5000


Children of generation 20 with 1 new evaluated individuals
Fitness
8000
7000
6000
5000