

Study On Estimation of Cargo Hold Ship Construction Container 100 TEUS With Mathematical And 3D Modelling Method Autodesk Inventor

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Abstract— Estimate the ship's weight steel is very important before pre-design. This is useful to ensure that the ship's weight does not exceed the basic design requested by the owner. 3D modeling is made in order to shorten the work time and produce a more precise calculation of the weight of the ship compared using mathematical calculations. The study compares the ship weight by using a mathematical method and using the 3D modelling method using autodesk inventor software. The result of the estimation of the weight of the ship's steel cargo hold construction using 3D modelling method for the block system. It was found that the calculation of the weight of steel using the autodesk inventor method has a fairly good difference with the mathematical method. Calculation with 3D modelling autodesk inventor has a total steel weight of 255,077 tons and 259,868 tons for the mathematical method. The difference in autodesk inventor result is 4,791 tons or 1,84% less than the ship's weight steel mathematical method. The result of the ship's steel weight being smaller due to several factor that are not included in 3D modelling and the completeness of drawing, because the more detailed the modeled drawing, will be smaller the difference in the ship's weight steel produced. Total estimation cost of the modeled cargo holds grandblock with matematical methods Rp.2.235.543.621. while the total cost of using 3D modelling autodesk inventor Rp.2.298.621..

Keywords— Autodesk Inventor, Ship Steel Weight, 3D Ship Modelling..

I. INTRODUCTION

Ships as a mode of sea transportation are one of the most promising commercial segments in Indonesia's shipping industry.

Estimating the weight of the ship's steel construction is crucial for the time function of a task since it allows the shipyard to choose the right capacity crane for the assembly of ship hulls block by block. Cost estimates must be known before to beginning a project in order to simplify the budget and maximize project effectiveness. Because 3D modeling may provide more accurate ship designs, it is intended to simplify and shorten production time.

Software like Ship Constructor, Maxsurf, Autoship, and tribal can be used for 3D ship construction modeling needs Ship designers utilize these programs to help with the process of designing ships. However, there are still certain flaws in this software. The file format of the drawing results, the definition of databases, and the complexity of these software's database files are some of the problems. The software is divided into additional software according to whatever section of the construction will be represented, which further complicates the design process flow. The 3D design must then be updated using the Autodesk Inventor software. A CAD program called Autodesk Inventor is built on a three-dimensional solid model and is intended to meet the needs of mechanical product design and depiction [1]. Grandblock models, which are currently 2D data, may be easily converted into 3D shapes by combining individual frames using the software

Autodesk Inventor. These speeds up the design process for 3D modeling.

In this study, the ship design utilized as a reference is Container 100 Teus, and the 3D modeling is based on blocks in accordance with the shipbuilding system employed at a shipyard. Only the cargo hold construction of the ship is calculated. The blocks, specifically blocks B-6-1 to B-9-2, are designed in Container 100 Teus.

The results of the 3D modeling comparison were found to be 255.077 tonnes for Autodesk Inventor and 259.868 tonnes for the mathematical method. 1.84% more different in comparison. It is clear that modeling with Autodesk Inventor generates quite accurate results, but the price of 4,809 tons is still significant when used in production. To reduce the disparity, a point of things must be taken into account. For instance, Autodesk Inventor 3D program proficiency and accuracy, excluding welding elements, and drawing completeness. After estimating the ship's weight steel construction, the following step is to calculate the expected cost of ship production. The most crucial challenges is calculating the cost of production. Because you must be aware of the costs involved in the production of a product. In order for the owner to accurately calculate the initial investment and operating expenditures [2]. The estimated cost for the ship-building process using the mathematical method is IDR 2,235,542,621, and the estimated cost for 3D modeling is IDR 2,298,119,621, resulting in a disparity of 2.72%.

A. Shipbuilding

Shipbuilding is a sector of the construction industry where raw materials (such as steel, fiberglass, and wood) are transformed into finished goods like ships, offshore structures, and other floating structures. In addition, a shipyard is a location where ships are constructed or repaired. A specific kind of shipyard known as new building orientation constructs new ships in accordance with the owner's requirements. A multi-functional shipyard is how new construction, and repairs are

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oriented, which entails both the construction of new ships and their repair and modification [3]. In general, the process of building ships in a shipyard employs a block-by-block approach, with the blocks being assembled to form a grand block. Therefore, it is essential to ascertain the projected weight of the ship's steel so that the shipyard can be built with precision.

B. Container Ship Building Process

A container ship is a ship designed specifically to transport containers. It possesses a cell for storing the container. Cargo is loaded onto the ship at the container port using a crane or specialized crane that could be used quickly, finely, and at wharves [4].

Basically, the ship consists of construction components which are located transversely and elongated. From both main systems this is then known combination system (combination / mixed framing system). A ship can be made with a transverse system, or only certain parts (engine room / recesses) are made with a transverse system while the main part with a longitudinal system or a combination. System selection for ship construction is determined by measuring ship (in this case the length in relation with the need for longitudinal strength), the type/function of the ship makes the basis for considerations other.

According to the system, the shipbuilding process is separated into three steps, namely:

- The section system is a method of building ships in which the ship's hull is constructed from a sectional perspective.
- The section block system is a method of building ships in which the components that make up the ship's hull are created or assembled as sections to create section blocks.
- The block system is a method for building ships in which the hull is separated into many blocks, which are then completed (including the piping system) and ready for use.

Designing, fabrication, assembly (assembling), erection, launch, test, and delivery are all stages in the construction of a ship [6].

C. Ship Steel Construction Weight Estimation

Estimated weight of ship steel construction LWT (Light Weight Ship) is the weight of the empty ship, meaning that the weight of the ship's steel is only calculated based on the ship's steel components, the weight of the machinery, and the weight of the ship's equipment. DWT (Dead Weight Tonnage) is the total weight of the cargo that can be carried by the ship. DWT consists of the amount of cargo such as fuel, fresh water, lubricants, food stuff, auxiliary oil, amount crew, and payload. DWT percentage for payload is 90% of the total DWT. If DWT and LWT are combined, then it can be referred to as Displacement [7]. If displacement multiplied by the specific gravity of water, you will find the total weight of the ship. The weight of the ship's structure is denoted by W_{st} including the weight of the hull and the weight of the superstructure, although not all of the ship is made of steel.

In this study, several methods were used as a comparison to existing models. The method used is a mathematical method and design method 3D CAD modeling.

D. 3D Design Modelling

CAD is an abbreviation for Computer Aided Design, which is often used in computer-based devices to assist technical designers, architects, or professional designers who deal a lot with design tasks [8].

In CAD, solid models help us visualize parts and assemblies so that we can assemble them realistically. Additionally, 3D modeling has attributes like mass, volume, gravity center, surface area, etc.

E. Material Requirement Planning (MRP)

MRP is a logical and easy approach method to solving problems related to determining the requirement of parts, components, and materials to support a production. MRP also provides a detailed time schedule for when each component, material and part must be ordered or produced. There are four stages in the material requirements planning process, namely:

- Netting (Calculation of net requirements)
- Lot sizing (Determination of order size)
- Offsetting (Determination of the amount of stance)
- Exploding (The next calculation for the level below)

The purpose of Material Requirement Planning (MRP) to control inventory levels, determine priority items, and plan capacity to be charged to the production system. In general, the purpose of inventory management using the MRP system is no different from other systems, namely minimizing investment in inventory and also maximizing operating efficiency [9].

II. METHOD

A. Data Collection

The method of obtaining data that was employed was quantitative, and the information gathered came in the form of Building Berth and ship building support facilities, Lines Plans, General Arrangement of the ship, Profile Construction, Midship Section, Shell Expansion and details on the computation of the steel weight of the ship block by block.

Table 1 shows the dimensions of the container ship 100 TEUS. Figure 1 shows the profile construction, Figure 2 shows the midship section and Figure 3 shows the general arrangement of the ship and Figure 4 shows the shell expansion.

