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Development of a CAD-Based Subprogram for Bill of Materials Generation in Midship Section Area of Cargo Oil Tank

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Abstract

One of the shipbuilding challenges is managing Bill of Materials (BOM), due to the existence of separate BOM versions for the design, production, and maintenance stages. In addition, most BOM preparation still involves manual processes, requiring BOM transformation and repeated verification that increase the risk of data inconsistencies and duplication. This study aims to simplify BOM preparation by developing a CAD-integrated add-on program capable of automatically generating BOM from ship section design. The research method includes collecting material and reference midship section data, creating a material database, developing the add-on, preparing a manual BOM from the reference drawing, and validating the generated BOM. The add-on utilizes a database of marine structural profiles and plates to generate midship section model and automatically extract embedded information for BOM preparation. The proposed approach successfully produced an add-on capable of remodeling the midship section of an existing product oil tanker and automatically generating a BOM from the resulting model. validation of the structural component weights against a manually prepared BOM showed excellent agreement, with deviations of 0.0010% for plate components, -0.0191% for profile components, and -0.0039% for the total structural weight. These results demonstrate that the developed add-on can reliably generate accurate BOM data while significantly reducing manual effort. By integrating structural modeling and BOM generation into a single workflow, the add-on has potential to improve data consistency between shipyard divisions and engineering processes during ship construction.

1. Introduction

The shipbuilding industry is a complex manufacturing sector involving numerous stages, from design and fabrication to assembly and maintenance [1]. Throughout these stages, the Bill of Materials (BOM) plays a critical role in defining and documenting ship components and structures. However, in practice, BOMs are often compiled separately by different shipyard divisions, resulting in various versions such as the Engineering BOM (EBOM), Manufacturing BOM (MBOM), and Maintenance BOM (MBOM) [2]. This fragmentation necessitates additional work for BOM transformation, which is highly susceptible to data duplication, human error, and inconsistencies especially when considering many revision that might happen on each designed ship [3]. Such inefficiencies can lead to unplanned expenditures, inaccurate cost estimations, and compromised quality control. To mitigate these issues, a structured method is required to facilitate direct and consistent BOM data transfer with minimal manual intervention.

One potential solution is the integration of BOM data into digital design models using computer software. While commercial professional ship design software like NAPA Designer, Cadmatic Marine Design, and AVEVA Marine offer integrated BOM features, their high licensing costs and high complexity present significant financial and operational burdens for many shipyards. As a comparation, total price of the perpetual license of NAPA from one of its distributor in Indonesia can reach up to EUR 80,310 [4], while the license package of Cadmatic can go up to EUR 54,489.88 [5]. Previous research has explored various ways to reduce BOM transformation needs. For instance, Zhao et al [6] and Ren et al [7] bring up similar concepts about systems integrating Model-Based Definition (MBD) to ensure data consistency throughout the product lifecycle, though this is often limited to products with pre-existing complete datasets. Okubo et al [8] proposed a new advanced bill of material that integrates product, process, and production resource information to facilitate systematic coordination between the design and production sides, with objective to improve the synchronization of BOM when ther are design plan changes. Other researchers, such as Liu et al [9], have focused on algorithms to transform existing MBOMs into maintenance formats. Another research that similar to the approach on this study is carried out by Putra et al [10] which develop a program that can automatically generate bill of material for cable straight from 2D PDF drawings.

In the current market, several existing software extensions and add-ons provide specific functionalities. ShipConstructor, an AutoCAD-based program, can generate production drawings and BOMs integrated with material data [11]. Similarly, Orca3D for Rhinoceros offers weight and cost tracking, although it is limited to detecting material data in generic shapes rather than specific ship structural components [12]. ExpressMarine provides a more advanced approach by generating BOMs based on structural templates like plates and profiles [13]. Despite these advancements, there remains a gap in providing an affordable yet comprehensive solution that handles structural part modeling and automatic BOM extraction.

