BACHELOR THESIS - ME184841

APPLICATION OF BLOCPLAN ALGORITHM AS LIQUIFIED NATURAL GAS (LNG) REGASIFICATION TERMINAL DESIGN METHOD

ZAKI ULFAUZI
NRP. 04211641000016

Supervisors:
Prof. Dr. Ketut Buda Artana, S.T., M.Sc.
Dr. Eng. Dhimas Widhi Handani, S.T., M.Sc.

DOUBLE DEGREE PROGRAM
DEPARTMENT OF MARINE ENGINEERING
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TUGAS AKHIR- ME184841

PENERAPAN ALGORITMA BLOCPLAN SEBAGAI METODE DESAIN TERMINAL REGASIFIKASI GAS ALAM CAIR (LNG)

ZAKI ULFAUZI
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FAKULTAS TEKNOLOGI KELAUTAN
INSTITUT TEKNOLOGI SEPULUH NOPEMBER
2020

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APPROVAL SHEET

APPLICATION OF BLOCPLAN ALGORITHM AS LIQUIFIED NATURAL GAS (LNG) REGASIFICATION TERMINAL DESIGN METHOD

BACHELOR THESIS

Submitted to comply one of the requirements to obtain a Bachelor Engineering degree
on
Field of Study Reliability, Availability, Management, and Safety (RAMS)
Undergraduate Program in Marine Engineering Department
Faculty of Marine Technology
Institut Teknologi Sepuluh Nopember

Prepared by:
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APPROVAL SHEET

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Submitted to Fulfill One of the Requirements to

Obtain an Engineering Degree

on

Reliability Availability Management and Safety Field of Study (RAMS)

Bachelor Program Department of Marine Engineering

Faculty of Marine Technology

Sepuluh Nopember Institute of Technology

by:

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SURABAYA

AGUSTUS, 2020

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DECLARATION OF HONOR

I as a result of this who signed below declare that:

This bachelor thesis has been written and developed independently without any plagiarism act. All content and ideas drawn directly from internal and external sources are indicated, such as cited sources, literature, and other professional sources.

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NRP	:	04211641000016
Bachelor Thesis Title	:	Application of BLOCPLAN Algorithm as Liquified Natural Gas (LNG) Regasification Terminal Design Method
Department	:	Marine Engineering

If there is any plagiarism act in the future, I will fully responsible and receive the penalty given by ITS according to the regulation applied.

Surabaya, August 2020

Zaki Ulfauzi

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APPLICATION OF BLOCPLAN ALGORITHM AS LIQUIFIED NATURAL GAS (LNG) REGASIFICATION TERMINAL DESIGN METHOD

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ABSTRACT

In the layout design of buildings using applications, such as in the fields of civil engineering, shipping, architecture, many design algorithm systems have been developed. Design algorithm is an approaching method in design where the computer system has been processed with several formulas to produce designs automatically and efficiently. The researcher tries to use one of the design algorithms for designing the LNG terminal layout, called the BLOCPLAN algorithm. The BLOCPLAN algorithm is used to improve the efficiency of space utilization and facility placement. BLOCPLAN works by generating several terminal layouts with a direct appraisal system. A most efficient design will be selected from generated designs after the re-analysis process. In determining the main terminal facilities, Excel Solver is also used to choose the best scenario with low investment capital. In this research, 15 layouts are generated by the algorithm. For the ranking process, the AHP method is used to change the character of the score from the cost criteria to the benefit criteria. The weighted value of each score is 0.1 for Adj.Score, 0.3 for R.Score, and 0.6 for the Rel-Dist Score. From the ranking results, layout number 14 is the best recommendation with a total score of 0.14987.

Keyword: Design algorithm, BLOCPLAN, Layout design, AHP

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PENERAPAN ALGORITMA BLOCPLAN SEBAGAI METODE DESAIN TERMINAL REGASIFIKASI GAS ALAM CAIR (LNG)

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ABSTRAK

Dalam perancangan tata letak fasilitas yang menggunakan aplikasi, seperti dalam bidang teknik sipil, perkapalan, arsitektur, banyak sistem algoritma perancangan yang telah dikembangkan. Algoritma perancangan merupakan salah satu metode pendekatan dalam perancangan dimana sistem komputer telah diolah dengan beberapa rumus untuk menghasilkan rancangan secara otomatis dan efisien. Peneliti mencoba menggunakan salah satu algoritma perancangan untuk mendesain layout terminal LNG yang disebut algoritma BLOCPLAN. Algoritma BLOCPLAN digunakan untuk meningkatkan efisiensi pemanfaatan ruang dan penempatan fasilitas. BLOCPLAN bekerja dengan menghasilkan beberapa tata letak terminal dengan sistem penilaian langsung. Desain yang paling efisien akan dipilih dari desain yang dihasilkan setelah proses analisis ulang. Dalam menentukan fasilitas terminal utama, Excel Solver juga digunakan untuk memilih skenario terbaik dengan parameter modal investasi yang rendah. Dalam penelitian ini, 15 layout dihasilkan oleh algoritma. Untuk proses perankingan, metode AHP digunakan untuk mengubah karakter skor dari *cost criteria* menjadi *benefit criteria*. Nilai bobot untuk masing-masing skor adalah 0.1 untuk Adj.Score, 0.3 untuk R.Score, dan 0.6 untuk Rel-Dist Score. Dari hasil pemeringkatan, layout nomor 14 menjadi rekomendasi terbaik dengan total skor 0.14987.

Kata Kunci: Algoritma Perancangan, BLOCPLAN, Desain Layout, AHP

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PREFACE

First of all, give thanks to Allah SWT for his blessing and grace, so the author can complete this thesis well and on time. Thesis with the title;

"Application of BLOCPLAN Algorithm as Liquified Natural Gas (LNG) Regasification Terminal Design Method"

Submitted as one of the requirements for graduation of engineering programs in the Department of Marine Engineering, Faculty of Marine Technology, Institut Teknologi Sepuluh Nopember Surabaya. On this occasion, the author would like to thank all those who have provided assistance and support so that this thesis can be resolved properly. In particular, the author would like to thank:

1. My Parent, brother, sister, and other extended families who always provide motivation and moral support to the writer.
2. Prof. Dr. Ketut Buda Artana, ST., M.Sc as the first supervisor who is willing to take the time to share knowledge and be available to guide the writer until this thesis is completed. Thank you also for the motivation that is always given to the writer all this time.
3. Dr. Eng. Dhimas Widhi Handani, S.T., M.Sc. as the second supervisor, thank you for the guidance and input that is always given to the author when the writer experiences obstacles in working on this thesis.
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5. The entire RAMS laboratory extended family, ranging from lecturers, staff, and students who always take the time to help the writer in completing this thesis.
6. All lecturers of Marine Engineering Department ITS who have provided knowledge to the author for four years of education in college.
7. All parties who have helped either directly or indirectly that the author cannot mention one by one.

The author is fully aware that the research undertaken is still far from perfect so it needs to get criticism, suggestions, and corrections from readers. Finally, I hope this research can be useful for writers and readers for the advancement of Science.

Surabaya, August 2020

Zaki Ulfauzi

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CHAPTER I
INTRODUCTION

1.1. Background

Nowadays, LNG is rapidly playing a bigger role in the energy market due to its cost-competitive and cleaner energy. This increase has implications for the need to build many new facilities for LNG processing, one of them is the regasification plant. From 2010 to 2019, global receiving terminal capacity continues to increase by 3.3% annually in line with the increase in LNG energy consumption. As of February 2019, global LNG regasification capacity reached a high of 824 MTPA, continuing a path of consistent expansion. The majority of regasification capacity growth is still expected to occur in established importing markets, particularly in Asia through additions in China, India, and elsewhere in the region. Many new LNG importers also continue to add or plan to develop regasification terminals, which could ultimately add a significant aggregate capacity volume in the future. The trend of adding new importers to the global LNG market is expected to continue with a few new markets expected to emerge per year in the near-term. The number of importers with regasification infrastructure has expanded significantly in recent years, more than tripling over the past 15 years (IGU, 2019).

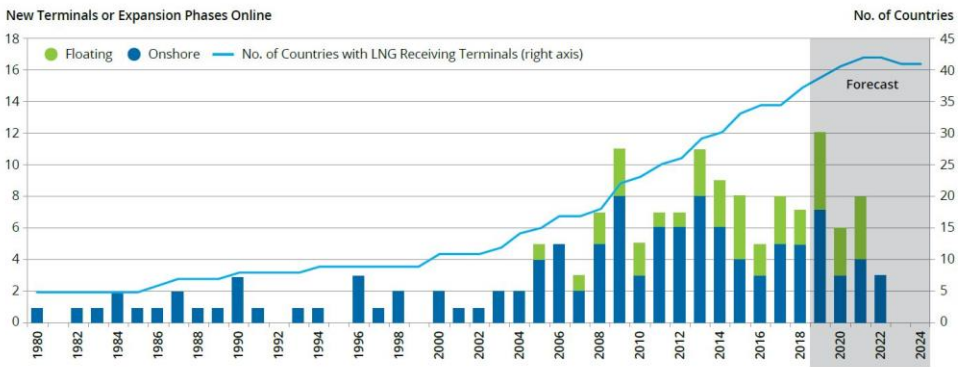

Figure 1.1 Start-ups of LNG receiving terminals, 1980 – 2024
Source: (IGU, 2019)

Note: Forecast only includes under-construction terminals as of February 2019. Owing to short construction timelines for regasification terminals, additional projects that have not yet been sanctioned may still come online in the forecast period. The decreased in the number of the market with receiving terminals is due to the expiration of FSRU charters, although new FSRU charters may be signed during this period.

The fact is also in line with data published by DNV GL that stated global regasification capacity will also surge, doubling its capacity to 1390 Mt/year in 2050 (DNV GL, 2018). As illustrated in Figure 1.2, most regions will experience significant regasification-capacity growth in the period. These data indicate that shortly there will be a lot of new LNG receiving terminal construction.

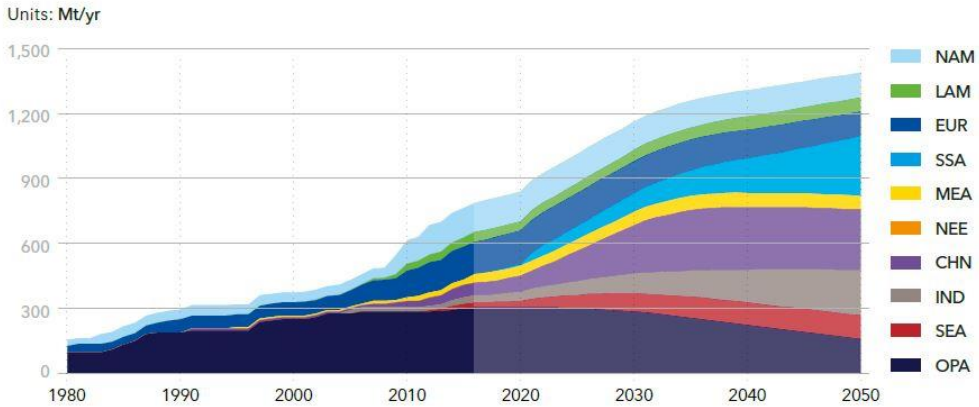

Figure 1.2 LNG regasification capacity by region
Source: (DNV GL, 2018)

When discussing new construction, it is closely related to the design of the building. In initiating the LNG terminal layout design process, designers often use diagrams and sketches to produce an initial layout design. In making diagrams, the designer draws a proximity diagram between the facility, the results is known as topological patterns of the layout. In sketching, the designer draws the area of the facility and their respective geometric shapes based on the topology pattern, so that the designer combines the topology and geometric shapes of the layout. Thus, if the existing design algorithm is used directly as an initial solution for the new design process, two benefits are obtained (Manfaat, 2013): The task of the designer to create a new layout design is reduced, and designers can utilize a combination of patterns topology and geometric shapes using existing algorithms.

The purpose of the formulation of a design algorithm is to minimize the total cost of production between departments where related costs will relate to the distance between departments (Anjos and Vieira, 2017). The design algorithm itself has become an inseparable part of the field of operations research where its application has been carried out in a multi-disciplinary manner from industry to architecture. In this study, the method development was carried out at an early stage by using Excel solver to choose the best investment scenario followed by the use of a previously created design algorithm without developing a new method. The algorithm used in this study is the BLOCPLAN algorithm. BLOCPLAN algorithm can produce

multiple layout designs along with an appraisal system for the efficiency of each layout.

1.2. Problem Statement

Following the description above, the formulation of the problem is formulated as follows:

1. How to select the main LNG regasification terminal facilities based on the specified gas supply and demand model?
2. How to use a computer algorithm to produce the LNG regasification terminal layout?
3. How to determine the optimal layout of the LNG regasification terminal by considering several constraints?

1.3. Scope of Study/Research Limitation

This final project will be focused and organized with several limitations on the problem, which are:

1. Excel solver technical approach for the LNG terminal design is used in the process of selecting terminal specifications.
2. Environmental conditions are not considered in the designing process.
3. Some specific data that is difficult to obtain is also assumed following the general average data.
4. The standard for the terminal design used in this research is NFPA 59A.
5. A land topology where the terminal construction is assumed to be flat land.

1.4. Research Objective

Based on the problems mentioned above, the goals of this research are:

1. Selecting and planning the processing facilities at the LNG regasification terminal.
2. Determining the optimal terminal regasification layout design using a computer algorithm.

1.5. Research Benefit

This final project is expected to give benefits to various parties. The benefits that can be obtained are:

1. Speed up the LNG terminal designing process.
2. Save on production costs in the design of the LNG terminal.

3. Relieve the workload of the designer.
4. Design results are more optimum because it has been passed the evaluation process repeatedly.

CHAPTER II
LITERATURE STUDY

2.1. Design

In a general sense, design can be defined as the process or task of planning a strategy for creating something. However, we might ask whether the design is that simple? Of course, the design is not simple. Design is a process with a very high level of complexity that involves various kinds of problems in describing and combining all the attributes or features of the product to produce an acceptable product. Furthermore, the design has been discussed in a broader view when design can be used in a variety of activities, one of which is in the engineering field. Engineering design can simply be interpreted as a design that is directed to form an engineering product, by involving the development of concepts and outlining the details of an engineering product (Manfaat, 2013). The development of these concepts requires complex processes, including the creation, evaluation, and breakdown of concepts to obtain clearer ideas, views, and better analysis of products.

2.2. Facility Layout Design

Factory layout can be defined as a procedure for managing factory facilities to support the smooth production process (Apple, 1990). This arrangement will utilize the area (space) for the placement of machinery or other production support facilities, smooth movement of material movements, material storage (storage) both temporary and permanent, workers' personnel, and so on ". Meanwhile, according to Heizer and Render (Heizer and Render, 2006), the layout is an important decision that determines the efficiency of operation in the long run.