B. Block System Method Ship Building

The block system method is a development of the section method, namely by combine some section in workshop assembly production into one block or section the size of the block an adjusted to the capacity of the lifting and conveyance equipment owned by the shipyard [10]. With block-by-block system, the shipyard can estimate time efficiency as well as the necessity for shipbuilding equipment.

TABLE 1.
 PRINCIPAL DIMENSION OF CONTAINER 100 TEUS

Description	Value	Unit
LOA	74,05	M
LPP	69,20	M
B	17,20	M
T	4,90	M
VS	12	Knot
CB	0,78	
Displ	3,327	Tons

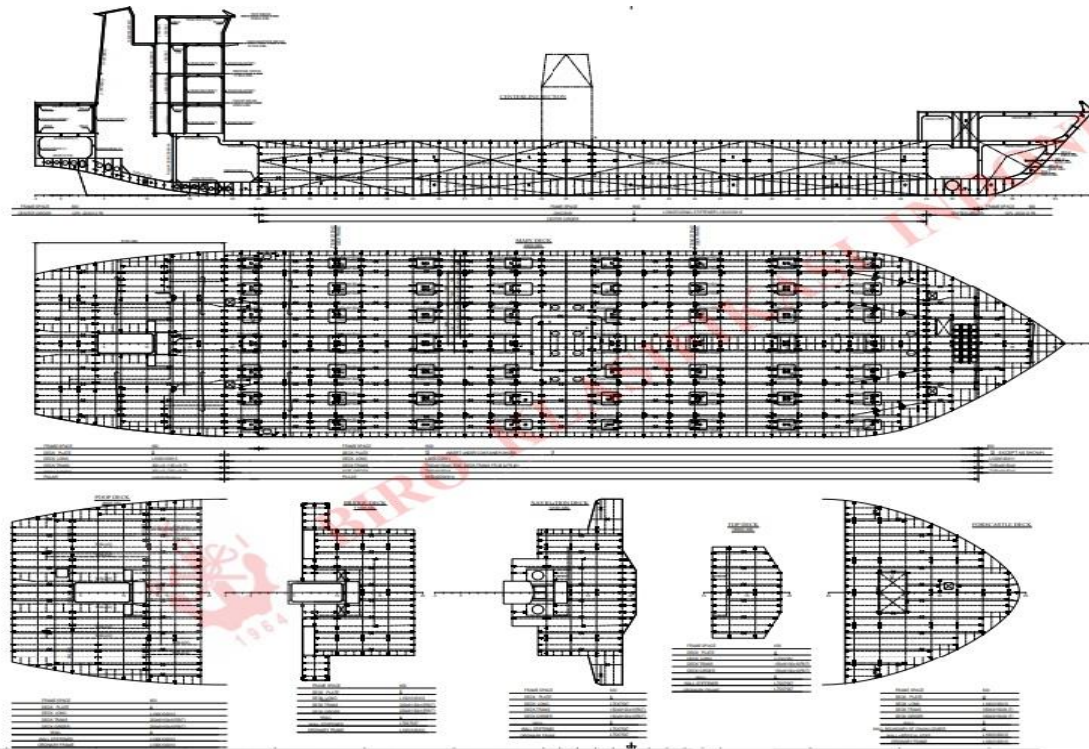


Figure. 1. Profile Construction Of Container Ship 100 Teus

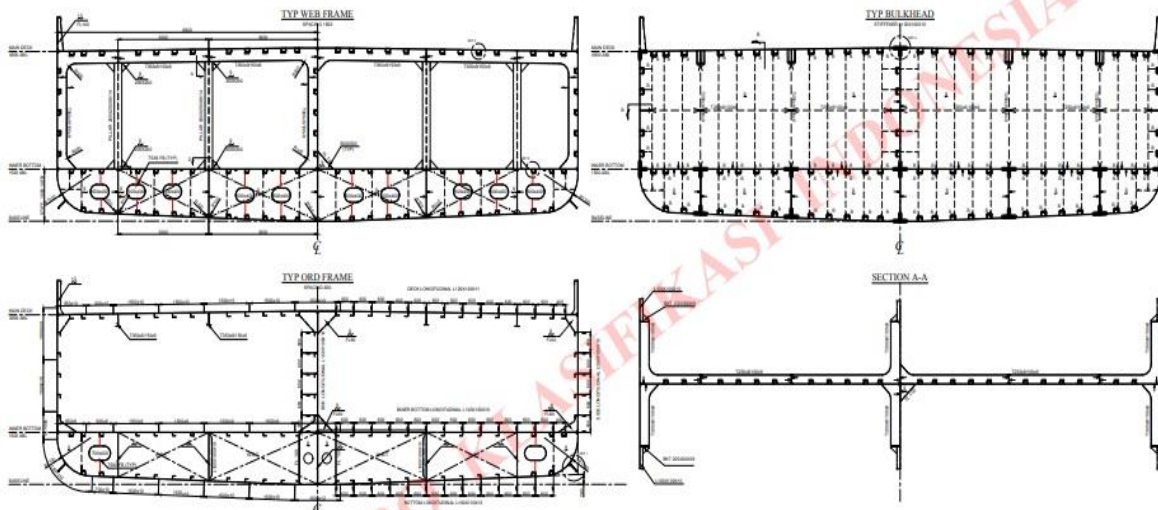


Figure. 2. Midship Section Of Container Ship 100 Teus

Figure 5 a detailed block drawing that informs the distribution of blocks contained in a cargo hold construction container ship 100 TEUS which is also a reference in 3D block-by-block mathematic calculations and modeling.