Bill of Material (BOM)

A bill of materials (BOM) is technical information that includes a list of parts or components that make up a product based on the context of its assembly (assembly, sub-assembly, or model). BOMs (Figure 1) are known by various names according to the terminology of each industry, such as recipes, formulas, composition lists, and so on. BOMs are widely used in industries that manufacture products. Initially, BOM referred to a list of manufacturing components, which only included the components needed by manufacturers to assemble products. The list of manufacturing components did not have a hierarchy that included the assembly sequence of product components or the structure of the product. However, with the development of industry and CAD technology, the definition of BOM has become a list that includes product configuration and product lifecycle information [14].

Material: BQ/2406/06/MT. ARTEMIS

Materials:

Ver	JobCode	Item code	Item name	Schedule	Estimasi Qty	Esti...	RoundUP Qty	Rou...
003	O99	W03.005.001	BESI PETAK UK. 3/4" X 6 MTR		6.00	MTR	1.00	LEN...
003	O99	W03.006.002	BESI SIKU UK. 75 X 75 X 7 MM X 6 MTR		72.00	MTR	12.00	LEN...
003	O99	W03.006.003	BESI SIKU UK. 100 X 100 X 10 MM X ...		60.00	MTR	10.00	LEN...
003	O99	W03.006.007	BESI SIKU UK. 90 X 90 X 9 MM X 6 MTR		4.00	LEN...	4.00	LEN...
003	O99	W04.001.002	PLAT KAPAL 6 MM X 6 X 20 @ 525 K...		525.00	KG	1.00	LBR
003	O99	W04.100.002	PLAT KAPAL 8 MM X 6 X 20 @ 700 K...		5,600.00	KG	8.00	LBR
003	O99	W04.200.002	PLAT KAPAL 10 MM X 6 X 20 @ 875 ...		875.00	KG	1.00	LBR
003	O99	W04.300.002	PLAT KAPAL 12 MM X 6 X 20 @ 1050...		1,050.00	KG	1.00	LBR
003	O99	W04.500.004	PLAT KAPAL 19 MM X 6 X 20 @ 1663...		1,663.00	KG	1.00	LBR
003	O99	W04.003.001	PLAT BUNGA UK. 6 MM X 4 X 8		1.00	LBR	1.00	LBR
003	O99	W04.004.001	LICHTGITTER STEEL GRATING TYPE ...		1.00	LBR	1.00	LBR
003	O99	W04.008.007	PLAT STRIP 9 MM X 100 X 6 MTR		2.00	LEN...	2.00	LEN...
003	O99	W04.008.008	PLAT STRIP 12 MM X 65 X 6 MTR		2.00	LEN...	2.00	LEN...
003	O99	W05.003.004	PIPA SEAMLESS SCH 40 UK. 1.1/4" X...		42.00	MTR	7.00	LEN...
003	O99	W05.003.011	PIPA SEAMLESS SCH 40 UK. 6" X 7,1...		6.00	MTR	1.00	LEN...
003	O99	W10.007.054	HANDLE / TOGGLE PINTU KEDAP		10.00	PCE	10.00	PCE
003	O99	W10.007.059	GREASE NEPPLE PIN HEAD UK. 1/4"		2.00	PCE	2.00	PCE

Figure 1. Example of a Bill of Materials (BOM) List

Generally, BOM contains various data including the name of the ship construction component, unit, quantity, type of material, component dimensions, and component weight. Each piece of data may vary depending on the type of component. For example, plate components generally use area units in m^2, while profile components use length units in meters. In calculating construction material requirements, material waste must also be considered. For this reason, the amount of material requirements is generally calculated by dividing the actual material requirements value by the material utilization factor, which is a constant that represents the level of efficiency in utilizing materials to produce a component. Mathematically, the material utilization factor in calculating material requirements can be expressed as in the following equation:

$$A_{gross} = A_{net}/\eta \text{ , or } L_{gross} = L_{net}/\eta \tag{1}$$

where A_{gross} is the material requirement in m^2, A_{net} is the actual material requirement in m^2, L_{gross} is the material requirement in meters, L_{net} is the actual material requirement in meters, and η is the material utilization factor. For example, if a base plate has a material utilization factor of 0.95, the production process can generate material waste of up to 0.05 or 5% of the required material.