In the factory layout, there are 2 (two) things that are regulated, namely the machine layout and the departmental arrangements of the factory (department layout). When we use the term factory layout, this is often interpreted as the arrangement of existing production equipment/facilities (the existing arrangement) or it can also be interpreted as a new factory layout plan (the new layout plan).

2.3. The Purpose of Factory Layout Planning and Arrangement

According to Heizer and Render (Heizer and Render, 2006), the layout has many strategic impacts because layout determines company competitiveness in terms of capacity, process, flexibility, and cost, as well as the quality of the work environment, customer contact, and company image. The purpose of the layout strategy is to build an economical layout that meets the company's competitive needs.

Broadly speaking, the main goal of the factory layout is to set the work area and all the most economical production facilities to operate safe and comfortable production so that it will be able to increase the morale and performance of the operator (Apple, 1990). More specifically a good layout will be able to provide benefits in the production system, which include the following:

1. Increase production output.
   A good layout will provide greater or fewer outputs, smaller man-hours, and/or reduce machine hours.

2. Reducing the waiting time (delay).
   Managing the balance between production operation time and a load of each department or machine is part of the work of those responsible for the design of the plant layout. A well-coordinated and well-planned layout setting can reduce excessive waiting times.

3. Reducing the material handling process.
   The process of planning and designing the plant layout will put more emphasis on the design of efforts to move the activities of moving materials during the production process.

4. Savings in the use of areas for production, warehouses, and services.
   Roadways, piling up materials, excessive distances between machines, etc. will all add to the area needed for the factory. An optimal layout planning will try to overcome all the problems of wasteful use of this room and try to correct it.

5. Greater empowerment from the use of machinery, labor, and/or other production facilities.
   Factors in the utilization of machinery, labor, and others are closely related to production costs. A well-planned layout will help a lot more effectively and efficiently utilize production elements.

6. Reducing inventory in the process.
   The production system requires as far as possible raw materials to move from one direct operation to the next as quickly as possible and try to reduce the accumulation of semi-finished materials. This problem can be mainly solved by reducing the waiting time (delay) and the material waiting to be processed immediately.

7. Shorter manufacturing process.
   By shortening the distance between operations one with surgery next and reduce the waiting material and unneeded storage, the time required from raw materials to move from one place to another within the plant can be shortened so that the total production time will also be shortened.

8. Reducing risks to the health and safety of the operator.
   Plant layout planning is also intended to make a comfortable and safe working atmosphere for those who work in it. Matters that can be considered dangerous to the health and safety of the work of the operator must be avoided.

9. Improve morale and job satisfaction.
   Basically, people want to work in a factory where everything is arranged in an orderly, neat, and good manner. Enough lighting, good circulation, and others will create a pleasant working environment so that morale and job satisfaction will be further enhanced. The positive outcome of this condition is of course in the form of better work performance and leads to increased work productivity.

10. Facilitate supervision activities.
    A well-planned factory layout will be able to facilitate supervision activities. By placing the office/room above, a supervisor will be able to easily observe all activities that are taking place in the work area under his supervision and responsibility.

11. Reduces congestion and confusion.
    Material awaiting, unnecessary movement, and the number of intersections (intersection) of the existing cross will cause confusion which will eventually lead to congestion. By using material directly and quickly, and keeping it moving, labor costs can be reduced by around 40%, and more importantly, this will reduce the problem of confusion and congestion in material transfer activities. A good layout will provide enough space for all operations needed and the process can be easy and simple.

12. Reducing factors that can adversely affect the quality of raw materials or finished products.
    A well-planned layout can reduce damages that can occur in raw materials or finished products. Vibrations, dust, heat, etc. can easily damage the quality of the material or the product produced.

2.4. Types of Layout

There are two main and frequent types of patterns used (Assauri, 2008), namely:

1. Process layout
   In this type of layout, all machines and equipment are placed in the same department. This pattern is usually applied to companies that product based on job orders or job shops.

   The advantages of the process layout pattern include:

   a. Lower investment in the use of machinery.
   b. The flexibility of conducting production is very high.
   c. Production costs are usually lower, because although the variety is large but the amount is small.
   d. Damage to one of the machines does not cause significant disruption to the overall process.
   e. Because the machines are almost the same, the specialization will be formed from the process supervisors.

   Disadvantages of this type include:

   a. The entry of new orders makes the work of routing, scheduling, and cost accounting difficult because of the re-planning.
   b. Material handling and material transportation costs are high.
   c. The need for space for the implementation of the production process becomes greater.

2. Product layout
   The layout arrangement pattern is based on the process sequence of production activity.

   The advantages of this type include:

   a. The use of automatic machines results in shorter completion times for each product.
   b. The use of material handling equipment which still results in faster material handling activities and lower material handling costs.
   c. Supervision of the production process can be simplified and recording activities can be arranged more quickly.
   d. There are fewer activities to supervise the production process.
   e. Raw material needs can be estimated more quickly.

   The disadvantages of this type include:

   a. If there is damage to one of the machines, the production process is interrupted.

b. The efficiency and productivity of workers can decrease due to monotonous production patterns, causing boredom.
c. Requires a fairly high investment for the procurement of machinery.
d. Requires a large enough cost if there is a change because of inflexible.
e. The level of production is fixed.

2.5. Layout Design of Production Facility

The production facility is something that is built, held, or invested to carry out production activities. Planning for facility layout is the same as designing plant layout which can be defined as the procedure for managing factory facilities to support the smooth production process (Apple, 1990).

2.5.1. Considerations in planning a new or existing plant

New plant planning, the activities here include planning a completely new plant installation that is from product planning to be made up to planning the factory building (Apple, 1990). Whereas the redesign/replanning here concerns the planning of new products or new layouts based on existing production facilities. In general, plant re-planning is caused by several specific reasons, namely:

1. There are changes in product design, models, and others.
2. A change in the location of the factory.
3. There is a change or increase in production volume which ultimately leads to changes towards the modification of all existing production facilities.
4. There are complaints from workers regarding the condition of the work area that does not meet certain requirements.
5. The existence of bottlenecks (bottlenecks) in the activity of moving materials, warehouses that are too narrow, and so forth.

2.5.2. Production facility layout type

In general, the layout of production facilities can be classified into three types (Apple, 1990), namely:

1. Layout based on product flow (product layout).
   If a factory will specifically produce one type of product or product group in large quantities/volumes and long production time, then all production facilities of the factory must be arranged so that the production process can take place as efficiently as possible. With a

layout based on product flow, machines and other production facilities will be organized according to the "machine after machine" principle regardless of the type of machine used. By using the product flow type layout, all facilities for the production process (both fabrication and assembly) will be located based on the product's flow line. The types of product flow lines (product flow lines) that might be applied are:

a. Straight line.
   Flow patterns based on straight lines or straight lines are commonly used when the production process is short, relatively simple, and generally consists of several components or several kinds of production equipment. This material flow pattern based on straight lines will provide:

   i. The shortest distance between two points.
   ii. Production processes or activities take place along a straight line from the number one machine to the last machine.
   iii. The total material handling distance will be small because the distance between each machine is as short as possible.

b. Serpentine (S-Shaped).
   Flow patterns based on these broken lines are very well applied when the production process flow is longer than the area available. For this reason, the flow of material will be deflected to increase the length of the existing flowlines, and economically this will be able to overcome all the limitations of the area and the size of the existing factory building (Apple, 1990).

c. U-Shaped.
   This U-Shaped flow pattern will be used if it is desired that the end of the production process will be at the same location as the beginning of the production process. This will facilitate the utilization of transportation facilities and also greatly facilitates supervision for the entry and exit of material to and from the factory. The application of material lines is relatively long, so the U-Shaped will be inefficient and for this, it is better to use a zig-zag type material flow pattern.

d. Circular.

Flow patterns based on circular shape are best used when it is desired to return material or products to the starting point of the production flow. This is also good if the department of receiving and shipping materials or finished products is planned to be in the same location in the factory concerned.

e. Odd angle.
This flow pattern based on odd-angle is not very well known compared to other flow patterns. This pattern is very common and good for conditions such as (Apple, 1990):

i. When the handling process is carried out mechanically.
ii. When space constraints cause other flow patterns to be forced can not be applied.
iii. Whenever a desirable flow pattern is desired from existing production facilities, it is desirable.

This Odd-angle will provide a short trajectory and especially will feel its usefulness for a small area.

2. Layout based on process flow (process layout).
Layouts based on process flow (process layout) are often referred to as functional layouts. A functional layout is a method of arranging and placing machines and all production facilities of the same type/type in a department. Here all machines or production facilities that have the same operating characteristics or work functions are placed in a department. Layout based on process flow is generally applied to industries that work with a relatively small amount/volume of production and especially for types of products that are not standardized. The layout of this type of process flow will be far more flexible when compared to the layout of the product flow type. Industries operating based on job orders will be more appropriate if they apply the layout of process flow types to manage production facilities (Apple, 1990).

3. Layout based on position (fixed position layout).
For layouts based on fixed positions, the material and components of the main product will remain in its position/location while production facilities such as tools, machinery, people, and other small components will move towards the location of the main product material or components. In the assembly process, the fixed position type layout will often be found because here the work tools (tools) will be easily moved.

2.6. Computer-Aided Layout

The development of computer technology today is very advanced and can be seen from the entry of computer functions into various aspects of life. We can take an example as in layout determination. At this time, the layout designer only needs to use the computer to get the layout changes from before or create a new layout that can meet the current production targets which are quite fluctuating (Hadiguna and Setiawan, 2008).

The program to create a layout that has existed to date includes CRAFT (Computerized Relative Allocation of Facilities Techniques) CORELAP (Computerized Relationship Layout Technique), COFAD (Computerized Facilities Design), PLANET (Plant Layout Analysis and Evaluation Technique), ALDEPEP (Automated Layout Design Program), BLOCPLAN, MIP (Mix Integer Programming), LOGIC (Layout Optimization with Guillotine Induced Cuts), MULTIPLE (MULTI-floor Plant Layout Evaluation), Mulrow, and still many are not traded. All types of programs have their advantages and disadvantages. However, given the limitations of software available on the market, not all computer-aided layout programs can be discussed.

2.6.1. BLOCPLAN

Another method in designing departmental layouts is often used is BLOCPLAN. BLOCPLAN is a facility layout design system developed by Donaghey and Pire in the industrial engineering department, University of Houston. This program creates and evaluates types of layout in response to input data. BLOCPLAN has similarities with CRAFT in the preparation of departments. The difference between BLOCPLAN and CRAFT is that BLOCPLAN can use linkage maps as input data, whereas CRAFT only uses maps from (to-chart). Layout costs can be measured both by distance and proximity rules. The number of lines in BLOCPLAN is determined by the program and usually two or three lines.

Similar to CRAFT, BLOCPLAN also has weaknesses that is, it won't capture the initial layout accurately. Layout development can only be sought by making changes or exchanging departmental locations with one another. In addition to the BLOCPLAN linkage map, sometimes it also uses other data inputs, namely maps from to chart, only the two inputs are only used when evaluating the layout. The layout cannot be evaluated by combining both data, linkage maps, and data flow (Purnomo, 2004).

To run the BLOCPLAN program the first step must be done is to enter data input. Information needed to run BLOCPLAN includes the number of departments, the names of departments, and the area of each department. Another very important

and indispensable information is the data related to each department. The code or link symbols used in BLOCPLAN use symbols developed by Muther in Systematic Layout Planning (SLP) (Ignasius, 2017).

BLOCPLAN will make several layout dependent alternatives user wishes (maximum 20 alternatives). Departments will be randomly assigned to certain layout areas. An alternative layout will be displayed with a certain scale and each alternative will be calculated. To determine the best alternative layout, you can choose one by one starting from alternative 1 to the last alternative. BLOCPLAN will present one by one the alternative layout and the score. The highest score can be proposed as the best alternative.

2.6.2. Activity relationship chart (ARC)

Activity Relationship Chart or activities between each part that illustrates the importance of the proximity of the room. This method connects activities in pairs so that all activities will be known to their level of relationship. The activity relationship can be reviewed in terms of organizational interrelation, flow interrelation, environmental interrelation, and process interrelation. ARC arranged based on certain reasons and the level of importance symbolized by the letters A, I, E, O, U, and X. These letters indicate how the activities of each work station will have a direct or close relationship with each other. Figure 2.1 is an example from the ARC diagram.

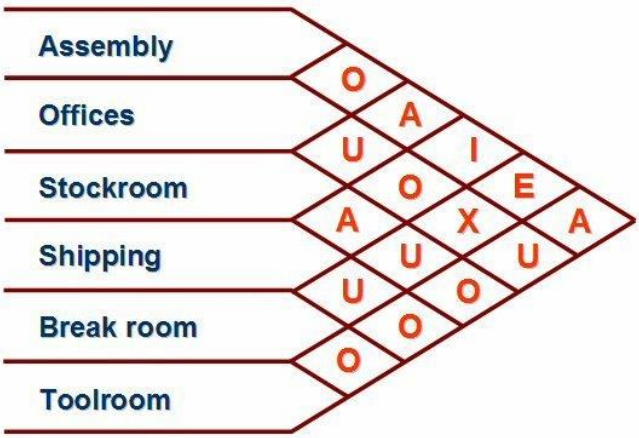

Figure 2.1 Activity relationship chart example
Source: (Lawrence Loucka, 2006)

The value of each symbol of the actual department's interrelation determined by each BLOCPLAN user. For example, in an application, the user feels that symbol A has value three times more important than the value E. However for other problems

it may only be twice as important. Usually, the system will bring up the value of these symbols that might be acceptable. The value of these linking symbols can be changed if the user wants to change them.

A = 10 = Absolutely essential,
E = 5 = Essential,
I = 2 = Important,
O = 1 = Ordinary closeness ,
U = 0 = Unimportant,
X = -10 = Undesirable

2.6.3. Layout form

BLOCPLAN will display five choices of length and width ratio of the desired layout shape. The ratios that can be chosen respectively are, for the first choice is 1.35: 1, the second choice is 2: 1, the third choice is 1: 1, the fourth choice is 1: 2, the fifth choice of the user determines the desired length and width.

2.7. Determination of Required Land Area

Determination of the area is needed to determine whether the existing area following the needs of the area. The space needed by facilities is related to equipment, materials, employees, and activities (Apple, 1990). Determination of the need for this area, it requires additional leeway of 40% to 60% for the aisle (aisle) and the operator. In addition, for each machine or supporting facility, 0.50 - 1-meter tolerance are used on each side of the machine.