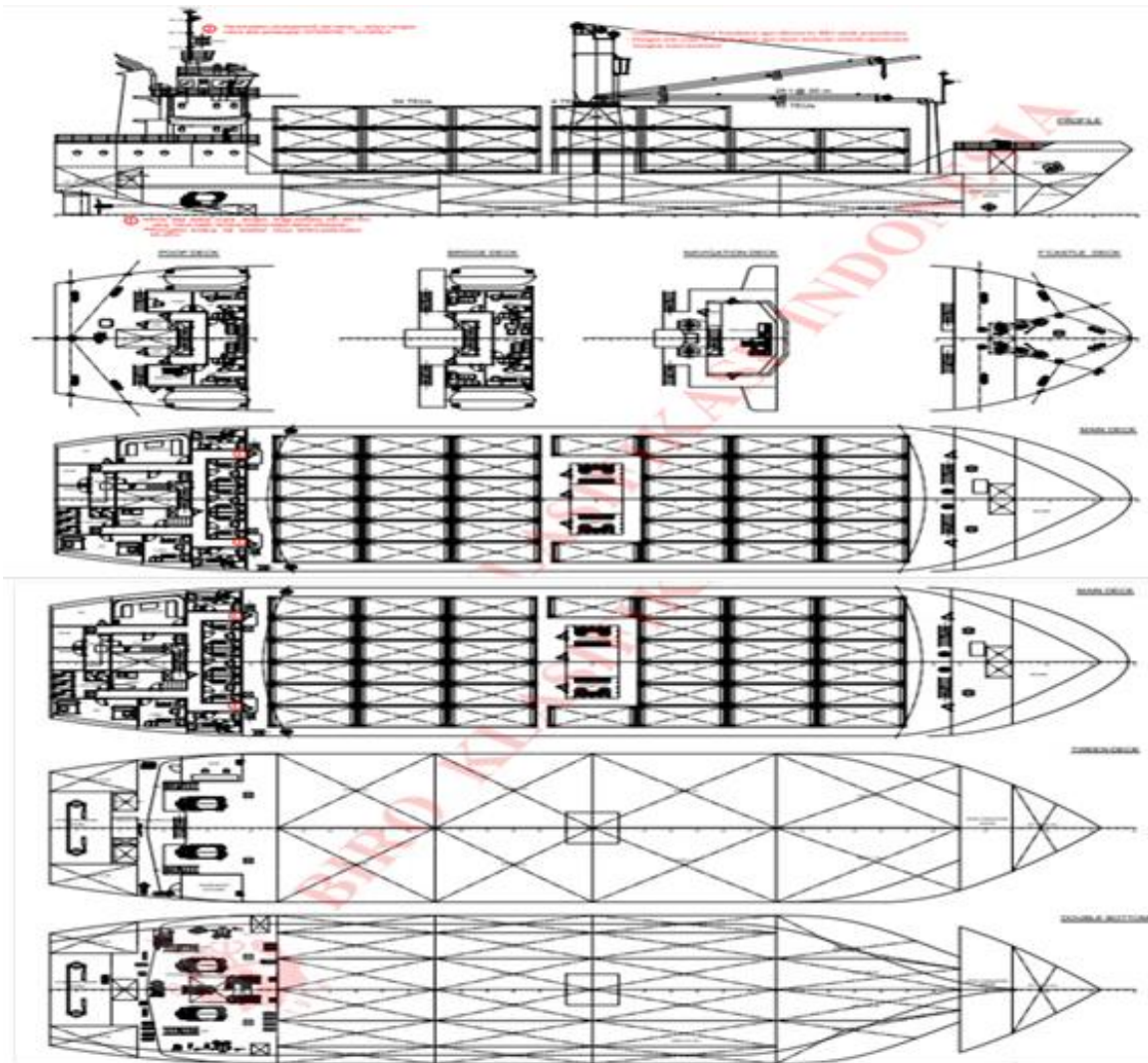


Figure. 3. General Arrangement Of Container Ship 100 Teus

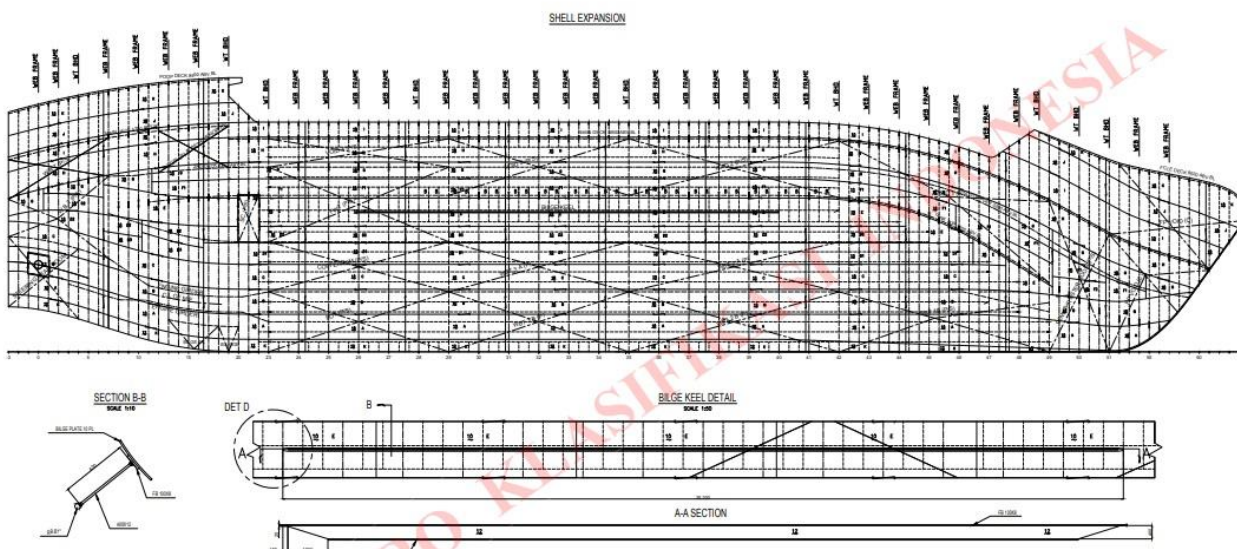


Figure. 4. Shell Expantion of Container Ship 100 Teus

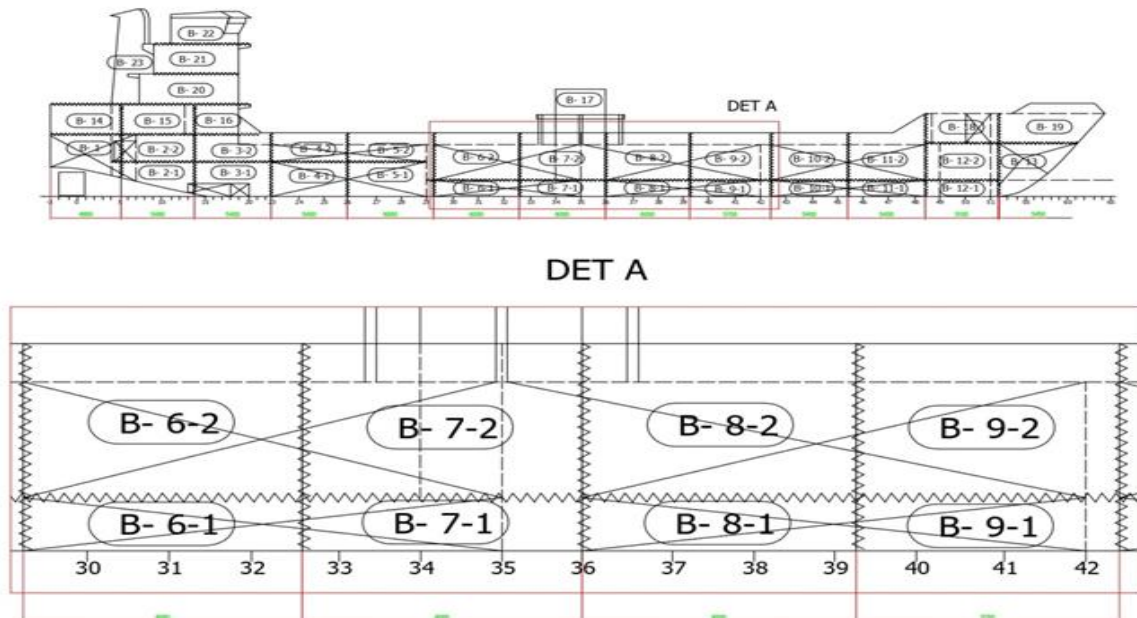


Figure. 5. Grandblock of Container Ship 100 TEUS

Table 2 is information regarding the weight of steel ship construction block by block contained in a container ship 100 TEUS which will later be used as a reference and also for a comparison. Meanwhile Table 3 shows the model elemen for calculation in the web frame of ship.

TABLE 2.
 SHIP'S REAL STEEL WEIGHT OF CONTAINER 100 TEUS

Block	Frame	Position	Weight (Kg)
Block B-1	Fr.-3 - Fr.5	APT	38.715,63
Block B-2-1	Fr.5 - Fr.14	Engine Room	24.706,18
Block B-2-2	Fr.5 - Fr.14	Tween Deck	15.259,61
Block B-3-1	Fr.14 - Fr.23	Engine Room	37.050,20
Block B-3-2	Fr.14 - Fr.23	Tween Deck	19.254,38
Block B-4-1	Fr.23 - Fr.26	Hull	52.716,60
Block B-4-2	Fr.23 - Fr.26	Hull	24.786,18
Block B-5-1	Fr.26 - Fr.29	Hull	56.907,12
Block B-5-2	Fr.26 - Fr.29	Hull	26.750,17
Block B-6-1	Fr.29 - Fr.32	DB* RM	32.751,40
Block B-6-2	Fr.29 - Fr.32	Cargo Hold	29.182,86
Block B-7-1	Fr.32 - Fr.36	DB* RM	30.710,91
Block B-7-2	Fr.32 - Fr.36	Cargo Hold	43.364,49
Block B-8-1	Fr.36 - Fr.39	DB* RM	30.449,90
Block B-8-2	Fr.36 - Fr.39	Cargo Hold	30.832,24
Block B-9-1	Fr.39 - Fr.42	DB* RM	29.328,27
Block B-9-2	Fr.39 - Fr.42	Cargo Hold	32.926,43

C. Mathematic Method

The mathematical calculations are performed by identifying the members list elemen of hull construction, which can be found in the web frame, main frame, and bulkhead of the cargo hold of the ship container 100 TEUS.

where:

$$\begin{aligned} \text{GB} &= \text{Total grandblok of steel weight} \\ &= \text{Total Weight of the n Block} \end{aligned}$$

To determine can be done with the formula:

$$i = \text{Total Fn} (\text{Wt GB} + \text{Wt GK} + \text{WtS}) \quad (2)$$

Total Fn = Total Frame

W_t GB = Total Weight of Web Frame

W_t GK = Total Weight of Main Frame

W_t S = Total Weight of Bulkhead

A. Modeling Method

3D modeling construction ships produced with use *Autodesk Inventor* can immediately know the volume of material installed using command *mass properties* which is found in *Autodesk Inventor*. Order *mass properties* which is found in *Autodesk Inventor* can quickly and accurately provide calculation data including volume, dimensions, and center of gravity of the material based on the 3D ship construction model contained in the model drawings.