The weight of components in BOM is generally obtained by multiplying the volume of the component by the density of the material and the quantity. The volume of the component is obtained from the component dimension data, which varies depending on the type of component. Mathematically, the weight of the component can be calculated using the following equations:

$$W_{plate} = t \times A_{gross} \times \rho \tag{2}$$

$$W_{profile} = l \times A_{section} \times \rho \tag{3}$$

where W_{plate} is the weight of plate material in tons, $W_{profile}$ is the weight of plate material in tons, A_{gross} is the material requirement in m^2, $A_{section}$ is the cross-sectional area of the profile in m^2, t is the plate thickness in meters, l is the profile length in meters, dan ρ is the density in ton/m^3.

Add-on Program

Add-ons, often referred to as extensions or plugins, are additional programs that are intentionally installed into a main software to provide new functions or features [15]. The main function of an add-on is to expand the capabilities of a software without having to dismantle or change the original program code, so that the main software remains secure and stable [16]. This concept is based on the principle of software engineering, whereby a system is built from separate parts (components) that can be assembled and disassembled according to user needs [17]. In practice, these separate components include various functions and features, ranging from task automation to enabling software interaction with other software. For example, in Figure 2, adding a special add-on to connect a word processing application with a reference manager such as Mendeley [18], [19]. With add-ons, software can be flexibly developed by anyone according to their needs without having to wait for official updates from the main software developer. This concept is driven by the increasingly massive and complex nature of computer programs in line with technological developments. In such conditions, if all features are included in one software program, the software will become very heavy and difficult to repair if errors or bugs occur [20]. Therefore, software developers began designing systems with a modular concept, where additional features are only installed when necessary. Over time, this approach has become a mandatory standard in the world of technology, from operating systems and office applications to cloud-based services [21].

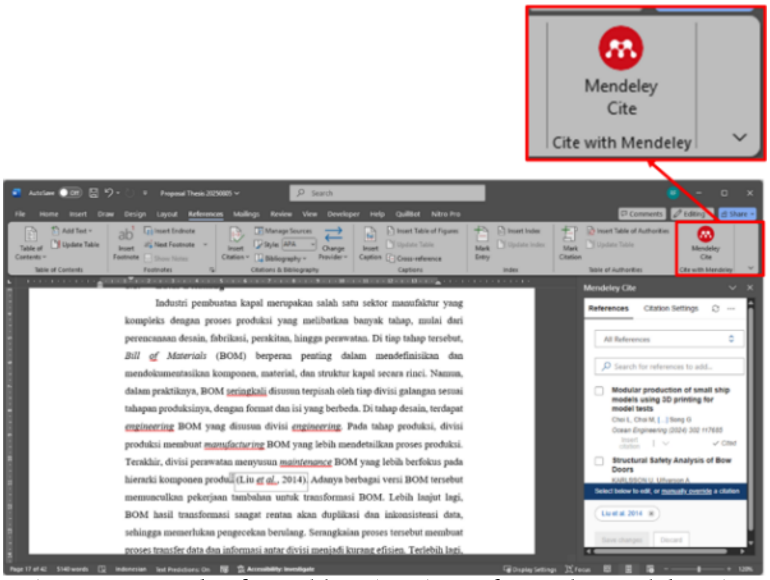


Figure 2. Example of an Add-on in Microsoft Word: Mendeley Cite

In engineering, the use of add-on concepts has a significant impact, especially on engineering design software such as CAD (Computer-Aided Design) and BIM (Building Information Modeling), which involve many mathematical calculations and complex modeling [22]. This situation has forced developers to limit the default features of their main software. Instead, to accommodate users' need for special features, some developers provide an Add-on Developer platform that allows various parties, both institutions and individuals, to get involved in developing add-ons for the software. This platform creates a collaborative digital work environment with a user-to-user concept. Each party can publish add-ons, develop or improve existing add-ons, and buy and sell add-ons.

Computer-Aided Design (CAD)

Computer-Aided Design, or CAD, is the use of computer-based software for designing, modeling, modifying, analyzing, optimizing, and documenting an engineering design [23]. The use of CAD today has greatly helped make the engineering design process more efficient. CAD technology has integrated various functions to accommodate the diverse needs of engineers, enabling CAD to produce accurate digital representations of designed products or objects, which can be modified, analyzed, and optimized in real time.