2.8. The Relationship Between Factory Layout Design and Productivity

Improvement of factory layout design is needed due to several conditions that occur in the company for example due to the policies of top-level management related to the company's target to increase production output, so it is necessary to improve layout design to provide greater production output with the same production costs /less. Production time is too long due to the number of delays (waiting time), the number of complaints from workers due to conditions in the work area that do not meet the requirements so that worker productivity decreases. Some of these conditions can be used as reasons why we have to improve factory layout design. To be more specific, here are some reasons why you should improve your factory layout design:

1. Increase production output.
2. Reducing waiting times.
3. Reducing the material handling process.

4. Savings in the use of areas for production, warehouses, and services.
5. Utilization of production facilities and labor more optimally.
6. Reducing the cost of storing semi-finished products (in-process inventory).
7. Shorten the manufacturing process.
8. Reducing the occupational health and safety risks of the operator.
9. Facilitate supervision activities (work supervision).
10. Reduces congestion and confusion in the flow of material.
11. Reducing factors that can affect the quality of raw materials and finished product.

2.9. LNG Terminal Standard

International LNG terminal standards mean to the extent not inconsistent with the express requirements of the common terms agreement, the international standards, and practices applicable to the design, construction, equipment, operation or maintenance of LNG receiving, exporting, liquefaction and regasification terminals, established by the following (such standards to apply in the following order of priority):

I. A government authority having jurisdiction over the borrower.
II. The Society of International Gas Tanker and Terminal Operators (SIGTTO) (or any successor body of the same).
III. Any other internationally recognized non-governmental agency or organization with whose standards and practices it is customary for reasonable and prudent operators of LNG receiving, exporting, liquefaction and regasification terminals to comply.

In the event of a conflict between any of the priorities noted above, the priority with the lowest roman numeral noted above shall prevail ("International LNG Terminal Standards," n.d.). Some examples of standards commonly used in the LNG terminal design process are API STD 625, BS EN 1473, BS EN 1160, NFPA 59A, etc.

2.9.1. API STD 625

The standard regulated tank systems for refrigerated liquified gas storage. This standard covers low pressure, aboveground, vertical, and cylindrical tank systems storing liquefied gases requiring refrigeration. This standard provides general requirements on responsibilities, selection of storage concept, performance criteria, accessories/appurtenances, quality assurance, insulation, and commissioning of tank systems. These general requirements address issues common to all of these tank systems, issues involving coordination of the components of the tank system, and

issues of the tank system acting in an integrated way. This standard covers tank systems having a storage capacity of 800 cubic meters (5000 bbls) and larger (API 625, 2014).

2.9.2. BS EN 1473

The title of this standard is "Installation and equipment for liquified natural gas – Design of onshore installations". The objective of this European Standard is to give functional guidelines for LNG installations. It recommends procedures and practices that will result in safe and environmentally acceptable design, construction, and operation of LNG plants. It need not be applied retrospectively, but the application is recommended when major modifications of existing installations are being considered. This European Standard gives guidelines for the design, construction, and operation of all onshore liquefied natural gas (LNG) installations including those for the liquefaction, storage, vaporization, transfer, and handling of LNG. This European Standard is valid for the following plant types:

- LNG export installations (plant), between the designated gas inlet boundary limit, and the ship manifold.
- LNG receiving installations (plant), between the ship manifold and the designated gas outlet boundary limit.
- Peak-shaving plants, between the designated gas inlet and outlet boundary limits.

Satellite plants are excluded from this European Standard. Satellite plants with a storage capacity of fewer than 200 tons are covered by EN 13645 (EN-1473, 2007).

2.9.3. BS EN 1160

The title of this standard is "Installation and equipment for liquified natural gas – General characteristics of liquified natural gas". This European Standard gives guidance on the characteristics of liquefied natural gas (LNG) and the cryogenic materials used in the LNG industry. It also gives guidance on health and safety matters. It is intended to act as a reference document for the implementation of other standards of CEN/TC 282, Installations and equipment for liquefied natural gas. It is intended as a reference for use by persons who design or operate LNG facilities (EN1160, 1997).

2.9.4. NFPA 59A

NFPA 59A "Standard for the Production, Storage, and Handling of Liquified Natural Gas (LNG)" establishes essential requirements and standards for the design, installation, and safe operation of liquefied natural gas (LNG) facilities. It guides all persons concerned with the construction and operation equipment for the production, storage, and handling of LNG. It is not a design handbook, and competent

engineering judgment is necessary for its proper use. This standard shall apply to the following;

- Facilities that liquefy natural gas.
- Facilities that store, vaporize, transfer, and handle liquefied natural gas (LNG).
- The training of all personnel involved with LNG.
- The design, location, construction, maintenance, and operation of all LNG facilities.

The purpose of this standard is to provide minimum fire protection, safety, and related requirements for the location, design construction, security, operation, and maintenance of LNG plants (NFPA 59A, 2013).

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CHAPTER III
METHODOLOGY

3.1. Research Scheme

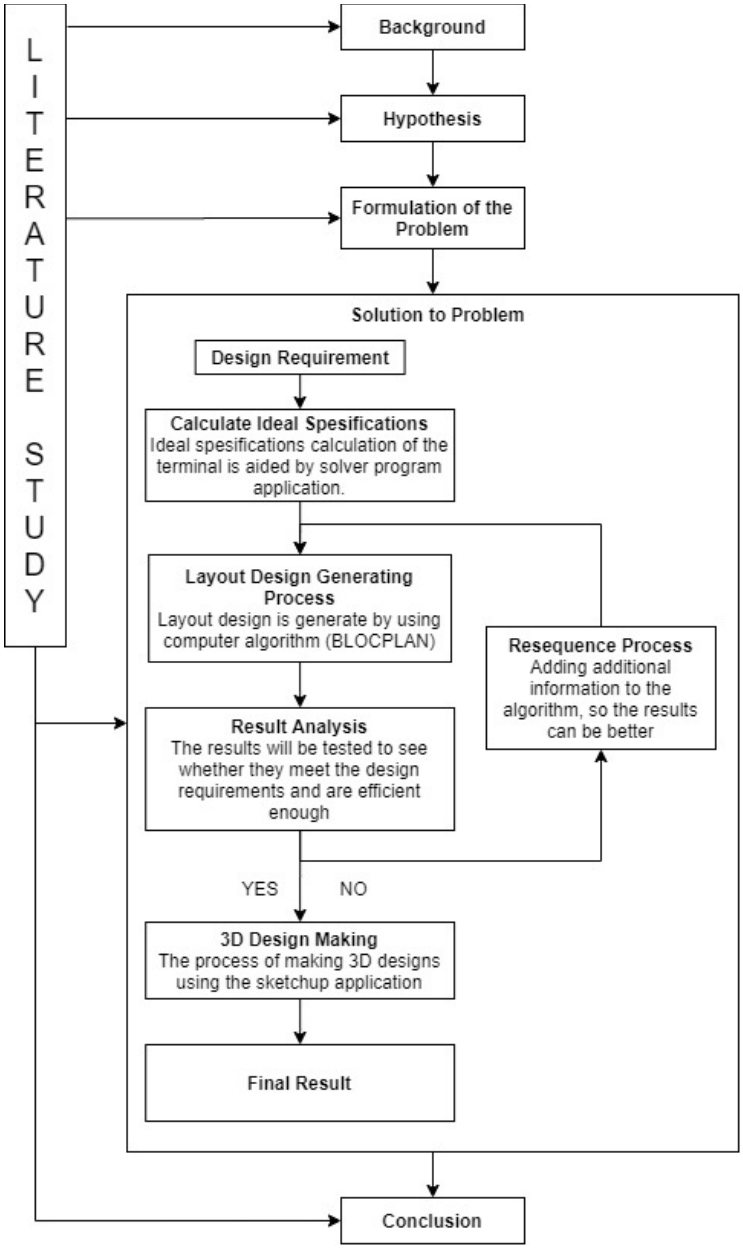


Figure 3.1 Methodology scheme

3.2. Methodology Identification

This research started due to researchers concerned about the current design methods that are considered to be long-winded and less efficient. Through the unrest, the researchers finally decided to try to utilize a computer system that could simplify the work of engineers and increase efficiency at the same time. This system uses a computer algorithm to simplify the designer's work. By using a computer algorithm, the designer can generate several layout designs with more efficiency. This way of the process can save time in designing and designer also can get more reliable result because of the result that designer want was calculated by the computer system.

In this research, several methods will be used including methods, among other linear programming methods and computer algorithm methods. These methods used to obtain the essential outcomes and achieve the specific objectives of this research project. As the goal of this thesis is to provide a design method to simplify the designer's works.

3.3. Research Flow

This research will be based on various steps to achieve its result and goals. Hereby are the further explanation of methodological flow from the beginning of the process, literature study, data collecting, solving the problem, until the final process resulting in the objectives of this research.

3.3.1. Literature Study

Literature studies are carried out for each process in progress. Also from the literature study, the authors found problems that exist in current design work. Which guides the researcher to find the solution for the problems. A literature study aims to have a better understanding of the author about the supporting information and problem related to this research. Data found in the literature study also can be used as a reference to understand the problem.

3.3.2. Background

The background raised in this research was obtained after the writer conducted a literacy study. Where in the literacy study the authors find a set of patterns that lead the writer to find a problem that exists in society. Background also represented how important this problem be solved.

3.3.3. Hypothesis

Based on supporting information obtained in the literature study, the author has understood enough of the issues raised. It helps the author to imagine how is the result of this thesis. The author is very confident if this thesis can achieve the result as imagined by the author from the beginning.

3.3.4. Formulation of the Problem

After doing enough literacy studies, found several problems that are considered important to solve. After that, the problems are formulated into several important points. This is to help the author in the research process so that the research process carried out to be directed to solve specific problems.

3.3.5. The solution to the Problem

First of all the Excel solver program is used to optimize the specifications of the LNG terminal to be designed. The optimization process starts with modeling the gas balance in the area supplied. Supply and demand modeling is based on existing data. Modeling is carried out to describe the condition of future gas balance to determine the specifications of the main LNG terminal facilities. From the modeling, it is obtained the amount of LNG demand in a certain area and the level of daily LNG gas consumption. Then In determining the main specifications of the terminal, the solver feature in Excel applications is used to simplify and speed up the process of determining the main specifications. Several scenarios are made to compare. The parameter used to determine the best scenario is the initial investment capital of the terminal construction. Excel Solver can determine the number and type of facilities needed with minimal capital cost while still meeting the design requirements. After obtaining the terminal specifications, it will proceed to the process of making the regasification terminal layout design.

The layout production facility is an overall shape and placement of facilities needed in the production process (Kovács and Kot, 2017). Creating a terminal layout using the BLOCPLAN algorithm is done by inputting area data and proximity relationships for each facility. Then the algorithm will produce several layout designs and assessment scores for each type of layout. The advantage of the BLOCPLAN algorithm is that it already can score the levels of efficiency, closeness, and several other assessments. So the designer doesn’t need to test the results again but rather directly assess the resulting score to determine which layout type is the most efficient for the terminal to be designed. At this stage, several processes must be carried out to obtain the desired results. To get the value of the relationship between each of the facilities available at the terminal, an approaching method called systematic layout planning is used. Systematic layout planning (SLP) is a prominent procedural approach and is widely used in layout design for various small and medium enterprises (Gilbert, 2004).

From the overall layout design produced, one design that has the highest score will be taken based on the algorithm calculation. the design will be re-analyzed to determine whether it meets the design requirements and is efficient enough or not. if the design does not meet the requirements then additional information related to the desired design will be entered into the BLOCPLAN algorithm to obtain better results. After the addition of design, information is done, the algorithm will produce more layout designs to match the information added earlier. When there is one design that meets all the requirements, the 3D design will be made to calculate the pipeline requirements for terminal construction.

3.3.6. Conclusion

The last stage is to conclude the whole process that had been done. This stage contains a short answer to the problems of this research. In conclusion, there will be a recommendation that can be given based on the results so that in the future these recommendations can be used by new researchers as a general description if they want to research or develop a similar system.

CHAPTER IV
RESULT AND DISCUSSION

4.1. Data Processing

4.1.1. Gas supply and demand modeling

Supply and demand modeling is carried out to determine the number of gas surpluses and deficits in a particular region. The area taken as a target supply sample is Region II Indonesia (Central Sumatra, Southern Sumatra, Riau Islands, and Western Java). The scenario of increasing gas demand per year is prepared with the following assumptions (Indonesia, n.d.);

1. Allocation for oil lifting is following the contract existing.
2. Growing gas demand for government programs through the household gas network and gas refueling station (SPBG**)** is 5% per year.
3. The growth of gas demand for fertilizer and petrochemical plants for 10 years has remained stable (according to plan).
4. Electricity sector gas demand growth of 5.5% per year (2018-2027 electricity supply business plan/RUPTL projection) following economic growth assumptions.
5. Growth in gas demand for the retail industry sector by 5.5% per year from the contract and non-retail value following factory capacity and potential demand.

Meanwhile, the natural gas supply is calculated based on adding between existing supply and project supply. Existing supply is an estimate of natural gas volume that can be supplied and flowed from oil and gas fields that are in production (on stream). Project supply is an estimate of the volume of natural gas that can be supplied and flowed from oil and gas fields whose field development plans have been approved or are in the process of approval (Indonesia, n.d.)

Natural gas demand data from 2018-2027 for Region II Indonesia is shown in Table 4.1. Gas supply for each year from 2018-2027 is shown in Table 4.2. The regasification terminal model that will be designed in this research refers to gas demand and supply data in 2027. Natural gas demand data show that in 2027 the amount of gas needed by Region II in a year is 3,553.56 MMSCFD. While the available supply for the Region II is only 1,029.42 MMSCFD. Using the gas demand and supply data, gas balance in Region II can be calculated using the following formula,

$$\text{Gas balance} = \text{gas supply} - \text{gas demand} \quad (1)$$

From equation (1), then obtained a result of -2,524.14. Minus (-) sign indicates that Region II is in a state of supply shortage to meet gas needs in the region. So every year Region II needs 2,542.14 MMSCFD of gas to meet its gas needs.

Considering the distribution distance between the terminal and the state gas pipeline network, the regasification terminal to be built is located at Bandar Negeri, Labuhan Maringgai, East Lampung, Lampung (5 ° 24'45.16 "S 105 ° 49'11.82" E). The location is indicated by a purple square in a blue circle with a dashed line in Figure 4.1. The selection process assumes that the environmental conditions of the place have fulfilled the requirements as a terminal construction site. The red dashed line in Figure 4.1 shows the gas pipeline network that will be built, connecting Java and Sumatra.