3D modeling stage using *software Autodesk Inventor* divided into five parts like *sketching*, *3D modelling*, *assembling*, *presenting* and *drafting*.

Construction calculations after 3D modeling are easier done because there is no need to do the measurement and orting out the construction parts will be counted however completely based to the construction 3D model the ship in the master drawing.

B. Cost Estimation for the Construction of Container 100 Teus Blocks B-6-1 to B-9-2

The method used in the analysis of the steel construction cost of the ship loading Container 100 Teus using the MRP method. In general, the purpose of inventory management using the MRP system is no different from other systems, namely improving service to customers, minimizing the data that has been collected, processing, among others, by identifying to calculate and estimate the number of material requirements and man hours.

- Calculating Electrode Prices

The price for the AWS A5.20 E71T-1 electrode obtained is US\$ 1.35-2.2/kg. in Rupiah around Rp.18,000. The formula used in calculating the price of welding electrodes in shipbuilding Container 100 Teus using mathematical methods and 3D modeling *Autodesk Inventor* that is :

$$\text{BE} = L_{\text{the}} \times 4 \text{ layers} \times \text{electrode used (kg)} \times \text{electrode price/kg} \quad (3)$$

where :

BE : Electrode Charge

L_{the} : Welding Length (m)

- Calculating the cost of H Beam

H beam is used in the pillars *Web frame*, with a size of 250x250x9/14 with a length of 6m or the same as

434.5kg, you get IDR 9,398,000. The formula used is as follows:

$$\text{BBH} = W_{\text{pillar}} \times \text{Price of Hbeam/tonne} \quad (4)$$

where :

BBH = Cost of H Beam

W_{pillar} = Weight of steel pillar (tons)

- Calculating the cost of L Profile
The price for L profile with dimensions of 100x100x10mm with a length of 6m is IDR 1,750,000. The formula used is as follows:

$$\text{BBS} = L_{\text{BS}} \times \text{L profile prices/6meters} \quad (5)$$

where:

BBS = Prices of L profile

L_{BS} = Length Total of L Profile (m)

- Cost Welder
Work wage costs *welder* based on company x which is 150,000/day. The formula used is as follows:

$$\text{BW} = \text{Total Day Work} \times \text{Welder wages/day} \quad (6)$$

- Basic Cost Formula

$$\text{Cost} = (\text{Dimension} \times \text{Weight (kg)} \times \text{Prices}) \quad (7)$$

III. RESULTS AND DISCUSSION

A. Calculation of Ship Steel Weight by Mathematical Method

$$\begin{aligned} \text{GB} &= \text{Wt B1} + \text{Wt B2} + \text{Wt B3} + \text{Wt B4} \\ \text{GB} &= 67,508 + 76,191 + 55,051 + 61,118 \\ \text{GB} &= 259,868 \text{ ton} \end{aligned}$$

B. 3D Modeling with Autodesk Inventor

3D modeling only models one of the main frame, web frame, and bulkhead located in the ship's cargo hold container 100 Teus. frames 30+600 as main frame, frames 30 as web frame, and frame 35 as bulkhead. Due to the loading space construction form is contained in the parallel middle body of the loading space frames.

Modeling performed on main frames is the same as modeling large ivory frames. Namely by making such 3D modeling by size half the distance of the tusk in the direction of the AP and to FP direction, modeling made with 300 mm long in the FP direction and 300 mm in the AP direction with point 0 is main frame 30+600mm.

Modeling on bulkhead frames is the same as modeling web frames. Namely by making the 3D modeling with half the distance of the tusk toward the AP and towards the FP, modelling made long 300mm in the FP direction and 300mm in the AP direction with point 0 being *bulkhead* fr.35.

TABLE 4.
 CALCULATION BLOCK B-6-1 – B-9-2 WITH MATHEMATICAL METHOD

Block	Frame	Weight	Unit
B-6-1 & B-6-2	Fr.29 – Fr.33-600	67,508	Ton
B-7-1 & B-7-2	Fr.33 – Fr.36	76,191	Ton
B-8-1 & B-8-2	Fr.36+600 – Fr. 39+600	55,051	Ton
B-9-1 & B-9-2	Fr.40-600 – Fr.42+600	61,118	Ton

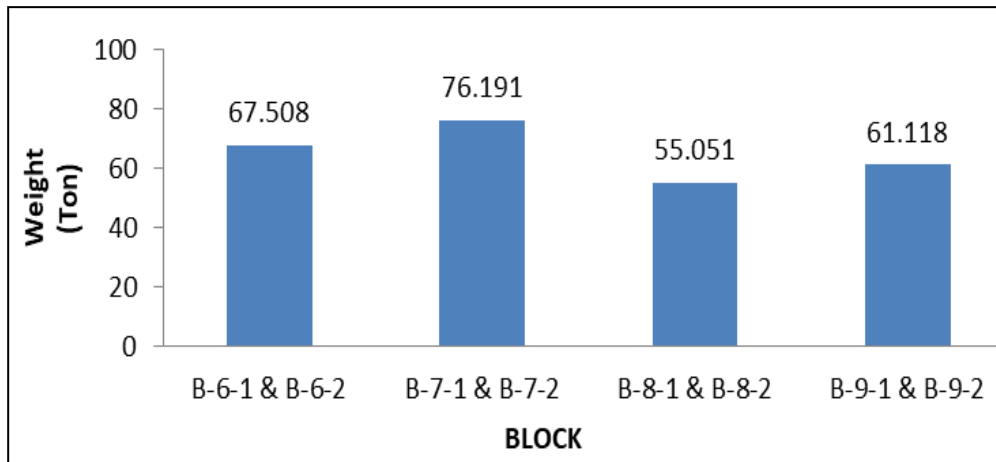


Figure. 6. Calculation Grandblock of Container Ship 100 TEUS with Mathematic Method