The history of CAD began with various computer programs developed for technical drawing purposes, including "UNISURF," which was developed by Pierre Bezier, a French engineer, in 1966-1968 to assist in the design process of components and tools for the automotive industry [24]. In addition, Ivan Sutherland from the Massachusetts Institute of Technology (MIT) also developed the SKETCHPAD program with similar functions. In the early days, CAD programs that were developed and used were computer programs with the main function of performing digital technical drawing processes as a replacement for the manual process of technical drawing on drawing boards. However, with the development of computer technology and programming in the field of solid modeling, CAD evolved from initially focusing on the digitization of 2D drafting processes to 3D modeling [25].

In today's era, CAD was widely implemented and has indirectly become the standard in the design process in various types of manufacturing and construction industries. With the rapid development of computer technology and software, CAD is now available in various software brands with a range of advantages and more affordable prices compared to its predecessor programs. Furthermore, CAD has now developed further with systems integrated with computer-aided manufacturing (CAM) for NC (numerically controlled) fabrication processes and AI (artificial intelligence) that improves the performance of analysis and design optimization processes.

AutoCAD .NET API

The AutoCAD .NET API is an Application Programming Interface (API) provided by AutoCAD software products. In the world of software development, an API is a set of rules, protocols, and mechanisms that act as an intermediary, enabling one software program to communicate or interact with another. The API is provided in the form of a .NET library containing classes, methods, and properties that represent objects and operation commands within the scope of the program. Through this library, users can access various geometric object databases, support systems, and various core AutoCAD commands in a structured manner. This API can be accessed using .NET-based programming languages such as C# and VB.NET to automate and customize AutoCAD functions [26]. This approach is also used in the development of AutoCAD add-ons to enrich its workflow and features without changing the AutoCAD main program itself.

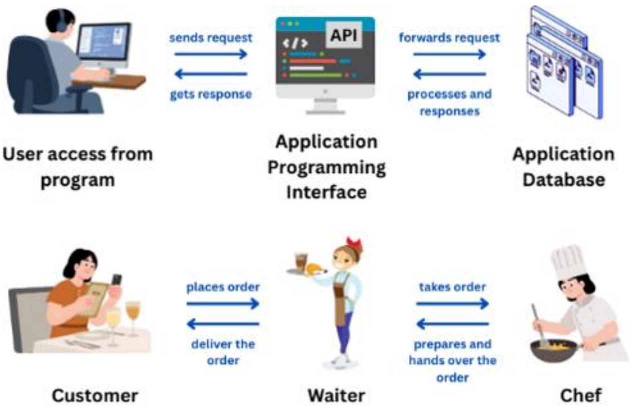


Figure 3. Restaurant Analogy of How API Work

In its application, the AutoCAD .NET API, as described in Figure 3, is widely used to develop simple commands to complex add-ons to reduce manual work in the creation and processing of technical drawings [27]. Through programming, various tasks such as creating repetitive objects, adding annotations, and calculating dimensions can be performed automatically based on specified rules. Several previous conducted studies [28] prove that programs developed from AutoCAD .NET API can improve the time efficiency and accuracy of the design process. In addition to AutoCAD .NET API, AutoCAD also has two other APIs, namely AutoLISP and ObjectARX, which have the same basic functions with different levels of access to the AutoCAD program structure, development complexity, and capabilities.

This research aims to bridge this gap by developing an integrated CAD add-on specifically designed for ship section designing and automated BOM generation. Unlike full-scale software, an add-on is more economical and requires less user training as it utilizes the existing interface of the host CAD software. The primary objectives of this study are to design algorithms for extracting technical data, such as material types and dimensions, directly from the ship section design to produce accurate BOMs automatically. Furthermore, the research validates the accuracy of the generated BOM through comparison with a manually prepared BOM and demonstrates the feasibility of integrating automatic BOM generation into the ship section design process. The benefits of this study include providing a technical reference for maritime software development and producing a functional add-on with potential for future commercialization. By streamlining the data transfer between divisions, this solution is expected to reduce data inconsistency and accelerate decision-making in ship construction.

2. Method

This research is carried out through several steps, starting with data collection, material data collection, program development, midship section remodeling, BOM manual calculations, and validation. In the program development step, there are 3 parts of subprogram and algorithm that would be developed, which are Drawing Tools, Part Identification Algorithm, and BOM Calculation. The whole process follows flowchart like shown in Figure 4. Detailed explanation of those research steps would be provided in the following sub-chapters.