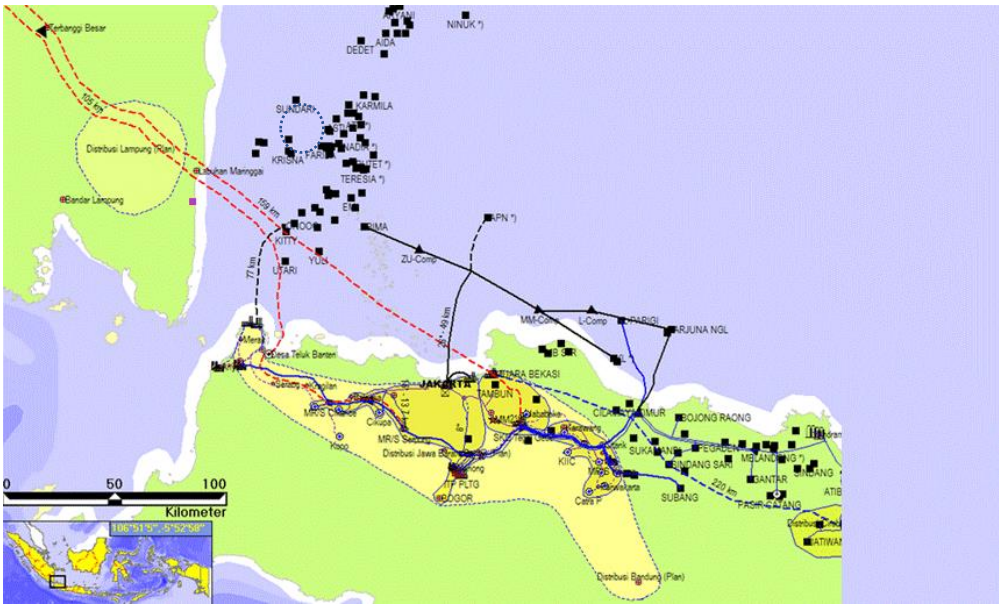


Figure 4.1 Indonesia gas network pipe map.

Table 4.1 Gas demand data for Region II Indonesia (Indonesia, n.d.).

Description	2018	2022	2027
Petroleum lifting	180.95	140.95	113.30
Government program			
Transportation	23.99	29.16	37.22
Household	4.36	5.3	6.76
Fertilizer and petrochemicals	343	330	300
Electricity	689.8	773.9	1,009.3
Industry			
Retail industry	967.03	1,175.43	1,500.18
Non-retail industry	159.50	251.50	371.5
LNG export/commitment	926.9	895.90	215.3
Total demand	**3,295.53**	**3,602.14**	**3,553.56**

Table 4.2 Gas supply data for Region II Indonesia (Indonesia, n.d.)

Condition	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Total Supply	2816	2909	3075	2866	2589	2180	1757	1483	1258	1029.42

4.1.2. Ship selection

Table 4.3 Ship specification.

Data	Ship Name		
	WSD50 5K	**WSD50 7.5K**	**AP460**
LOA [m]	99.99	115.1	90
LPP [m]	94.5	110.6	86.8
B [m]	12.2	18.6	15.7
H [m]	9.3	10.15	9.4
T [m]	5.2	6	4.72
DWT [tons]	3,350	4,100	2,820
Vs [knots]	14	13.5	12.5
Cargo capacity [m^3]	5,100	7,500	4,080
Endurance[a] [nm]	3,350	8,000	1,200
GT	5,580	6,850	3,870
Main engine [kW]	4,000	3,000	3,200
Ship crew [persons]	18	18	12
Cargo pump cap. [m^3/h]	800[b]	1,000[c]	900[d]
MDO capacity (fuel) [m^3]	180	400	-
MDO consumption [tons/day]	15.8	10.4	14.65
Ship cost[e] [USD]	40,000,000	50,000,000	35,000,000

[a] Using MDO as ship's fuel
[b] 2 x 400 m^3/h. one each tank
[c] 2 x 500 m^3/h. one each tank
[d] 2 x 450 m^3/h. one each tank
[e] The price of the vessel is not the actual price, but the average price of a similar vessel

The ship was chosen as the main distribution mode to supply LNG to the regasification terminal due to its efficiency in long-distance LNG distribution. The LNG to be supplied comes from Badak LNG, Bontang, East Kalimantan. In this study, three ships were tested economically to supply LNG to the regasification terminal. Data from the three ships are shown in Table 4.3 and more specifically is shown in APPENDIX A.

The three ships are compared based on the initial investment capital value needed for each type of ship. The objective is to choose the type of ship with the

lowest investment cost while still meeting the terminal requirements. The general data used for the calculation are shown in Table 4.4. Some data is assumed due to the difficulty of getting authentic data, for example, the cost of building a jetty. Using existing data, the initial investment costs can be calculated for each type of LNG carrier. All of these calculations are carried out assuming there are no additional costs incurred at any time caused by certain factors that cannot be controlled.

Table 4.4 General data.

Description	Amount
Ship operational days	340
Distance from the origin [nm]	907
Gas Demand [m^3]	2,524.14
LNGρ [ton/m^3]	0.47
MDO cost [USD/ton]	250

The calculation used in the ship selection process is as follows,

$$T_{od} = 2 \text{ x } \frac{S_{od}}{V_s} \tag{2}$$

$$T_p = 2 \text{ x } \frac{C_{ship}}{Q_{pump}} \tag{3}$$

$$R_{min} = \frac{\text{Gas demand}}{C_{ship}} \tag{4}$$

$$R_t = (T_{od} + T_p) \text{ x } R_{min} \tag{5}$$

$$\text{Fuel cost at sea time} = \text{FOC x } \frac{T_{od}}{24} \text{ x } R_{min} \text{ x Fuel cost} \tag{6}$$

$$\text{Fuel cost at port time} = \text{FOC x } \frac{T_p}{24} \text{ x } R_{min} \text{ x Fuel cost x } 20\% \tag{7}$$

The results of the calculation of investment costs for the three ships tested are shown in Table 4.5. From the three vessels compared, the AP460 with a cargo

capacity of 4,080 m^3 is the most efficient ship with a total investment of $38,263,039 and the maximum operating time of 4,262.1 hours.

Table 4.5 Capital cost calculation.

Description	WSD50 5K	WSD50 7.5K	AP460
Round trip duration/year			
Sea time [hour]	129.6	134.4	145.1
Port time [hour]	12.8	15	9.1
Min. round trip per year	22.11	15.04	27.64
Round trip duration/year [hour]	3147.3	2246.1	4262.1
Status[a]	Accept	Accept	Accept
Bunkering cost			
MDO consumption at sea time [USD]	471,584.8	218,896,7	612,164.83
MDO consumption at port time [USD]	9,280.91	4,887.16	7,649.25
Bunkering cost [USD]	480,866	223,784	619,814
Jetty construction cost [USD]	2,000,000	2,300,000	1,900,000
Total investment [USD]	**43,224,091**	**53,267,009**	**38,263,039**

[a]Round trip, duration/year must not exceed maximum ship operations duration in a year [340 days/8160 hours]

4.1.3. Tank selection

To find the number and type of tank needed for the terminal, an excel solver is used to optimizing the process. There are four types of tanks from different sizes used in this research. Data from the four tanks are shown in Table 4.6. With the existing tank specification data, investment values for each type of tank can be found according to the type of vessel used. Calculation data for each scenario, starting from using the WSD50 5K, WSD50 7.5K, and AP460 vessels, are shown in Table 4.7 until Table 4.9. The constraint used in the Solver program is the total capacity that can be accommodated by the terminal. The terminal must be able to accommodate all LNG carried by LNG carriers. Furthermore, the number of tanks needed can be calculated.

Table 4.6 Tank specification data.

Description	Tank model			
	EN 13458	**VT 108**	**LC 200V38**	**LC 318V42**
Gross vol. [m^3]	95	107.57	200	318
Net cap. (95%) [m^3]	90.25	102.192	190	295.745
LNG cap [ton]	42.4175	48.03024	89.3	139
Max. working pressure [bar]	5	11	5	5
Width [m]	3.35	3	3.81	4.21
Tank cost [USD]	100,000	170,000	200,000	265,000
Tank diameter [m]	3.85	3.28	3.81	4.21
Gas_ρ [ton/m^3]	0.00075			

Table 4.7 Tank calculation for WSD50 5K.

		EN 13458	**VT108**	**LC 200V38**	**LC 318V42**
Input	Capacity [m^3]	90.25	102.19	190	295.75
	Tank cost [USD]	100,000	170,000	200,000	265,000
	Land area [m^2]	14.82	10.76	14.52	17.72
	Land cost [USD]	50			
Constraint	Terminal capacity ≥ Ship capacity	5,323.41 ≥ 5,100			
Output	Total tank	-	-	-	18
Objective Function	Investment [USD]	4,785,951.69			

Table 4.8 Tank calculation for WSD50 7.5K

		EN 13458	**VT108**	**LC 200V38**	**LC 318V42**
Input	Capacity [m^3]	90.25	102.19	190	295.75
	Tank cost [USD]	100,000	170,000	200,000	265,000
	Land area [m^2]	14.82	10.76	14.52	17.72
	Land cost [USD]	50			
Constraint	Terminal capacity ≥ Ship capacity	7,689.37 ≥ 7,500			
Output	Total tank	-	-	-	26
Objective Function	Investment [USD]	6,913,041.33			

Table 4.9 Tank calculation for AP460.

		EN 13458	VT108	LC 200V38	LC 318V42
Input	Capacity [m^3]	90.25	102.19	190	295.75
	Tank cost [USD]	100,000	170,000	200,000	265,000
	Land area [m^2]	14.82	10.76	14.52	17.72
	Land cost [USD]	50			
Constraint	Terminal capacity ≥ Ship capacity	4,140.4 ≥ 4,080			
Output	Total tank	-	-	-	14
Objective Function	Investment [USD]	3,722,407			

The choice of tank-type is carried out to minimize the cost of constructing the terminal. This is done by multiplying the cost of purchasing the tank and the amount of land needed for the construction of the tank for each type of tank. After that, the total cost compared to each other between the four types of tanks used. The tank with the lowest initial investment capital is considered the most optimum result. Using the investment results for ships and storage tanks, total inventment value is calculated to choose the cheapest investment scenario. The data is shown in Table 4.10.

Table 4.10 Investment value for each scenario.

Scenario	Ships investment	Tanks investment	Total investment for ship and tanks
I WSD50 5K	$43,224,091	$4,785,952	$48,010,042
II WSD50 7.5K	$53,267,009	$6,913,041	$60,180,050
III AP460	$38,263,039	$3,722,407	$41,985,446

Ships and tanks are the largest investment value in a terminal, therefore taking into account these two facilities alone can represent the investment value of all facilities to choose the best investment scenario. From the results listed in Table 4.10, scenario III investments using AP460 as the LNG carrier and LC 318V42 is the cheapest scenario with investment value for ships and tanks of $41,985,446. Then all other supporting facilities for terminal needs are selected based on the specifications of the third scenario.

4.1.4. Vaporizer selection

Things that need to be considered in choosing a vaporizer are the minimum capacity requirement and discharge pressure of the gas. An efficient regasification terminal is applied to minimize overhaul time each year. Usually, a regasification

terminal will stop operating for maintenance every two years. Hence, the minimum regasification capacity that must be met by the terminal can be found by formula,

$$\text{Min. regasification capacity} = \frac{\text{Terminal operation capacity}}{365} \quad (8)$$

So the minimum regasification capacity for the terminal is 6.915 MMSCFD (8,068.027 m^3NG/h) with the minimum pressure to meet the operating pressure of the state's pipe gas network is 40 bar. The model chosen as the terminal regasification component is ǂSG1300SS-0.4 by the Thermax manufacturer. The specific data of the chosen vaporizer is shown in Table 4..11.

Table 4..11 Vaporizer specifications

Description	Value
Brand	Thermax
Model	ǂSG1300SS-0.4
Inlet connection size	3 inch
Outlet connection size	3 inch
Flow rate	2,900 m^3/h
Design pressure	41 bar
Working hour	8 hours
Dimension [cm]	W ; 256 L ; 290 H ; 1,052
Number of vaporizers	6

In one time period (8 hours), three vaporizers will work simultaneously. After one period expires the other three vaporizers will work while the others break while defrosting process.

4.1.5. Compressor selection

The minimum compression level of the compressor must adjust the level of boil-off gas (BOG) produced by the storage tank. With an evaporation rate of 1%/day, the LC 318V42 tank produces a boil-off gas of around 1.39 mt/day (0.058 mt/h) or equivalent to 1,853.33 m^3 NG/day (77.22 m^3 NG/hour). The compressor chosen to serve terminal operations is shown in Table 4.12. The number selected is two, one compressor is used for standby mode if at any time the main compressor has a problem.

Table 4.12 Selected compressor specification.

Description	Value
Type	TS2/130-E2
Capacity [m^3/h]	160
Inlet pressure [bar]	1.08
Outlet pressure [bar]	7
Number of strokes	2
RPM	490
Installed power [kW]	11
Number of compressors	2
Dimension	L ; 350 cm B ; 100 cm H; 150 cm

4.1.6. Low pressure and high-pressure pump selection

The selected high-pressure pump must meet the minimum capacity of the terminal operating system and also need to consider the pressure of the operating system. The capacity is adjusted to the level of daily LNG consumption from the end-user. The minimum capacity of the terminal operation is 6.915 MMSCFD (12.87 m^3/h) and the target operating pressure is 40 bar (based on state's pipe gas network). The selected high-pressure pump model is VT-100 62D. Specific data of the chosen high-pressure pump is shown in Table 4.13. The number of high-pressure pumps selected is two, one pump is used for standby mode if at any time the main pump has a problem.

Table 4.13 Selected high-pressure pump specification.

Description	Value
Brand	VANZETTI
Model	VT-100 62D
Piston bore[mm]	100
Piston stroke [mm]	62
Minimum flow rate [m^3/h]	8 – 18.7
Power installed [kW]	45 - 110
Operating speed [rpm]	150 - 350
Maximum suction pressure [bar]	20
Maximum working pressure [bar]	120
Dimension [cm]	L ; 302, B ; 119 H ; 115
Number of pumps	2

In choosing a low-pressure pump, the conditions that must be considered the same as the high-pressure pump. The minimum capacity of the terminal operating system and the pressure of the operating system. But the system pressure takes into account is the working pressure of the storage tank (5 bar). The storage tank pressure is the minimum pump pressure/maximum allowable suction pressure. The selected low-pressure pump model is DSM 185. The specific data of the pump is shown in Table 4.14. The number of low pressure pumps selected is two, one pump is used for standby mode if at any time the main low-pressure pump is under maintenance.

Table 4.14 Selected low-pressure pump specification.