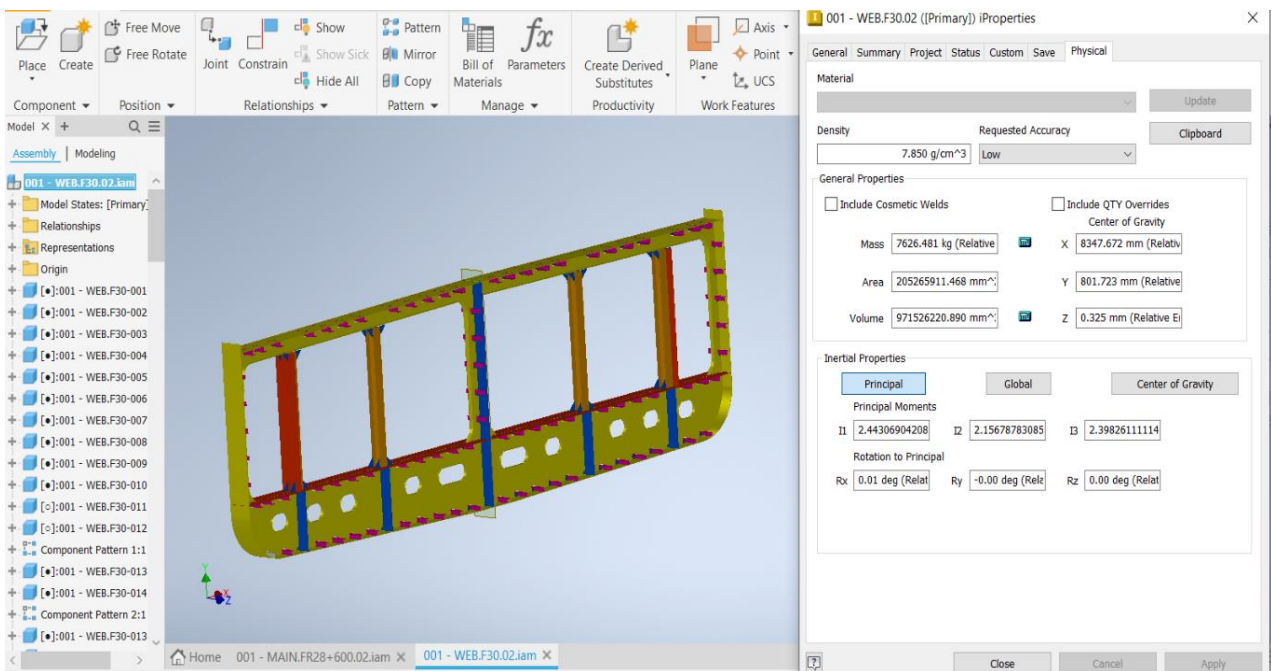


Figure. 7. Web Frame Modeling with Autodesk Inventor Software

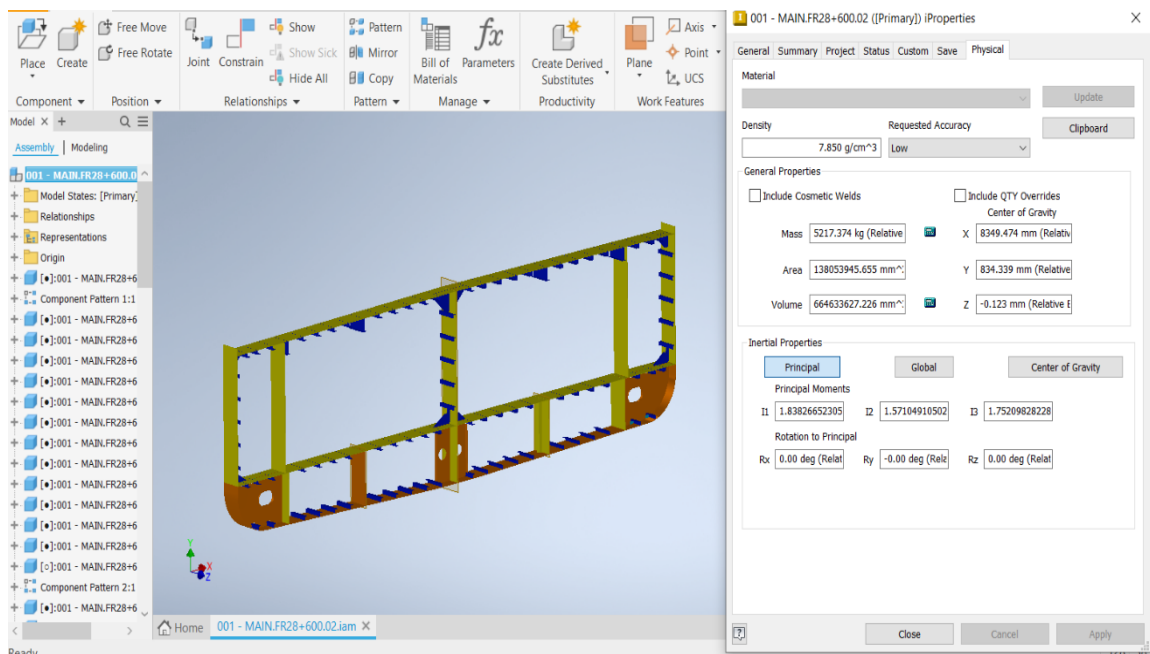


Figure 8. Main Frame with Autodesk Inventor Software

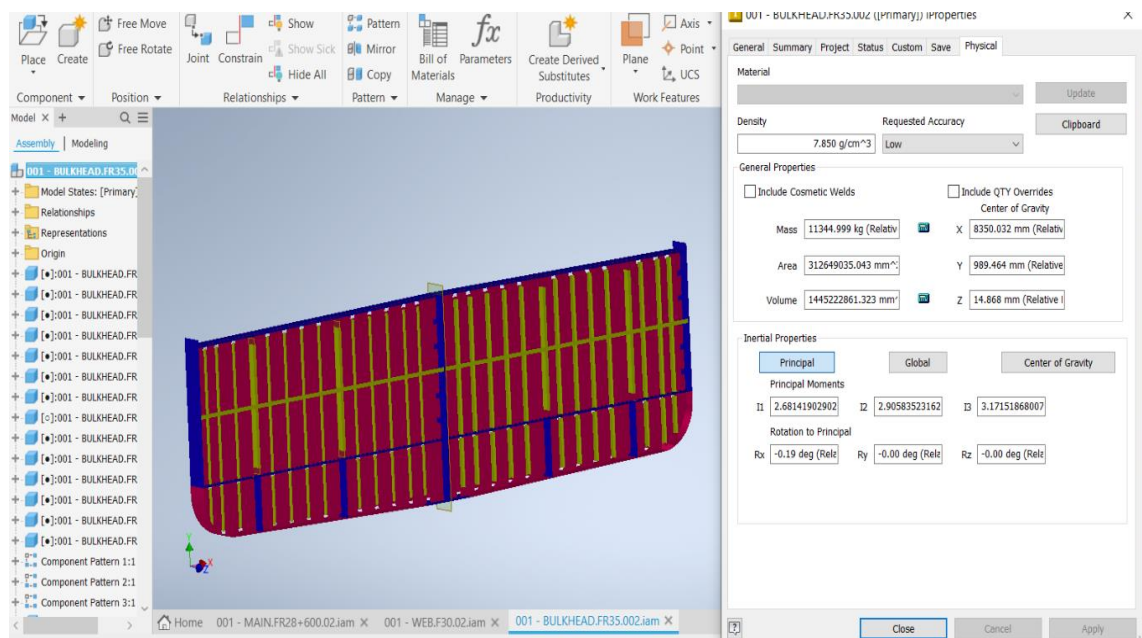


Figure 9. Bulkhead Modeling with Autodesk Inventor Software

In Figures 8, 9, and 10 is the result of modeling with Autodesk Inventor. In this case the weight of steel can be seen using tools mass properties on Autodesk Inventor. On web frame for elongated construction, modeling is done by making half the size of the ivory distance towards AP and towards FP. For example, for shell, center girder, side girder, inner bottom plate, bottom plate is made with a length of 300mm towards FP and 300 mm towards AP with a point 0 exists web frame 30.

Obtained the weight of steel at web frame by using Autodesk Inventor namely 7.626 tons. Next to the ordinary frame each tusk has 2 ordinary frames. Modeling done on ordinary frame. The same is true for modeling a large tusk, namely by making the 3D modeling half the distance between the tusk to the AP and to the FP direction. Obtain the weight of steel at ordinary frame by using Autodesk Inventor namely 5.217 tons. Then for modeling on Bulkhead found in fr.35 and fr.42. obtained steel weight on Bulkhead of 11.344 tons.