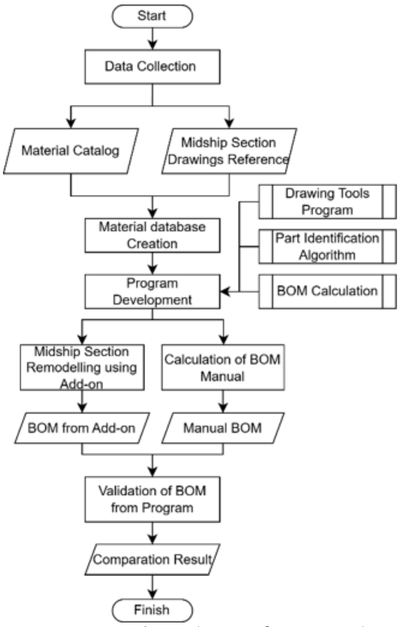
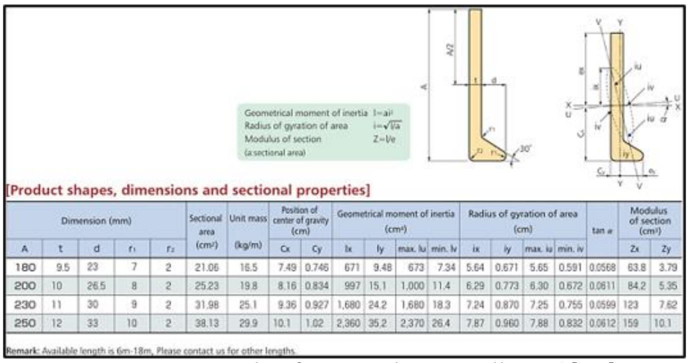


Figure 4. Flowchart of Research

2.1. Data Collection and Material Database Creation

One important piece of information required for add-on development is ship material data. The material data collected (Figure 5) consists of the specifications of commercially available marine-grade profiles, including dimensions, weight per unit length, cross-sectional properties, and other relevant characteristics. These data are compiled into a material database that serves as the primary reference for generating the geometric representation of structural profiles within the AutoCAD add-on.



[Product shapes, dimensions and sectional properties]

Dimension (mm)					Sectional area (cm²)	Unit mass (kg/m)	Position of center of gravity (cm)		Geometrical moment of inertia (cm⁴)				Radius of gyration of area (cm)				tan α	Modulus of section (cm³)	
A	t	d	r_1	r_2			Cx	Cy	Ix	Iy	max. Iu	min. Iv	ix	iy	max. iu	min. iv		Zx	Zy
180	9.5	23	7	2	21.06	16.5	7.49	0.746	671	9.48	673	7.34	5.64	0.671	5.65	0.591	0.0568	63.8	3.79
200	10	26.5	8	2	25.23	19.8	8.16	0.834	997	15.1	1,000	11.4	6.29	0.773	6.30	0.672	0.0611	84.2	5.35
230	11	30	9	2	31.98	25.1	9.36	0.927	1,680	24.2	1,680	18.3	7.24	0.870	7.25	0.755	0.0599	123	7.62
250	12	33	10	2	38.13	29.9	10.1	1.02	2,360	35.2	2,370	26.4	7.87	0.960	7.88	0.832	0.0612	159	10.1

Remark: Available length is 6m-18m, Please contact us for other lengths.

Figure 5. Example of Material Data Collected [29]

The database is stored in Comma-Separated Values (CSV) format and contains information such as profile name, weight per unit length, cross-sectional dimensions, and the recommended profile manufacturer. The CSV format was selected because the material data are inherently tabular and are accessed primarily for data retrieval during geometry generation, making a more complex database management system unnecessary. Furthermore, CSV files can be easily maintained using commonly available spreadsheet software and integrated into the add-on with minimal processing overhead. The database is also readily scalable because new profile sizes, additional section series, manufacturers, or material properties can be incorporated by simply adding new records or fields without modifying the underlying data structure. This enables the same database to support the broader range of structural members required across different vessel types and sizes, from small craft to large commercial ships, while maintaining compatibility with the add-on's data retrieval workflow.