Description	Value
Brand	VANZETTI
Model	DSM 185
Power installed [kW]	5.5 – 7.5
Max Operating speed [rpm]	2950
Maximum suction pressure [bar]	6
Maximum working pressure [bar]	23
Max flow rate [m^3/h]	18
Dimension [cm]	L ; 68.8 B ; 27.2 H ; 39.2
Number of pumps	2

4.1.7. BOG reliquefaction plant

The selection of plant reliquefaction is done by considering the normal rate of boil-off gas produced by the tank. With an evaporation rate of 1%/day, the LC 318V42 tank produces a boil-off gas of around 1.39 mt/day (0.058 mt/h) or equivalent to 1,853.33 m^3 NG/day (77.22 m^3 NG/hour). The specific data of the selected liquefaction facility is shown in Table 4.15. The number of facilities chosen is only one. If the facility is not operated, the gas will be discharged through the combustion process in the flare tower.

Table 4.15 Selected BOG reliquefaction plant spesification.

Description	Value
Name	TBF-175
Reliquefaction range [t/h]	0.2
Electrical consumption [kW]	195
Dimension [m]	L ; 9.5 W ; 1.7 H ; 3

4.1.8. Gas Flaring Tower

Gas flaring is a facility where the combustion of associated gas is produced from chemical processes at the terminal. At the regasification terminal, the gas that is burned is the gas that results from the evaporation process in the tank (BOG) or the residual gas that is considered uneconomical for reprocessing. In this research, the dimensions of the flaring tower are taken from the average size of the flaring tower at similar or close terminals size. The size of the flaring tower is 4 x 4 m.

4.2. Facility Area

The process of making layouts in this study using the BLOCPLAN algorithm. The data used to create a layout using BLOCPLAN are the area of each facility and the proximity relationship between each facility. The area for each facility is searched manually by the designer taking into account the rules of the NFPA 59A. Some rules that affect the terminal layout include (NFPA 59A, 2013),

- **Table 6.3.1** The minimum distance between storage containers. Storage tanks of greater than 265 m^3. The minimum distance between storage containers is ¼ of the sum of the diameters of adjacent containers (1.5 m minimum).
- **6.3.3** A clear space of at least 0.9 m shall be provided for access to all isolation valves serving multiple containers.
- **6.3.4** LNG container of greater than 0.5 m^3 capacity shall not be located in the buildings. [6.3.4]
- **6.4.1** Vaporizers using flammable heat transfer fluids and their primary heat sources shall be located at least 15 m from any other source of ignition.
- **6.4.6** A clearance of at least 1.5 m shall be maintained between vaporizers.
- **6.5.1** Process equipment containing LNG, refrigerant, flammable liquids, or flammable gases shall be located at least 15 m from sources of ignition, a property line that can be built upon, control centers, offices, shops, and other occupied structures.
- **6.5.3** Fired equipment and other sources of ignition shall be located at least 15 m from any impounding area or container drainage system.
- **6.6.1** A pier or dock used for pipeline transfer of LNG shall be located so that any marine vessel being loaded or unloaded is at least 30 m from any bridge crossing a navigable waterway.

- **6.6.2** The loading or unloading manifold shall be at least 61 m from such a bridge.
- **6.6.3** LNG and flammable refrigerant loading and unloading connections shall be at least 15 m from uncontrolled sources of ignition, process areas, storage containers, control buildings, offices, shops, and other occupied or important plant structures unless the equipment is directly associated with the transfer operation.
- **6.7.2** Building not covered by sections 12.5 through 12.7 shall be located no less than 15 m from tanks, vessels, and gasketed or sealed connections to equipment containing LNG and other hazardous fluids.

4.2.1. Tank area

The number of tanks used in the terminal is 14 tanks, with the diameter (d) of each tank is 4.21 meter. The tanks plot used to calculate the area of the facility is shown in Figure 4.2. The distance between the tanks is 1.5 meters.

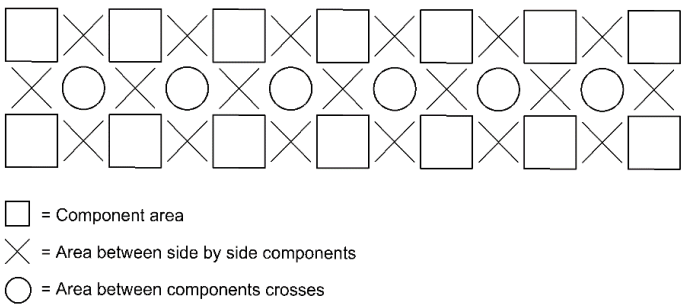


Figure 4.2 Tank plot to calculate facility area

□ = Number of tanks x d^2
= 14 x 4.21^2
= 248.14 m^2

X = Number of variables x Distance between component x d
= 19 x 1.5 x 4.21
= 119.985 m^2

O = Number of variables x (Distance between components)^2
= 6 x 1.5^2
= 13.5 m^2

Total area for tanks facility= □ + X + O
= 248.14 + 119.985 + 13.5
= 381.625 m^2

So, the area of land needed for tank facilities is 381.625 m^2.

4.2.2. Reliquefaction area

The reliquefaction facility used at the terminal is one. The dimension of the component is length; 9.5 m, width; 1.7 m, and height; 3 m. Because the number of components used is only one, the distance between components is not considered in the facility area. So the area of the facility itself is the same as the area of land required for the component.

Total facility area = Number of facility x Length x Width
= 1 x 9.5 x 1.7
= 16.15 m^2

So, the area of land needed for reliquefaction facilities is 16.15 m^2.

4.2.3. Vaporizer area

There are six vaporizers used in the terminal design with all the same specifications. The vaporizer's dimensions are length; 2.9 m, width; 2.9, and height; 10.52 m. The six vaporizers are arranged in a 3 x 2 plot as shown in Figure 4.3. Determined that the distance between components is 1.5 meters.

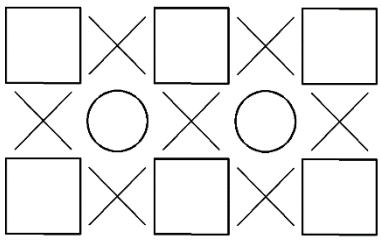


Figure 4.3 Vaporizer plot to calculate the facility area.

Then the area of the facility can be searched in the following way,

□ = Number of vaporizers x Length x Width
= 6 x 2.9 x 2.56
= 44.54 m^2

X = Number of variables x Distance between components x Length
= 7 x 1.5 x 2.9
= 30.45 m^2

O = Number of variables x (Distance between components)^2
= 2 x 1.5^2
= 4.5 m^2

Total area for the facility = □ + X + O
= 44.54 + 30.45 + 4.5
= 79.49 m^2

So, the area of land needed for vaporizer facilities is 79.49 m^2.

4.2.4. Pump area

There are two types of pumps used in terminals, high-pressure pumps and low-pressure pumps. The dimensions of the high-pressure pump used are length; 3.02 m, width; 1.19 m, and height; 1.55 m. The dimensions of the low-pressure pump used are length; 0.688 m, width; 0.272 m, and height; 0.392 m. For calculating the area needed by the pump facility, the pump placement is set as shown in Figure 4.4. Due to different pump dimensions between high-pressure pumps and low-pressure pumps, the area calculation is done by adding up the area of the two types of pumps. The distance between pumps is 1.5 meters. The area between components crosses is replaced by the area between the two types of pumps. In length following the widest pump distance.

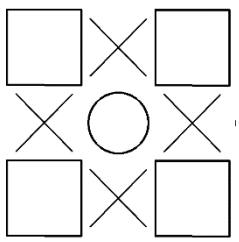


Figure 4.4 Pump plot to calculate the facility area.

□ = Number of pumps x Length x Width
= (2 x 3.02 x 1.19) + (2 x 0.688 x 0.272)
= 7.19 + 0.37
= 7.56 m^2

X_{HP} = Number of variables x Distance between components x Length
= 1 x 1.5 x 3.02
= 4.53 m^2

X_{LP} = Number of variables x Distance between components x Length
= 1 x 1.5 x 0.688
= 1.03 m^2

X_{HP-LP} = Number of variables x Distance between components x Length
= 1 x 1.5 x ((1.19 x 2) + 1.5)
= 5.82 m^2

Total area for the facility = □ + X_{HP} + X_{LP} + X_{HP-LP}
= 7.56 + 4.53 + 1.03 + 5.82
= 18.94 m^2

So, the area of land needed for vaporizer facilities is 18.94 m^2.

4.2.5. Gas flaring tower area

The gas flaring tower facility used at the terminal is one. The dimension of the component is length; 4 m and width; 4 m. Because the number of components used is only one, the distance between components is not considered in the facility area. So the area of the facility itself is the same as the area of land required for the component.

Total facility area = Number of facility x Length x Width
= 1 x 4 x 4
= 16 m^2

So, the area of land needed for gas flaring tower facilities is 16 m^2.

4.2.6. Compressor area

There are two compressors used in the terminal design with all the same specifications. The compressor's dimensions are length; 3.5 m and width; 1 m. The two vaporizers are arranged in a 1 x 2 plot as shown in. Determined that the distance between components is 1.5 meters. Because there are only two components used, there is no area between components crosses.

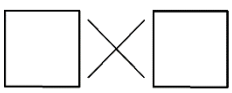


Figure 4.5 Compressor plot to calculate the facility area.

□ = Number of compressors x Length x Width
= 2 x 3.5 x 1
= 7 m^2

X = Number of variables x Distance between components x Length
= 1 x 1.5 x 3.5
= 5.25 m^2

Total facility area = □ + X
= 7 + 5.25
= 12.25 m^2

So, the area of land needed for compressor facilities is 12.25 m^2.

4.2.7. Distance between facility area

BLOCPLAN has limitations that only can process areas data. Then the distance between facilities is processed first into an area before being inputted into the BLOCPLAN algorithm. The distance between one facility to another is 15 meters. To ease calculation, the distance between facilities is divided into two and each facility is added an area with a distance between facilities 7.5 meters. Area calculation results of the distance between facilities are shown in APPENDIX C.

4.2.8. Total facility area

The total area of the facility is the sum of the component areas, the distance between facilities, and the distance between components. mathematically the total area of the facility can be written as follows,

Total area = □ + X + O + Length way area + Width way area + Corner area

The sum of the total area of the facility is shown in APPENDIX C. Tank facilities are facilities that require the largest land area, which is 1332.47 meters.

4.3. Activity Relationship Chart

To process the existing area data, the proximity relationship parameters for each facility are also needed, the data is shown in Table 4.16. In this study, the proximity relationship between facilities is inputted based on the subjectivity of the designer. The objective of the closeness rate is to bring operations-related facilities closer together to minimize the use of pipes to produce cost-effective designs.

Table 4.16 Proximity relationship matrix.

Facility	Reliquefaction	Vaporizer	Pump	Flaring tower	Compressor
Storage tank	U	U	E	X	A
Reliquefaction		U	E	U	A
Vaporizer			A	U	U
Pump				U	U
Flaring tower					E
Compressor					

There are 6 levels of value indicators used in the proximity relationship between facilities, among others,

A = 10 = Absolutely essential,
E = 5 = Essential,
I = 2 = Important,
O = 1 = Ordinary closeness ,
U = 0 = Unimportant,
X = -10 = Undesirable

4.4. Layout Making

The process of making the layout is done automatically using the BLOCPLAN algorithm. The BLOCPLAN algorithm works by processing inputs (facility area and activity relationship charts) into facility layouts. BLOCPLAN is also able to calculate the effectiveness score of each layout produced.

4.4.1. Data input

The first data needed to solve a problem with the BLOCPLAN algorithm is data about the number of departments, department names, and the area of each department. The calculated total area is entered manually into the algorithm. The maximum number of facilities that can be processed by BLOCPLAN in one work is 18 facilities. The results of the department specification data input on the BLOCPLAN software can be seen in Figure 4.6. By inputting the department's specification data it will be known what is the total area of the entire area for the departments of the terminal.

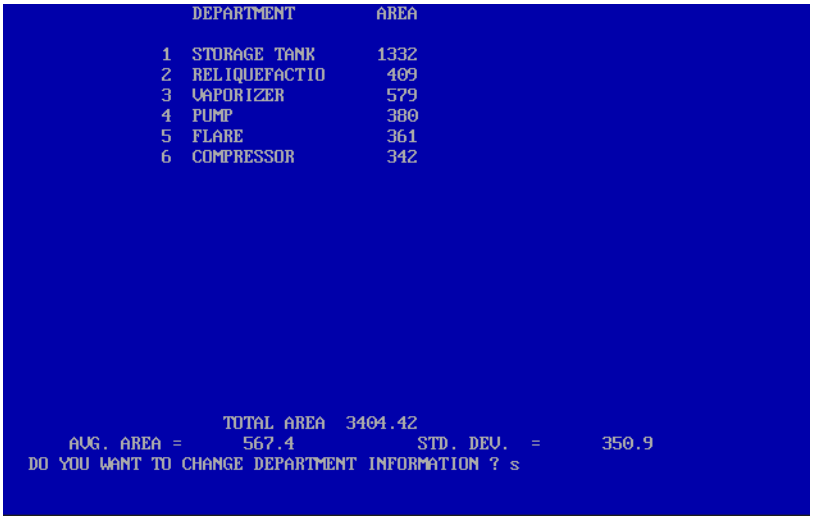


Figure 4.6 Facility area inputted.

After the area of each facility is entered, the predetermined activity relationship chart (ARC) data is also inputted manually one by one. The activity relationship chart (ARC) data that has been inputted into the algorithm is shown in Figure 4.7.

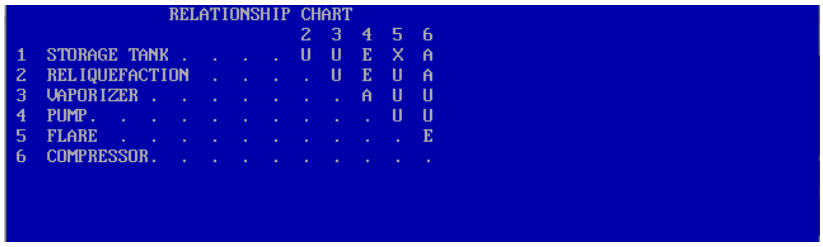
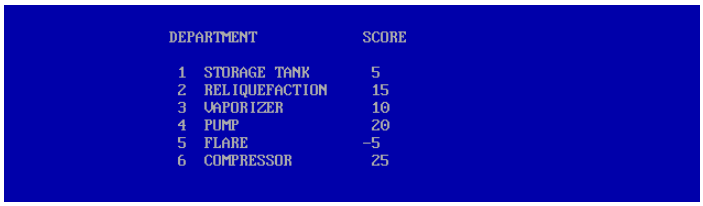


Figure 4.7 Activity relationship chart (ARC) inputted.

Each code (letter) on the linkage map above can be weighted according to the designer's wishes. The selected weight value in this research can be seen in Figure 4.8.