TABLE 5.
 TOTAL 3D MODELING CARGO HOLD STEEL WEIGHT AUTODESK INVENTOR BASED ON TOTAL FRAMES

Frame	Qty	Weight	Total	Unit
Web Frame	12	7,626	91,512	Ton
Ordinary Frame	27	5,217	140,859	Ton
Bulkhead	2	11,344	22,688	Ton
		Total	255,077	Ton

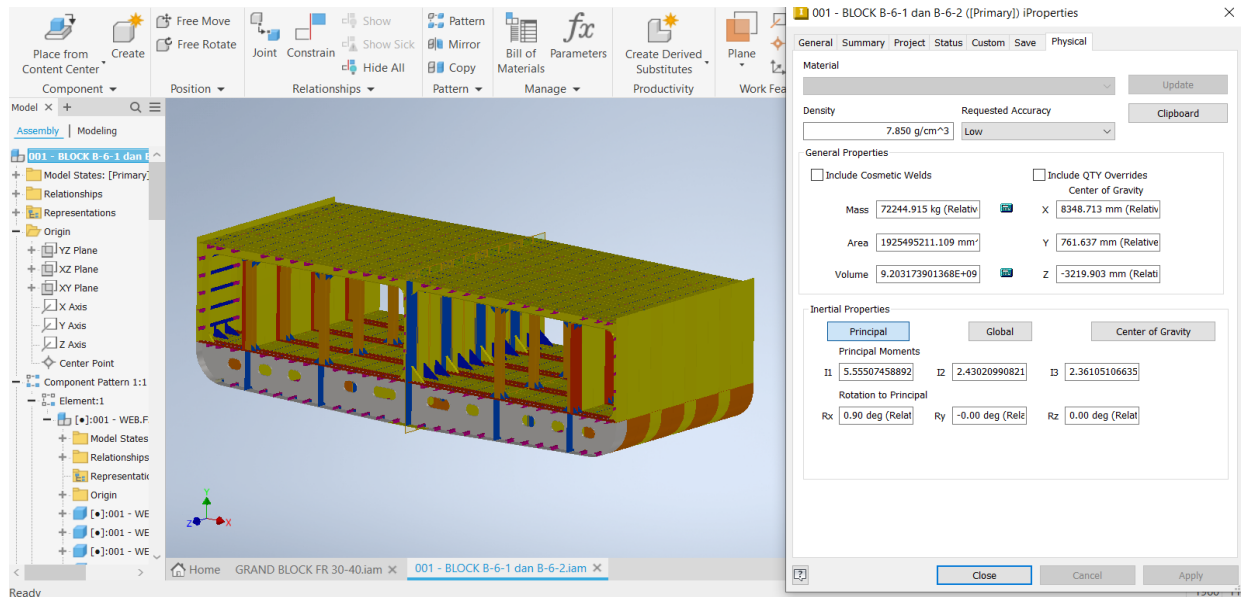


Figure. 10. Block Modeling B-6-1 & B-6-2

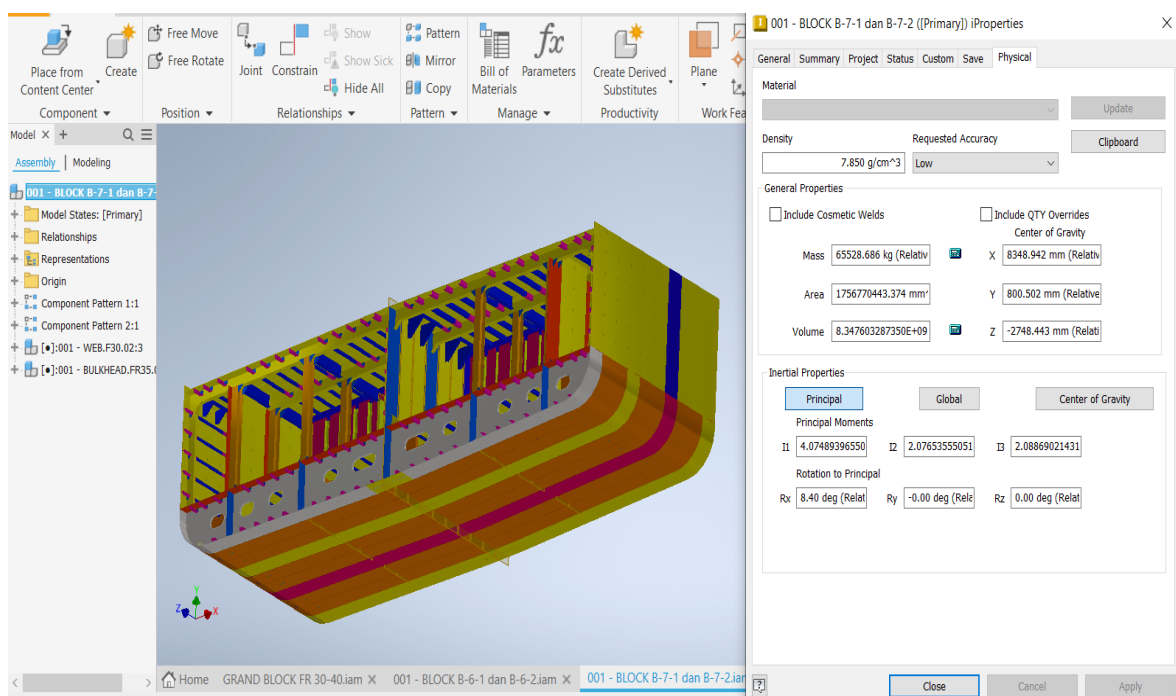


Figure. 11. Block Modeling B-7-1 & B-7-2

In Figure 11, 12, 13, and 14 Is the result of 3D modeling block by block consisting of ordinary frame construction, web frame, and bulkhead which are assembled into a block.

The blocks B-6-1 to block B-9-2 are the blocks in the cargo hold of container ship 100 TEUS which are used as a reference in calculating the weight of steel. Blocks B-6-1 and B-6-2 consist of 4 web frame and 8 main frames, there is no bulkhead construction inside.

The weight of the steel blocks B-6-1 and B-6-2 is 72.245 tons in blocks B-7-1 & B-7-2 there are 3 web frame, 6 main frame, and 1 bulkhead construction with a total weight of 65,529 tons. In blocks B-8-1 & B-8-2

there are 3 web frame, 7 main frame, and no bulkhead construction with a total weight of 59,401 tons. In blocks B-9-1 & B-9-2 there are 2 web frame, 5 main frame, and 1 bulkhead construction with a total weight of 57,902 tons.

C. Comparative Analysis of Ship Steel Weight Estimates

Figure 8. Is a graph of the difference between the weight of real steel ship construction, calculation of mathematical methods, and Autodesk Inventor 3D modeling methods. With the difference between the mathematical method and the real steel weight of 0.344