In addition to the profile database, engineering drawings of an existing cargo oil tank of product oil tanker were collected as the primary research object for validating the proposed add-on. The core of the primary research object that would be the reference for add-on development, existing structure remodeling, and program-generated BOM validation is longitudinal structural component of the ship. Cargo oil tank structure in midship area is chosen as a reference because the structural members on its construction were mostly comprised of the longitudinal structure, especially due to the existence of mandatory-applied structure like double bottom and wing tank [30] (Figure 6). Furthermore, the longitudinal structural member in midship area generally has less curvature, so the validation effort and the early development of the remodeling algorithm on the program would be far easier. The collected data consisted of the midship section drawing, which was obtained from the ship's design documentation and selected to represent longitudinal structural members commonly found in cargo oil tank construction. The longitudinal structural members in the midship section drawing would be identified and used as the reference for recreating the same structural arrangement using the developed add-on. Furthermore, the identified structure in the original engineering drawing. would also be used as reference to prepare manual BOM.

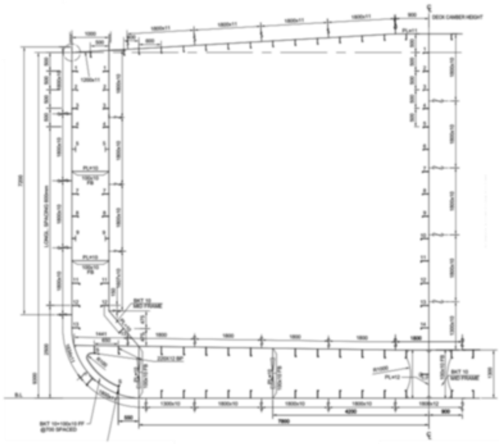


Figure 6. Illustration of the Midship Section Drawing Reference

Table 1. Reference Ship Reference Data

Ship Data	Value	Unit
Ship type	Product Oil Tanker	
LOA	108	meter
LPP	102	meter
Breadth Moulded	19.2	meter
Depth Moulded	9.3	meter
Draught Design	6	meter

2.2. Add-on Program Development

Overall, the add-on that will be developed consists of three main subprograms or algorithms, namely Drawing Tools, Part Identification, and BOM Calculation. Drawing Tools is a program that will be used in modeling the ship's cargo space structure. Part Identification is a program for recording information on each model generated by Drawing Tools, then applying identification labels to each model so that it can be detected as a part. BOM Calculation is a program that plays a role in calculating the BOM (bill of material) for each part in the ship structure model created by Drawing Tools. When combined, then the whole process of using those three for generate a midship section drawing and its BOM would follow flowchart shown in Figure 7.