Figure 4.8 Linkage relationship code and weight value

Using these weights, scores can be obtained for each department. This score is the result of the ARC's processing, so that each score indicates how important the facility is to be close to other facilities that have been determined in the ARC. The score can be seen in Figure 4.9.



DEPARTMENT		SCORE
1	STORAGE TANK	5
2	RELIQUEFACTION	15
3	VAPORIZER	10
4	PUMP	20
5	FLARE	-5
6	COMPRESSOR	25

Figure 4.9 Scores for each department with the BLOCPLAN software

The next process is to enter the total area of land that is owned for terminal construction. Because in this research it is not determined how much total land is owned. Then the land area for terminal development will adjust to the land area required by the facility but the land ratio is still determined. The ratio of the length and width of the terminal land used in this research is 1:1 (SEL.3). The process of inputting the terminal land area data is shown in Figure 4.*10*.

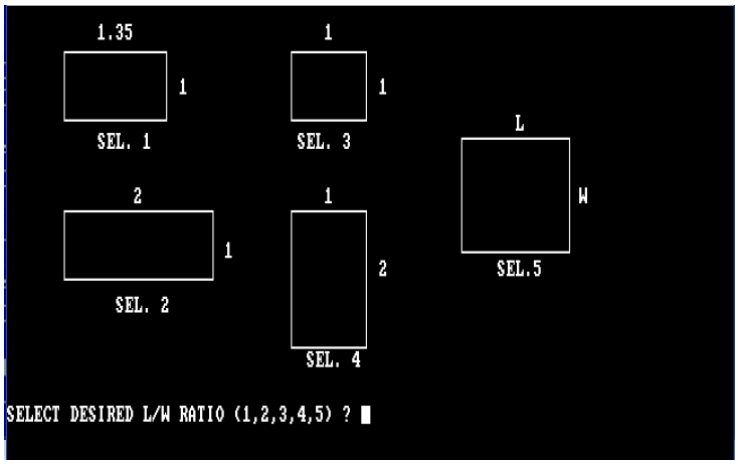


Figure 4.10 Total land area input

4.5. Result

By using land area data and proximity relationships between facilities, 15 layout designs were produced with each score as listed in Table 4.17.

Table 4.17 Layout score generated by BLOCPLAN.

Layout	Adjacency Score	R. score	Rel-dist score	Prod. movement
1	1.00	0.83	710	0
2	0.78	0.65	1053	0
3	1.00	0.81	754	0
4	0.67	0.68	938	0
5	0.89	0.58	1209	0
6	0.78	0.60	1088	0
7	0.89	0.58	1209	0
8	0.89	0.70	938	0
9	0.78	0.57	1173	0
10	0.89	0.91	524	0
11	0.67	0.58	1192	0
12	1.00	0.83	710	0
13	0.89	0.61	1132	0
14	0.89	0.83	479	0
15	0.67	0.54	1367	0

In the generating process, two suggestions are given to the algorithm. The first is storage tank location must be in the north because it considers the jetty position in the north. The second suggestion is the vaporizer position located in the south-east because it considers the distribution path to the end-user which is closer from that direction.

4.5.1. Layout ranking

In the process of ranking the layout, each criterion is given a different score weight. Adjacency score has a weighted value 0.1 of the total score, R.Score has a weighted value 0.3 of the total score, and the Rel-Dist score has a weighted value of 0.6 of the total score. The determination of the value weight for each criterion is done based on the subjectivity of the designer by considering several things. One example of consideration is the weighting of the value 0.6 for the Rel-Dist score because the Rel-Dist score represents the distance between one facility and another. The greater the Rel-Dist score, the longer the pipe required, so that the terminal design becomes economically less efficient.

The data properties of the three criteria (Adjacency score, R.Score, and Rel-Dist score) also differ. R.Score and Adjacency score have the same properties where the range of values ranges from 0 to 1, and the best score is indicated by the highest score. However, the Rel-Dist score has different properties, where the value ranges from zero to infinity and the best score is close to zero. Therefore, to find the total score, the properties of the Rel-Dist score are first changed using the AHP method.

AHP has a relationship criteria index that ranges from 1 to 9. where each index has the following meanings;

- 1 ; Equal
- 3 ; Moderate
- 5 ; Strong
- 7 ; Very strong
- 9 ; Extreme

In this research, the scoring system for the relationship between one value and another is carried out with the following formula;

$$\text{Score index} = \frac{\text{B - A}}{\text{Highest Rel-Dist score - Lowest Rel-Dist score}/9}$$

Note; B = Rail-Dist score from the layout on row
A = Rail-Dist score from the layout on column

The pairwise comparisons of the entire layout are shown in Table 4.18.

Table 4.18 Pairwise comparisons.

		ROW														
	Layout	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
COLUMN	**1**		3.48	0.45	2.31	5.06	3.83	5.06	2.31	4.69	-1.89	4.89	0.00	4.28	-2.34	6.66
	2			-3.03	-1.17	1.58	0.35	1.58	-1.17	1.22	-5.36	1.41	-3.48	0.80	-5.82	3.18
	3				1.86	4.61	3.39	4.61	1.86	4.25	-2.33	4.44	-0.45	3.83	-2.79	6.21
	4					2.75	1.52	2.75	0.00	2.38	-4.20	2.57	-2.31	1.97	-4.65	4.35
	5						-1.23	0.00	-2.75	-0.36	-6.94	-0.17	-5.06	-0.78	-7.40	1.60
	6							1.23	-1.52	0.86	-5.72	1.05	-3.83	0.45	-6.17	2.83
	7								-2.75	-0.36	-6.94	-0.17	-5.06	-0.78	-7.40	1.60
	8									2.38	-4.20	2.57	-2.31	1.97	-4.65	4.35
	9										-6.58	0.19	-4.69	-0.42	-7.03	1.97
	10											6.77	1.89	6.16	-0.46	8.54
	11												-4.89	-0.61	-7.23	1.77
	12													4.28	-2.34	6.66
	13														-6.62	2.38
	14															9
	15															

A positive result indicates that the column layout is better than the row layout. Conversely, a negative result indicates that the layout on the rows is better than the layout on the columns. For results that have a value ranging from -1 to 1 then all are converted to 1. Because the expert choice program can only process indexes ranging from 1 to 9. So the data inputted to the expert choice is shown in Figure 4.11

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1		3.48	1.0	2.31	5.06	3.83	5.06	2.31	4.69	1.89	4.89	1.0	4.28	2.34	6.66
2			3.03	1.17	1.58	1.0	1.58	1.17	1.22	5.36	1.41	3.48	1.0	5.82	3.18
3				1.86	4.61	3.39	4.61	1.86	4.25	2.33	4.44	1.0	3.83	2.79	6.21
4					2.75	1.52	2.75	1.0	2.38	4.2	2.57	2.31	1.97	4.65	4.35
5						1.23	1.0	2.75	1.0	6.94	1.0	5.06	1.0	7.4	1.6
6							1.23	1.52	1.0	5.72	1.0	3.83	1.0	6.17	2.83
7								2.75	1.0	6.94	1.0	5.06	1.0	7.4	1.6
8									2.38	4.2	2.57	2.31	1.97	4.65	4.35
9										6.58	1.0	4.69	1.0	7.03	1.97
10											6.77	1.89	6.16	1.0	8.54
11												4.89	1.0	7.23	1.77
12													4.28	2.34	6.66
13														6.62	2.38
14															9.0
15	Incon: 0.02														

Figure 4.11 Pairwise Comparisons

After the judging process is carried out, the priority results are obtained for each type of layout. The inconsistency of the result of the process is 0.02 and the judgment process is carried out completely with 0 missing judgments. The result of the judging process is shown in Figure 4.12.

Figure 4.12 Priorities derived from pairwise comparisons

So now the properties of the overall score are the same where the higher the score indicates the better result. Furthermore, the total score for each criterion is added up. Then each score from each layout is divided by the total score of each criterion to get interval data with a total score equal to 1. After that, each score is multiplied by the weighted score for each criterion. Finally, the scores for each layout are added up for the ranking process. The results of the ranking process can be seen in Table 4.19 and the layout with the highest score is layout 14.

Table 4.19 Layout Ranking

							Weighted Score				
							0.1	0.3	0.6		
Layout	**ADJ. Score**	**R. Score**	**Rel-Dist Priorities Score**	**ADJ.Score / ΣADJ.Score**	**R.Score / ΣR.Score**	**Rel-Dist Score / ΣRel-Dist Score**	**ADJ.Score**	**R.Score**	**Rel-Dist**	**TOTAL**	**RANK**
1	1.00	0.83	0.108	0.07880	0.08058	0.10789	0.00788	0.02417	0.06474	0.09679	3
2	0.78	0.65	0.050	0.06147	0.06311	0.04995	0.00615	0.01893	0.02997	0.05505	8
3	1.00	0.81	0.089	0.07880	0.07864	0.08891	0.00788	0.02359	0.05335	0.08482	5
4	0.67	0.68	0.051	0.05280	0.06602	0.05095	0.00528	0.01981	0.03057	0.05566	7
5	0.89	0.58	0.023	0.07013	0.05631	0.02298	0.00701	0.01689	0.01379	0.03769	12
6	0.78	0.60	0.030	0.06147	0.05825	0.02997	0.00615	0.01748	0.01798	0.04160	9
7	0.89	0.58	0.023	0.07013	0.05631	0.02298	0.00701	0.01689	0.01379	0.03769	12
8	0.89	0.70	0.051	0.07013	0.06796	0.05095	0.00701	0.02039	0.03057	0.05797	6
9	0.78	0.57	0.025	0.06147	0.05534	0.02498	0.00615	0.01660	0.01499	0.03773	11
10	0.89	0.91	0.180	0.07013	0.08835	0.17982	0.00701	0.02650	0.10789	0.14141	2
11	0.67	0.58	0.024	0.05280	0.05631	0.02398	0.00528	0.01689	0.01439	0.03656	14
12	1.00	0.83	0.108	0.07880	0.08058	0.10789	0.00788	0.02417	0.06474	0.09679	3
13	0.89	0.61	0.027	0.07013	0.05922	0.02697	0.00701	0.01777	0.01618	0.04096	10
14	0.89	0.83	0.198	0.07013	0.08058	0.19780	0.00701	0.02417	0.11868	0.14987	1
15	0.67	0.54	0.014	0.05280	0.05243	0.01399	0.00528	0.01573	0.00839	0.02940	15
ΣSUM	**12.69**	**10.30**	**1.001**								

4.5.2. Layout 14

layout 14 is the layout with the highest total score, which is 0.14987. The plot plan of each facility in layout 14 is shown in Figure 4.13. Specifically, the scores for layout 14 are as follows;

Lower bound ; 171.951
Upper bound ; 1963.002
R. Score ; 0.83
Rel-Dist score ; 479.3468
Adj. Score ; 0.89

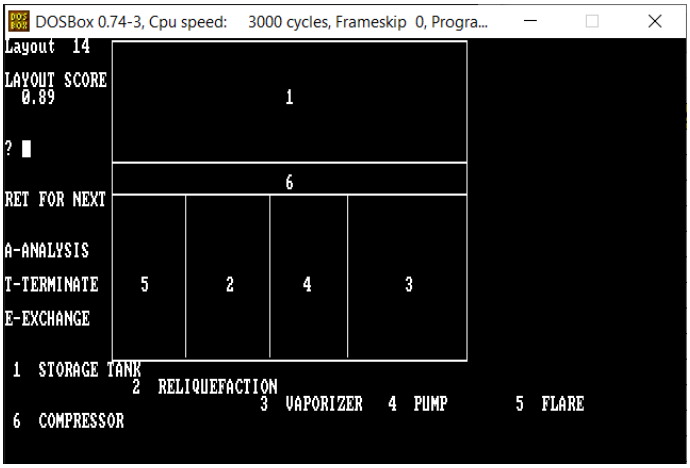


Figure 4.13 Plot plan of layout 14.

4.6. 3D Design of Terminal

By using data that has been obtained from the previous calculation process, the 3D design of the previous regasification terminal can be made. The terminal designing process uses the SketchUp application as a designing medium. The overall appearance of the terminal design is shown in Figure 4.14. For other terminal the viewpoint is shown in APPENDIX B.

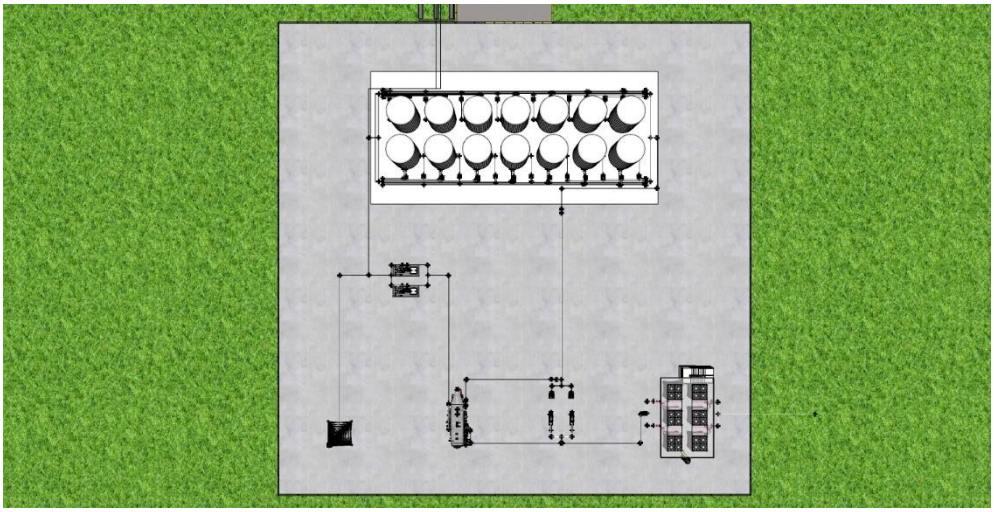


Figure 4.14 Top view of the terminal.

CHAPTER V
CONCLUSION

5.1. Conclusion

Based on the data analysis and discussion that has been carried out in this study regarding the designing of LNG regasification terminal, conclusions can be drawn from the results obtained as follows:

1. To meet the gas needs of 2,524.14 MMSCFD per year. Then used the AP460 LNG carrier ship with a capacity of 4.080 m^3 to supply gas to the terminal. The tank used in the terminal is LC318V42 with each capacity is 295.75 m^3, the total tanks used in the terminal are 14 tanks. And to meet the daily gas consumption of 6,915 MMSCFD, vaporizer with regas power of 2,900 m^3/h is used for a total of 6 vaporizers. To distribute gas in the regasification process, 2 types of pumps are used, low-pressure pumps and high-pressure pumps. The high-pressure pump used has a capacity of 8-18.7 m^3/h with a maximum working pressure of 120 bar and the low-pressure pump used has a maximum capacity of 18 m^3/h with a maximum working pressure of 23 bar. And to reprocess the formed Boil-off-gas of 1.39 mt/day, the TBF-175 model of the Reliquefaction plant was used with a power range of 0.2 mt/h. A compressor model TS2 / 130-E2 with a capacity of 160 m^3/h and a working pressure of 1.08-7 bar is also used to compress the Boil-off-gas.