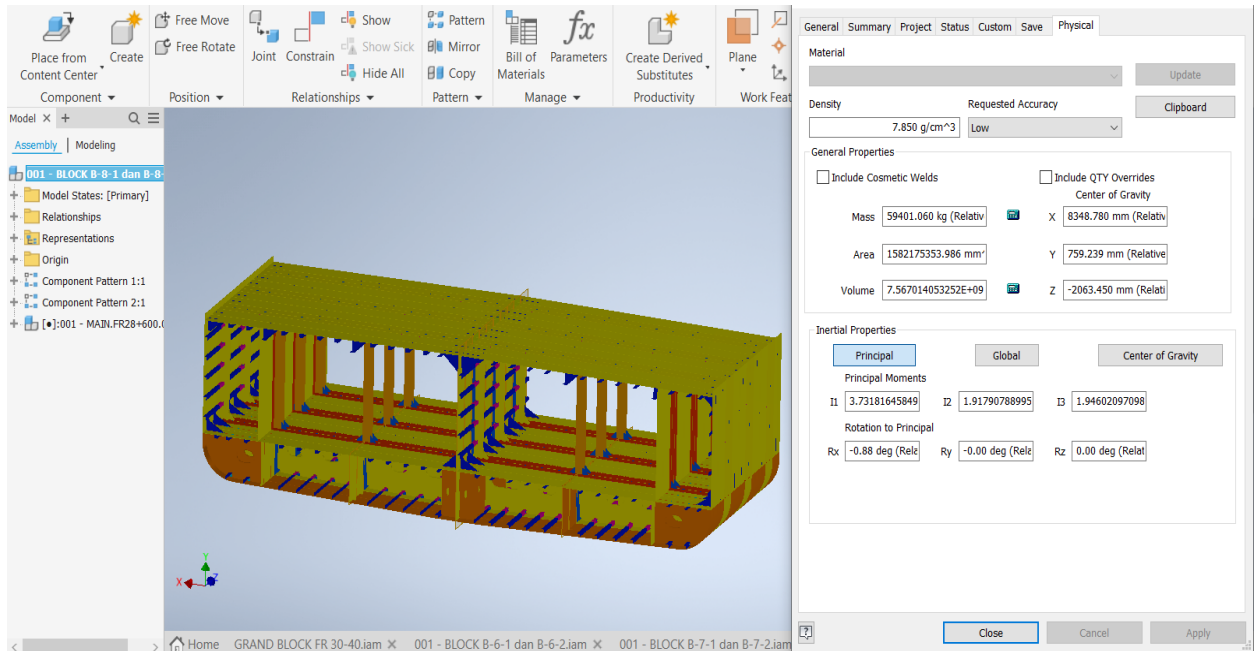


Figure 12. Block Modeling B-8-1 & B-8-2

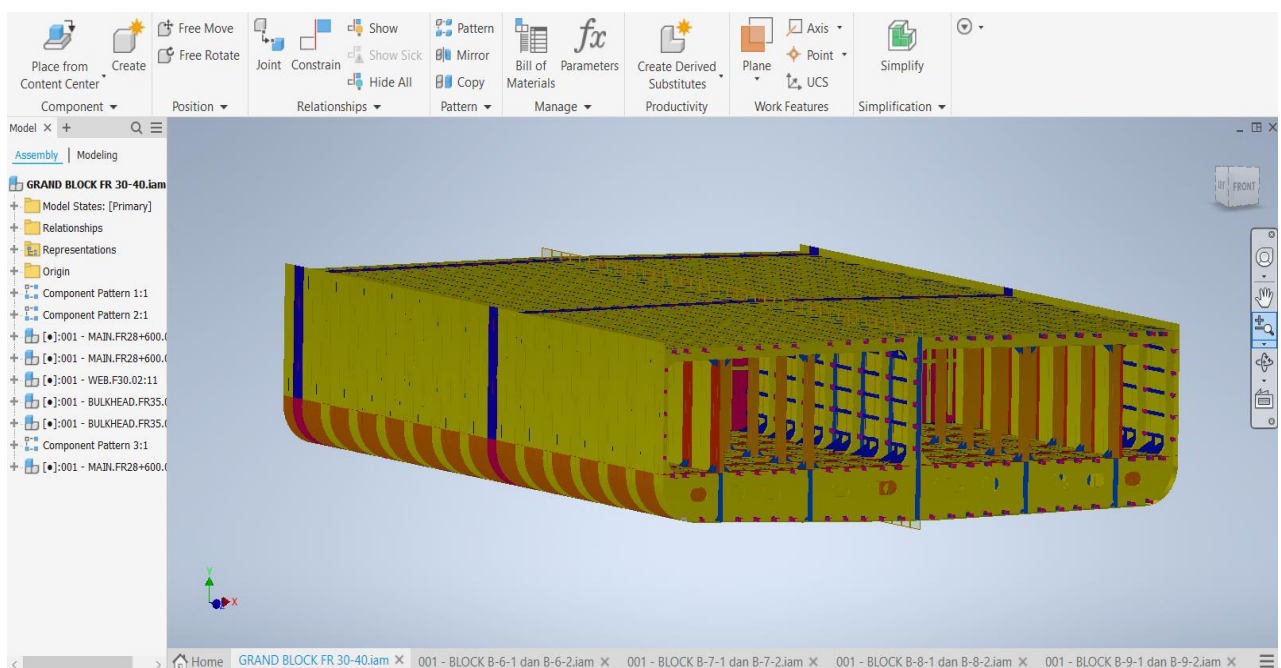


Figure 13. Blok Block modeling B-9-1 & B-9-2

tons, the difference between the 3D modeling method and the real steel weight is 4.447 tons, and the difference between the mathematical method and Autodesk Inventor 3D modeling is 4.791 tons or equal to 1.84%. Even though the difference in the weight of the ship's cargo hold steel produced is only around 1.84%, the price of 4.791 tons is still quite large when applied in the field because there are several factors that must be considered to minimize the difference between the estimated results and the actual weight of ship steel.

These factors are:

- Skill and accuracy in operating 3D applications

Autodesk Invento.

- Welding factors not included in 3D modeling.
- Completeness of drawing, in making a 3D model of a ship, sufficient drawing completeness is needed, because the more detailed the drawing, the smaller the resulting difference in numbers.

D. Economic Analysis

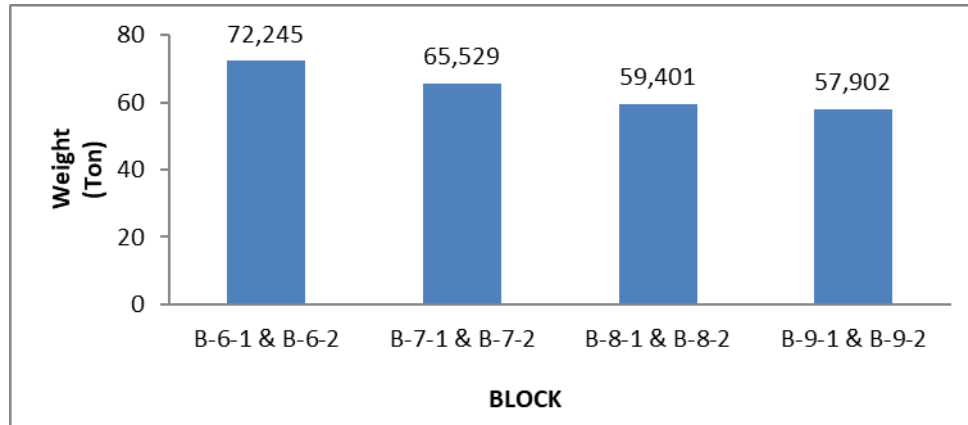


Figure. 14. 3D Modeling using Autodesk Inventor Based on Block-by-Block Graph

TABLE 6.
 DIFFERENCE CALCULATION METHOD 3D AUTODESK INVENTOR WITH MATHEMATICAL METHOD

Method	Ship Weight Steel (Ton)	Deviation
Berat Baja Real	259,868	
Mathematic	259,524	1,84%
3D Autodesk Inventor	255,077	

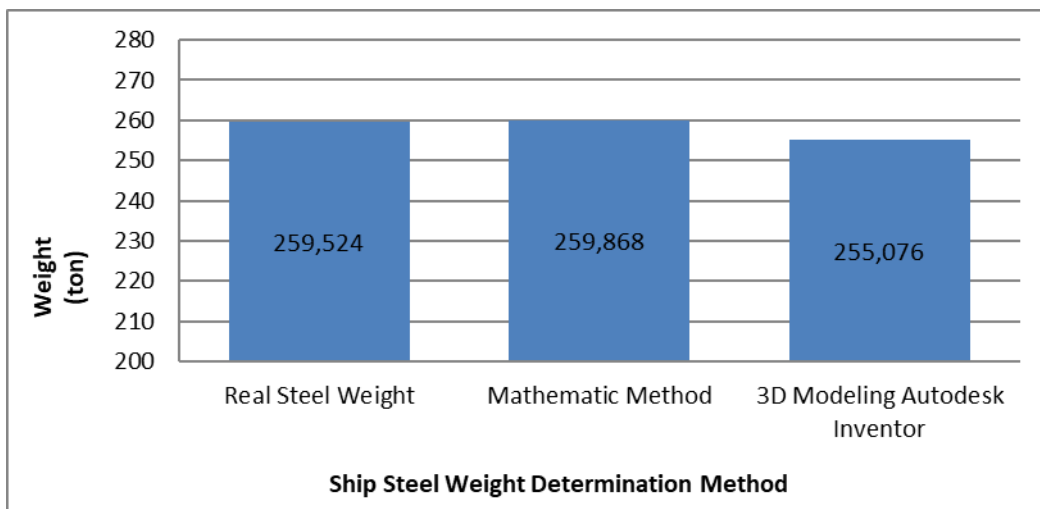


Figure. 15. Graph of the difference the calculation the weight of steel cargo hold construction Container 100 Teus