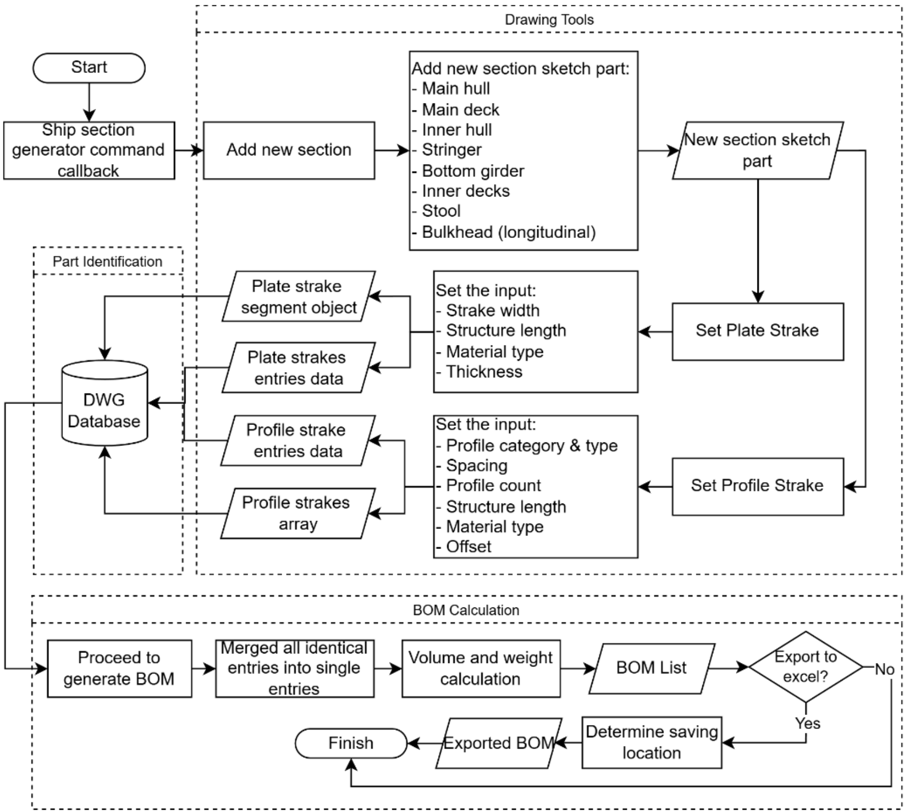


Figure 7. Complete Process of Add-on Use to Generate Midship Section Drawing and Its BOM

The three subprograms were developed using the C# programming language within the AutoCAD .NET API framework. C# was selected because it is the primary language supported by the AutoCAD .NET API, providing direct access to AutoCAD classes, methods, and drawing objects required for implementing automation algorithms. In addition, C# offers managed memory, object-oriented programming features, and extensive development support, enabling faster implementation and easier maintenance than lower-level alternatives such as C++ with ObjectARX.

The development approach adopts a modular architecture in which each subprogram performs an independent function while sharing common data and drawing resources. This modular design simplifies program development, testing, debugging, and future maintenance, as individual modules can be modified or extended without affecting the overall system. The profile database stored in CSV format serves as the common data source for all subprograms, allowing profile information to be updated independently of the program code. The selected approach offers several advantages, including seamless integration with the AutoCAD environment, simplified implementation through the AutoCAD .NET API, and flexibility for future expansion by incorporating additional profile data or automation functions. However, the approach is inherently dependent on the AutoCAD platform and the .NET framework, limiting its portability to other CAD software without substantial code modification.

2.2.1. BOM Calculation Program

The Drawing Tools program includes three main algorithms, namely Cargo Hold Section Sketch Drawing, Plate Strake Arrangement, and Profile Fitting Arrangement. Cargo Hold Section Sketch Drawing is an algorithm for creating sketch drawings of the transverse section of the ship's hull in the cargo hold. This algorithm is designed so that users can add sketches of the ship's hull cross-section based on the desired structural parts, such as the outer hull or main hull, inner hull, double bottom, main deck, and so on. The framework of this algorithm is roughly as illustrated in Figure 8.