2. The BLOCPLAN algorithm requires 3 main data to process facility layouts, There is the area for each facility in the terminal, the activity relationship chart (ARC) of one facility with another facility, and the area of land for terminal construction. BLOCPLAN will process the three data into facility layout recommendations along with the results of their scoring (Adjacency score, R. Score, and Rel-dist score).

3. From a total of 14 layout designs produced by the BLOCPLAN algorithm. Layout 1 is the best choice among others. Layout 15 has an adjacency score of 0.89 from a maximum score of 1, R. score of 0.83 from a maximum score of 1, and a Rel-dist score of 479 with the best score index close to zero.

5.2. Recommendation

Based on the analysis of BLOCPLAN application to design the LNG regasification terminal layout, the following recommendations can be submitted by the author for future research:

1. The future development of the algorithm can be expanded again by adding functions from other crucial aspects of assessment (e.g safety, environment, etc).
2. For future research, it is recommended to consider the topology of the land on which the terminal is built, because the impact is very significant on the terminal design.

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ATTACHMENT

APPENDIX A
Technical Data Sheet of Equipment

WSD50 5K

5,000m³ LNG Carrier

DATASHEET

Design highlights

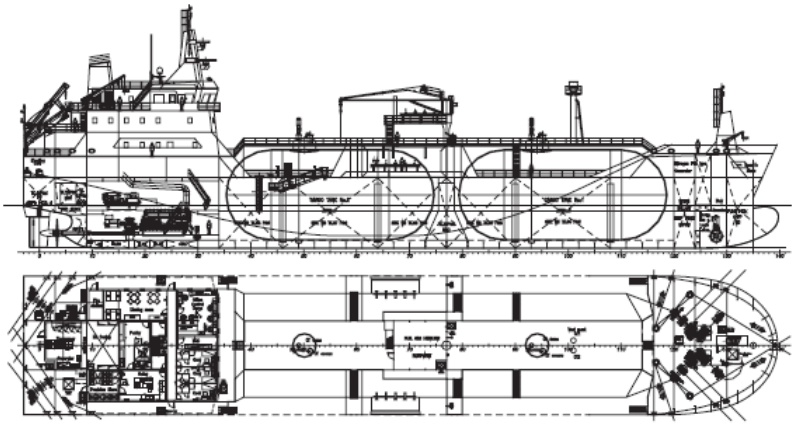
- Latest Dual Fuel Engine technology:
  - reduces emissions in LNG operation: SOx (100%), CO_2 (20%), NOx (80%)
  - compliant with MARPOL Tier III in gas mode
- Vessel is fueled by natural BOG and forced vaporizing
- Long flat side to satisfy terminal request for dolphin mooring
- Elevated LNG manifold - optional
- High manoeuvrability
- Over 40 years experience in merchant market and leading experts in LNG
- Core competence of Gas Handling Systems within Wärtsilä Ship Design Team

SPECIFICATION IN BRIEF

Length over all	99.9 m
Draught, design	5.00 m
Draught, maximum	5.20 m
Gross tonnage	5,580
Net tonnage	1,680
Deadweight, max	3,350 t
Service speed	14.0 knots
Operation area	"Worldwide"

M/E fuel consumption
(@Td, Service speed, 75% MCR, 15% SM)

Gas mode - LNG cons	13.7 t/day
Diesel mode - MDO cons	15.8 t/day



TECHNICAL SPECIFICATION

MAIN DIMENSIONS

Length over all	99.99 m
Length PP	94.50 m
Breadth moulded	12.20 m
Depth moulded, to upper deck	9.30 m
Draught, design	5.00 m
Draught, max	5.20 m
Deadweight, des draught	3,050 t
Deadweight, des draught	3,350 t

SPEED & ENDURANCE

Design speed (Td) (Td,@90%MCR, 15%SM)	14.0 kts
Max. speed (Td, @100%MCR)	14.5 kts
Endurance, service speed (LNG)	5,100 nm
Endurance, service speed (MDO)	3,350 nm

CAPACITIES

LNG (incl. 475m³ fuel) (cylindrical type C, 2x2550m³, 4.5bar)	5,100 m³
MDO (incl. 550m³ as cargo)	180 m³
BW	1,700 m³
FW	50 m³

CARGO EQUIPMENT

- Deepwell pumps 2x400m³/h
- Cargo heating/vaporising equipment
- Nitrogen Generator Unit Unit 2000 Nm³/h
- Boil of Gas Management options:
  - Gas Combustion Unit or
  - DF boiler or
  - Reliquefaction unit
- Fuel gas handling system
- Set of STS transfer equipment incl. LNG flexible hoses, Yokohama fenders, emergency release coupling etc. for STS operations – optional;

FUEL CONSUMPTION
(service speed, design draft, 15% SM)

Fuel consumption, (-S/G), LNG	13.7 t/d
Fuel consumption, (-S/G), MDO	15.8 t/d
Fuel consumption, (+S/G), LNG	13.9 t/d
Fuel consumption, (+S/G), MDO	16.0 t/d

ACCOMMODATION

- 18 persons in single cabin, fully air-conditioned

PROPULSION / MACHINERY

- 4-stroke Wärtsilä Dual Fuel Main Engine 1 x 4,000 kW 8L34DF
- 4-stroke Wärtsilä Generating sets 2 x 1,065 kWe 6L20DF
- Shaft Generator (PTO) 400 kWe
- 1 CP Propeller, dia. 4.00m
- 1 Reduction gear with output for PTO
- PTI 1 x 400kWe
- 1 x Emergency diesel generator, 150kW
- 1 x Bow thruster 550kW

CLASSIFICATION

DNVGL (or equivalent IACS) +1A Tanker for liquefied gas, Ship type 2G (-163°C,0.50 t/m²,4.5 barg), E0, Gas fueled.

Recommended additional notations: ICE class up to 1A*, Gas bunker, RP-1 (20%), NAUT-OC, BWM-T, CLEAN, TMON, BIS

WSD50 7.5K
7,500m³ LNG Carrier

DATASHEET

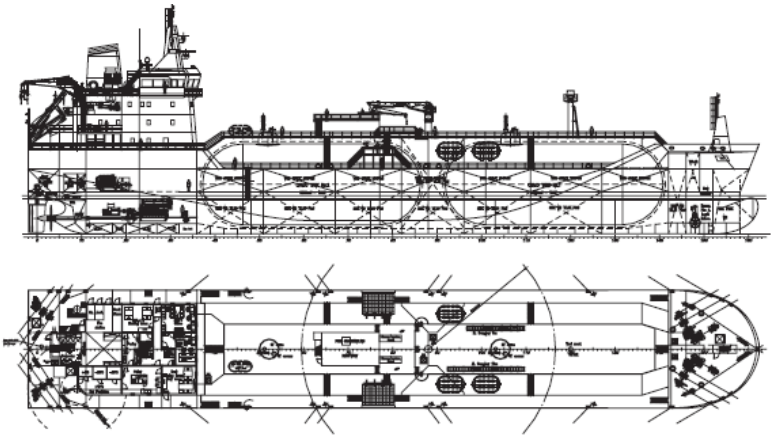
Design highlights

- Latest Dual Fuel Engine technology:
  - reduces emissions in LNG operation: SOx (100%), CO_2 (20%), NOx (80%)
  - compliant with MARPOL Tier III in gas mode
- Vessel is fueled by natural BOG and forced vaporizing
- Long flat side to satisfy terminal request for dolphin mooring
- Elevated LNG manifold - optional
- High manoeuvrability
- Over 40 years experience in merchant market and leading experts in LNG
- Core competence of Gas Handling Systems within Wärtsilä Ship Design Team

SPECIFICATION IN BRIEF

Length over all	115.1 m
Draught, design	5.50 m
Draught, maximum	6.00 m
Gross tonnage	6,850
Net tonnage	2,283
Deadweight, max	4,100 t
Service speed	13.5 knots
Operation area	"Worldwide"

M/E fuel consumption (@Td, Service speed, 75% MCR, 15% SM)	
Gas mode - LNG cons	8.4 t/day
Diesel mode - MDO cons	10.4 t/day



TECHNICAL SPECIFICATION

MAIN DIMENSIONS

Length over all ..... 115.10 m
Length PP ..... 110.60 m
Breadth moulded ..... 18.60 m
Depth moulded, to upper deck ..... 10.15 m
Draught, design ..... 5.50 m
Draught, max ..... 6.00 m
Deadweight, des draught ..... 3,800 t
Deadweight, des draught ..... 4,100 t

SPEED & ENDURANCE

Design speed (Td) ..... 13.5 kts
(Td,@90%MCR, 15%SM)
Max. speed (option) ..... 15.7 kts
(Td, @100%MCR, PTI boost option)
Endurance, service speed (LNG) ..... 5,650 nm
Endurance, service speed (MDO) ..... 8,000 nm

CAPACITIES

LNG (incl. 475m³ fuel) ..... 7,500 m³
(cylindrical type C, 2x3750m³, 4.5bar)
MDO (incl. 550m³ as cargo) ..... 400 m³
BW ..... 2,900 m³
FW ..... 150 m³

CARGO EQUIPMENT

- Deepwell pumps 2x500m³/h
- Cargo heating/vaporising equipment
- Nitrogen Generator Unit Unit 220 Nm³/h
- Boil of Gas Management options:
  - Gas Combustion Unit or
  - DF boiler or
  - Reliquefaction unit
- Fuel gas handling system
- Set of STS transfer equipment incl. LNG flexible hoses, Yokohama fenders, emergency release coupling etc. for STS operations – optional;

FUEL CONSUMPTION

(service speed, design draft, 15% SM)
Fuel consumption, (-S/G), LNG ..... 8.4 t/d
Fuel consumption, (-S/G), MDO ..... 10.4 t/d
Fuel consumption, (+S/G), LNG ..... 8.5 t/d
Fuel consumption, (+S/G), MDO ..... 10.6 t/d

ACCOMMODATION

- 18 persons in single cabin, fully air-conditioned

PROPULSION / MACHINERY

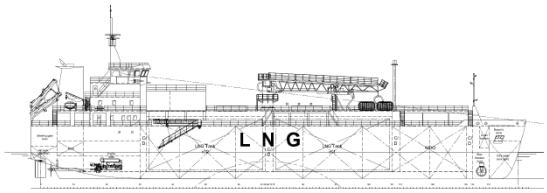
- 4-stroke Wärtsilä Dual Fuel Main Engine 1 x 3,000 kW 6L34DF
- 4-stroke Wärtsilä Generating sets 2 x 1,065 kWe 6L20DF
- Shaft Generator (PTO) 1,000 kWe
- 1 CP Propeller, dia. 4.00 m
- 1 Reduction gear with output for PTO - PTI 1 x 1,000kWe (PTI suitable for boost power) - optional
- 1 x Emergency diesel generator 150kW
- 1 x Bow thruster 550 kW

CLASSIFICATION

DNVGL (or equivalent IACS) +1A Tanker for liquefied gas, Ship type 2G(-163°C,0.50 t/m³,4.5 barg), E0, Gas fueled.

Recommended additional notations: ICE class up to 1A*, Gas bunker, RP-1(20%), NAUT-OC, BWM-T, CLEAN, TMON, BIS

4,000 m³ Bunker Vessel



Main Dimensions :

Length overall	90 m
Length between perpendiculars	86.8 m
Breath, moulded	15.7 m
Depth, at main deck	9.4 m
Depth, at trunk deck	12.1 m
Draft, Design	abt. 4.72 m
Draft, Ballast	abt. 2.96 m
Deadweight, at design draft	2 820 tons
Gross tonnage	abt. 3 870 UMS

Cargo Tanks :

2 Membrane cargo tanks, GTT – Mk III Flex

LNG Cargo Capacity (100%)	4 080 m³
Boil-Off-Rate	0.31 % per day
2 MDO Cargo tank, Total Capacity	940 m³

Other Tank Capacities :

Ballast water	2 320 m³
Marine Diesel Oil	87 m³
Fresh water	40 m³

Speed / Range :

Speed, at design draft, 90% MCR, 15% SM	12.5 knts
Range, at design draft (DO fuel only)	abt. 1 200 nm

Classification :

BV, LR, DNV, ABS, CCS or equivalent
+1A1 Tanker for Liquefied Gas,
Ship type 2G, Clean Design, Gas fuelled

Machinery :

Dual Fuel Mechanical Propulsion System	2 x 8L20 DF or equivalent
Two Propellers, Controllable pitch type	Diam. approx. 2.5 m
1 Generator Set	Abt 250 KW