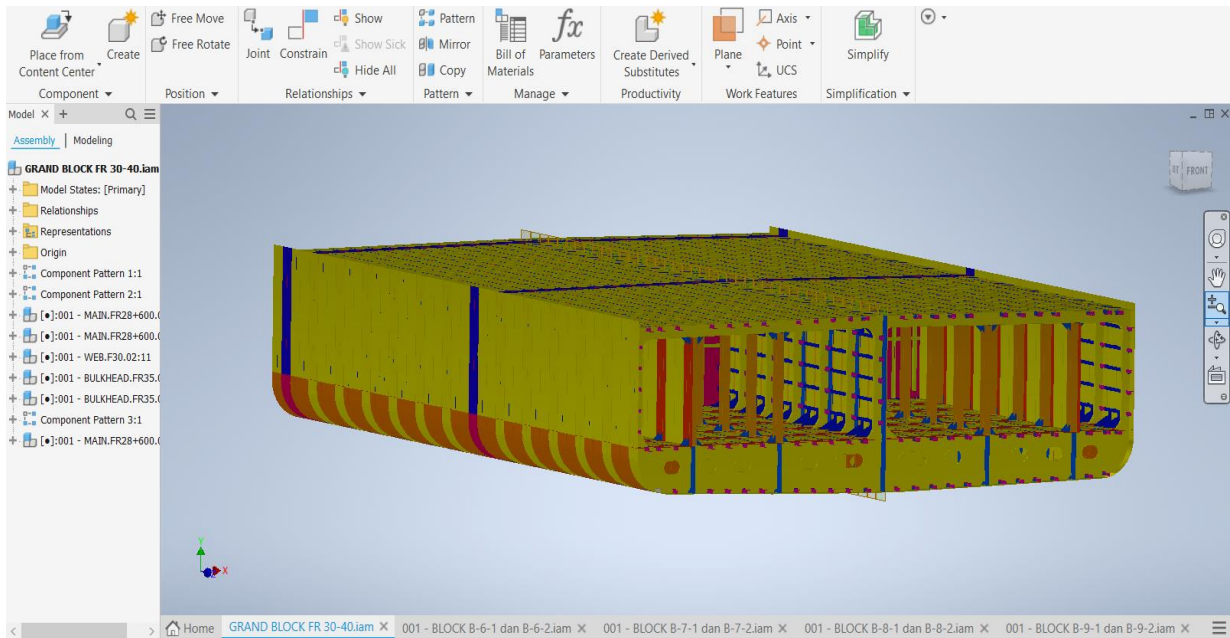


Figure 16. 3D Modeling Grand Blok Cargo Hold Construction Container 100 Teus Using Autodesk Inventor

TABLE 7.
 THE OVERALL COST OF BUILDING THE CARGO HOLD CONSTRUCTION CONTAINER 100 TEUS

	Prices	Total Mathematic Price	Total Autodesk Inventor Price
Elektrode Consumption	18.000/kg	Rp.203.113.872	Rp.203.113.872
Steel Weight	8.000.000/ton	Rp.1.665.832.000	Rp.1.728.408.000
H beam	9.9398/434,5kg	Rp.232.002.769	Rp.232.002.769
L Profile	1.750.000/6m	Rp.77.402.500	Rp.77.402.500
Welder Wages	150.000/hari	Rp.13.500.000	Rp.13.500.000
Welding Equipment	450.000/hari	Rp.40.500.000	Rp.40.500.000
Electrical Cost	1.478/kwh	Rp.3.192.480	Rp.3.192.480
Total		Rp.2.235.543.621	Rp.2.298.119.621

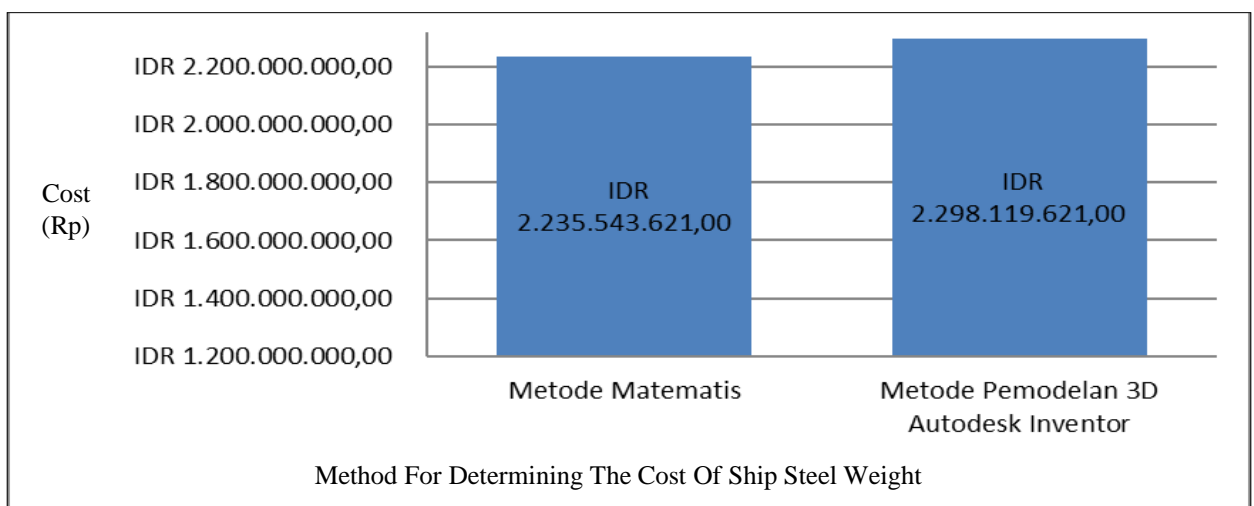


Figure 17. Graph of the difference in the cost of steel cargo Hold for a Container 100 Teus

After generating all the requirements that will be calculated to analyze the ship's economy, then by calculating the price of the plate cost and then with the needs of the electrodes used. Plate data is taken based on Sheel Expansion Container 100 Teus so that with the mathematical method the ship's steel weight is 208.229 ton of the total costs in Table 7 for the process of building cargo hold container 100 teus with the mathematical method of Rp. 2,235,543,621 and for 3D modeling Autodesk Inventor Rp. 2,298,119,621.

From Figure 18 above, the cost difference is obtained between the mathematical method and 3D modeling *Autodesk Inventor* for determining the cost of the ship's steel weight in the ship's cargo hold *container 100 teus* with a percentage of 2.72%.

IV. CONCLSION

From the results of the study, it can be concluded that:

1. The estimated weight of the ship's steel which was carried out using the mathematical method resulted in a fairly good level of accuracy, with a real ship's steel weight of 259.524 tons and the result of calculations using the mathematical method was 259.868 tons. The percentage difference in the weight of the steel produced is 0.344 tons.
2. Estimation of the ship's steel weight carried out by the method *Autodesk Inventor* produces a fairly good level of accuracy, with a real ship steel weight of 259.524 tons and the results of calculations using the mathematical method are 255.077 tons. The percentage difference in the weight of the steel produced is 4.447 tons.
3. 3d modeling method *Autodesk Inventor* which is proposed as the weight of the ship's steel by carrying out a similarities analysis of the ship's construction between frames by analyzing the cross-sectional drawings amidships and profile construction drawings. With the weight of the ship's steel produced in 3D modeling, namely 255.077 and with mathematical data of 259.868 tons. So that

the percentage difference in the weight of the ship's steel is 4.791 tons or an accuracy rate of 1.84%.

4. Analysis of the ship building process at the design stage and calculation of cargo space construction with 3D modeling is easier to do because there is no need to sort out the parts to be calculated but are fully. Based on the 3D model of ship construction block by block using *toolsmass properties*.
5. By determining the total weight of the steel part of the ship's loading space, it is possible to determine the estimated cost used for the ship's construction process with a mathematical method of Rp. 2,235,543,621 while the estimated cost with 3D modeling *Autodesk Inventor* in the amount of IDR 2,298,119,621.

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