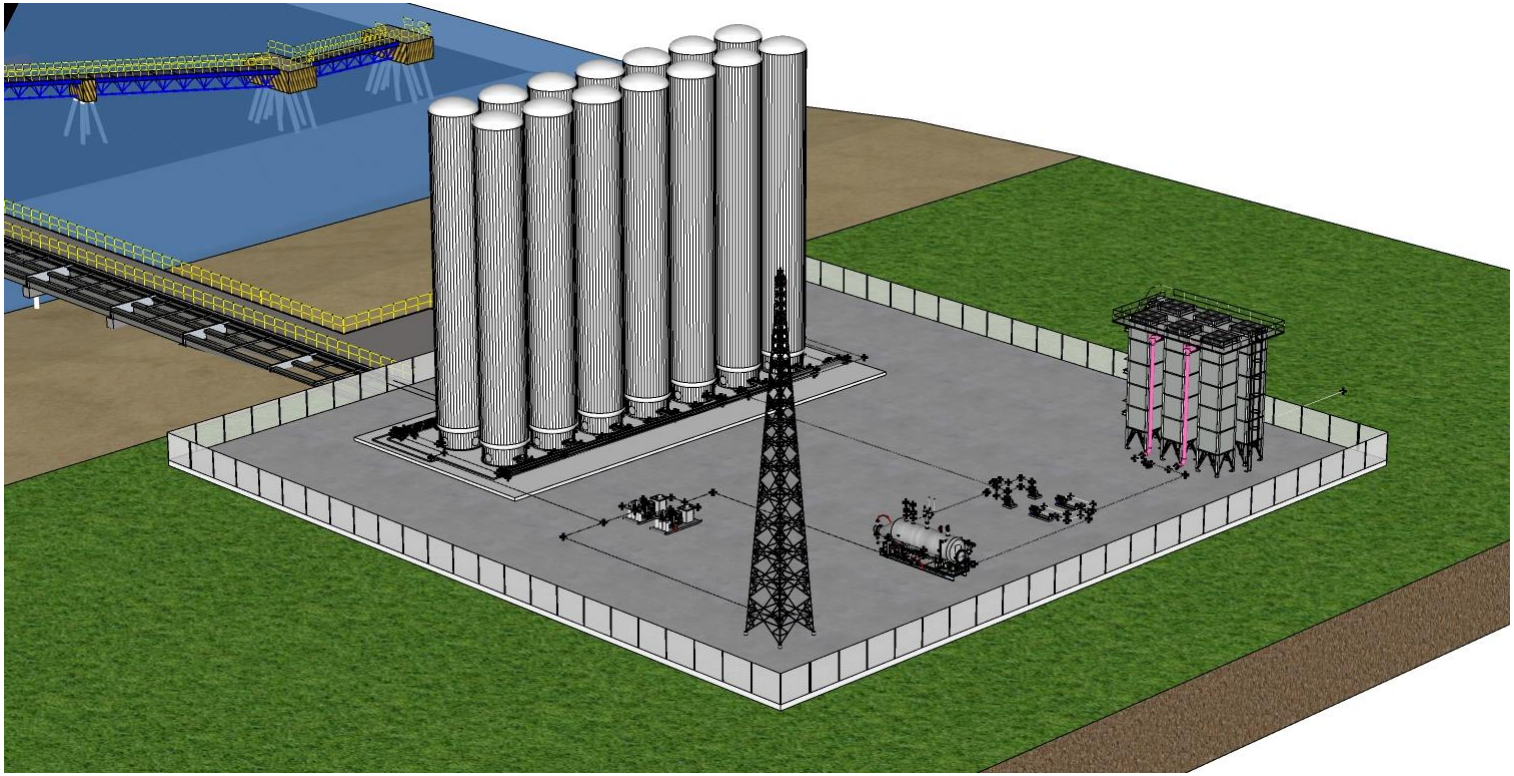
Cargo Equipment :

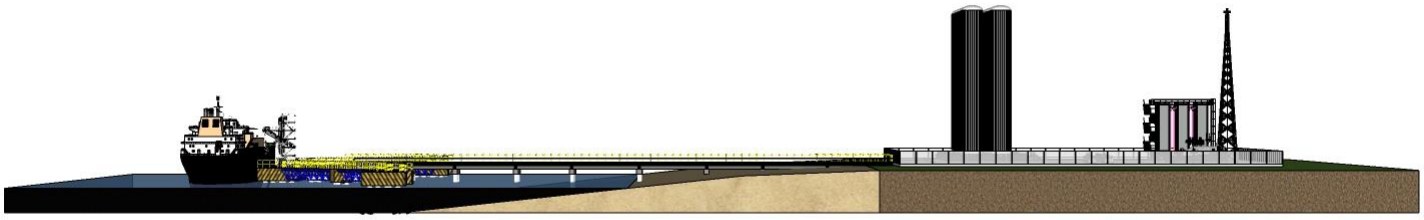
Main LNG pumps (2 per tank)	450 m³/h each
Stripping/Spray Pumps	2 x 20 m³/h
Fuel Pumps	2 x 1 m³/h
Emergency pump	1 x 150 m³/h
Manifold	L – V – L 8"
HD BOG compressor	2 x 4 500 m³/h
LD BOG Compressor	2 x 500 m³/h
Reliquefaction Unit (option)	6 tons/day
LNG transfer system + LNG metering system	
Main MDO pumps (1 per tank)	200 m³/h

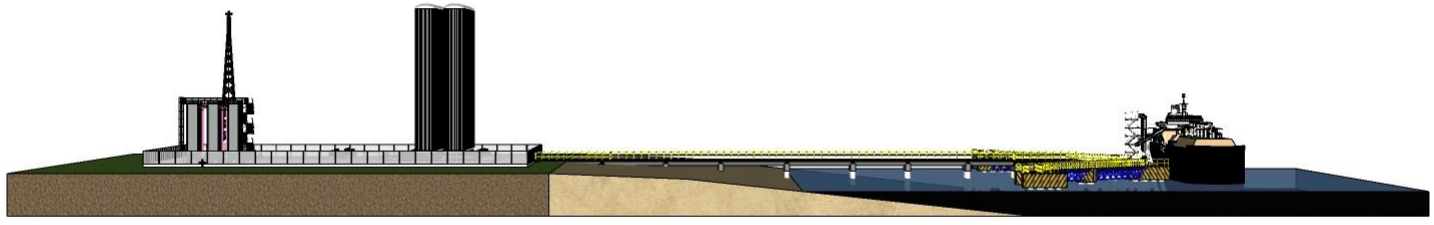
Other Ship 's Equipments

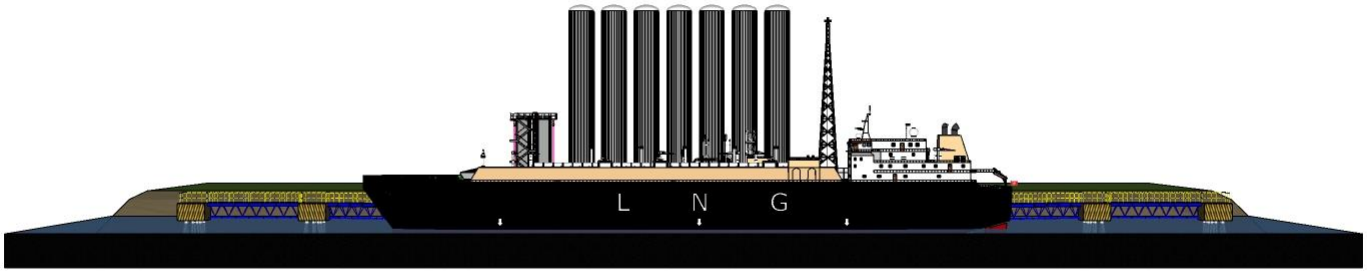
Bow thruster	400kW
Rudders	2 x Flap Type
Ballast pumps	2x 150 m³/h
Life-saving for 15 persons :	Lifeboats : 1 Free-fall
	1 Rescue boat
Provision & Machinery crane	1 x 2 t SWL
Accommodation	12 persons / 10 cabins

APPENDIX B
Terminal Viewpoint





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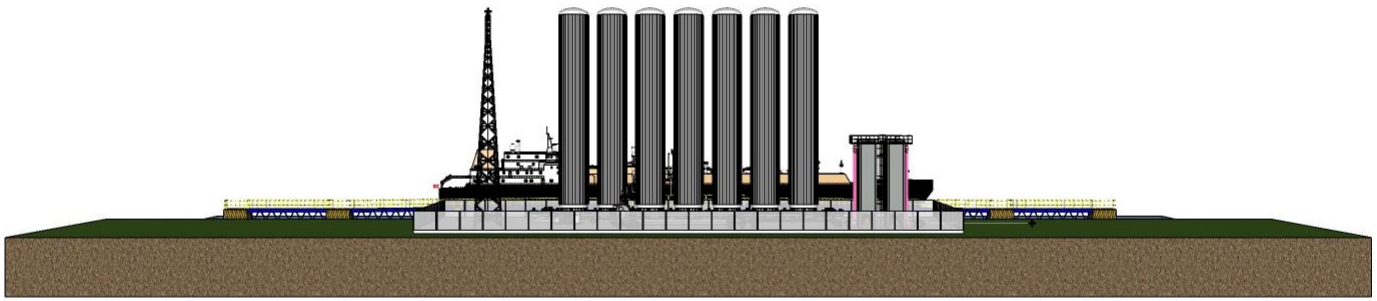

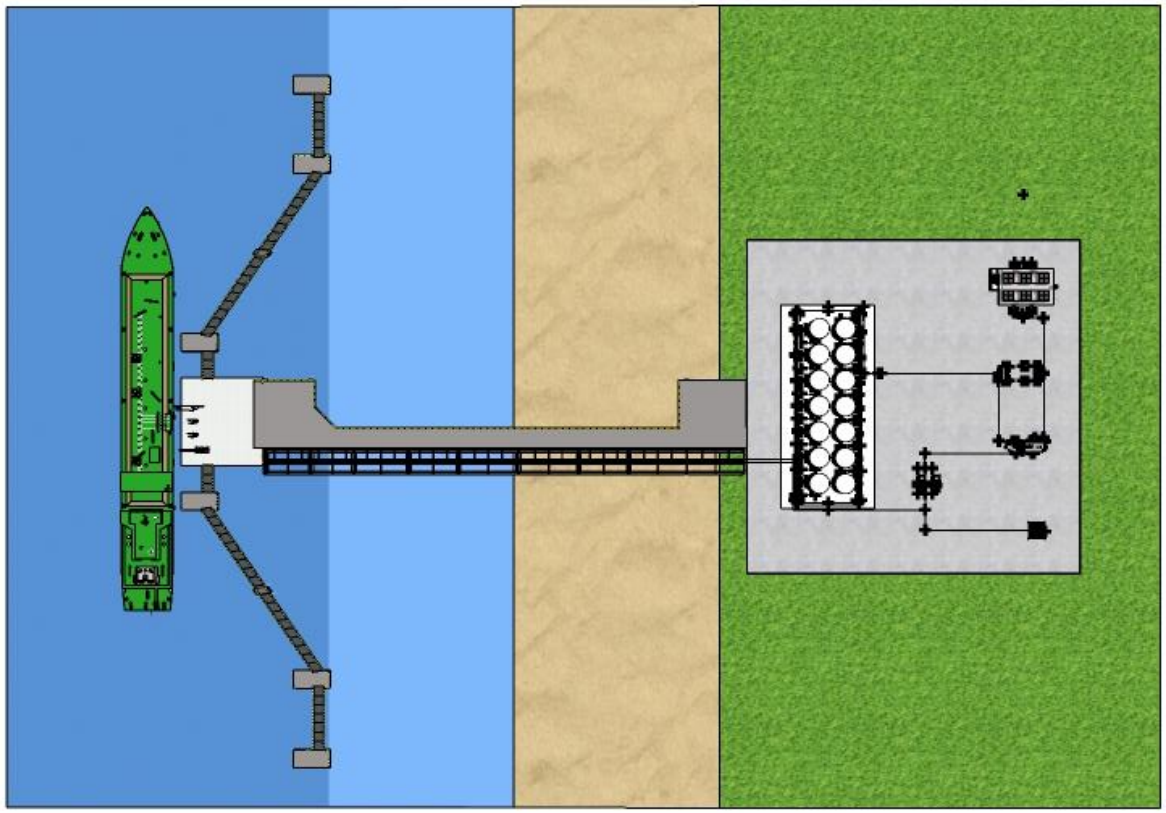

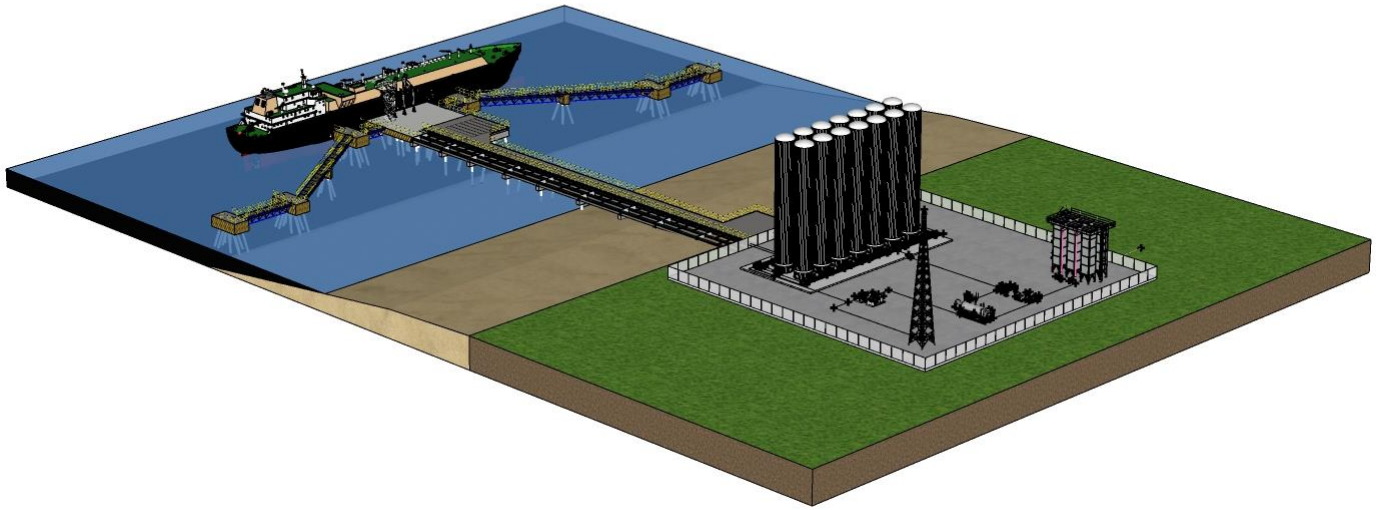

APPENDIX C
Total Facility Area

Description	Storage Tank	Reliquefaction	Vaporizer	Pump	Gas Flaring Tower	Compressor
Number of facilities	14	1	6	4	1	2
Each component area	17.72	16.15	7.42	3.78	16	3.5
Total component area	248.14	16.15	44.54	7.56	16	7
Area between side by side components	119.985	0	30.45	11.38	0	5.25
Area between components crosses	13.5	0	4.5	0	0	0
Length way component	7	1	3	2	1	2
Width way component	2	1	2	2	1	1
Length way area	577.05	142.50	175.50	58.20	60	52.50
Width way area	148.8	25.5	99.3	78.12	60	52.50
Corner area	225	225	225	225	225	225
Total area	**1332.47**	**409.15**	**579.29**	**380.26**	**361**	**342.25**

AUTHOR BIOGRAPHY

Born in Aceh on October 19, 1998, Zaki Ulfauzi spent his formative years in his hometown, attending MIN 1 Banda Aceh from 2004 to 2010, then moved to Junior High School 19 Percontohan Banda Aceh, and received education in Senior High School Modal Bangsa Aceh in 2013. He graduated in 2016 and pursued a Bachelor's Degree in Engineering at the Marine Engineering Department of Sepuluh Nopember Institute of Technology from 2016 to 2020. During the period of his study, he gained interest in the Maritime industry especially in subjects that intersect with the business and energy sector. He experienced an internship in PT. Industri Kapal Indonesia (2018) and PT. Biro Klasifikasi Indonesia (2019). In his fourth year, he became a member of the Marine Reliability and Safety Laboratory, and implement a computer algorithm as a designing method for his final project. In the meantime, he was (and still is) actively involved in the local economic discussion and reading books about the economy and self-improvement.

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