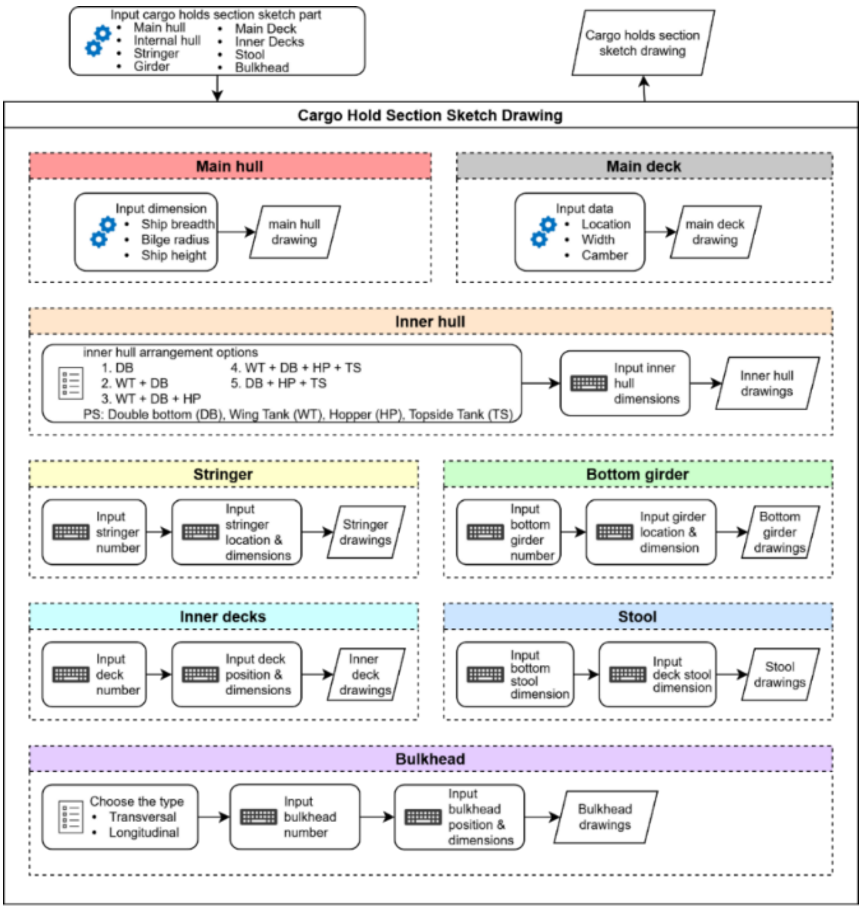


Figure 8. Cargo Hold Section Sketch Drawing Algorithm Framework

Each structural part sketch added will generate one sketch entry, which includes structural part characteristic data and images in the form of line or polyline objects representing cross-sections of the structural part. The characteristic data includes information such as the type of structural part, structure length, number of line objects in one entry, material type, and others that can also be adjusted by the user. The example of the drawings and its entry is shown in Figure 9.

The line drawings from each entry are then used by the Plate Strake Arrangement algorithm to add and arrange plate strakes according to the construction part. With this algorithm, users can add plate strake segments to each line in a single structural part sketch entry and can edit existing plate strake segments. When a segment is added to a line, the segment symbol will appear in the line, and a new plate strake entry will appear in the plate strake list. Each line in a structural part sketch entry has its own plate strake list, and each plate strake entry will include a set of segment symbols and plate strake characteristics, which contain information such as segment width, plate thickness, material type, unit weight, and so on. Some plate strake segment characteristic data is taken from the characteristic data of the parent structural part sketch entry, such as structure length and material type. This means that there is characteristic data for plate strakes that depends on the data belonging to the structural part sketch entry. The Profile Fitting Arrangement algorithm works in much the same way as Plate Strake Arrangement, the only difference being in the entry. As the name suggests, Profile Fitting Arrangement will generate profile component entries that include profile cross-sectional drawings and their characteristics, such as profile type, number of profiles in a line, material type, and so on. The list of characteristic data from the structural part sketch, plate strake, and profile components can be seen in Table 2, while the example of plate strake and profile components objects and entries can be seen in Figure 10 and Figure 11.

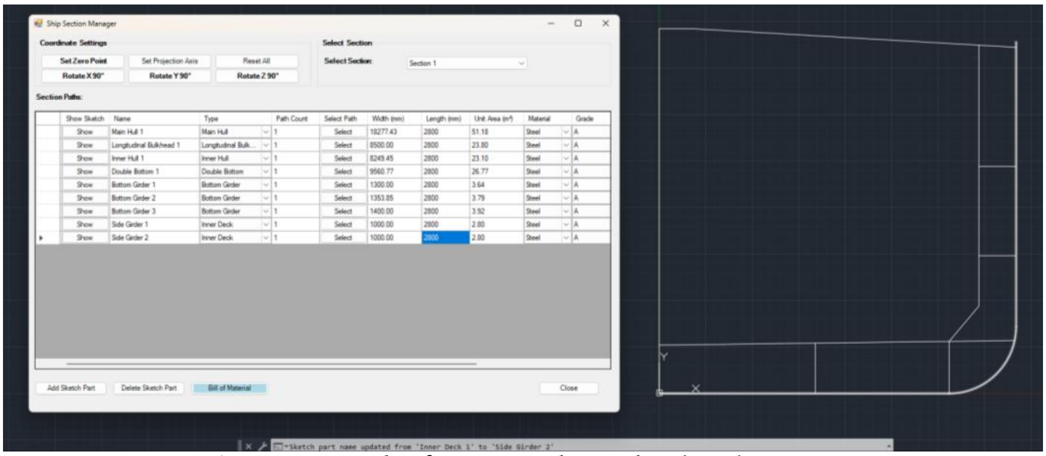
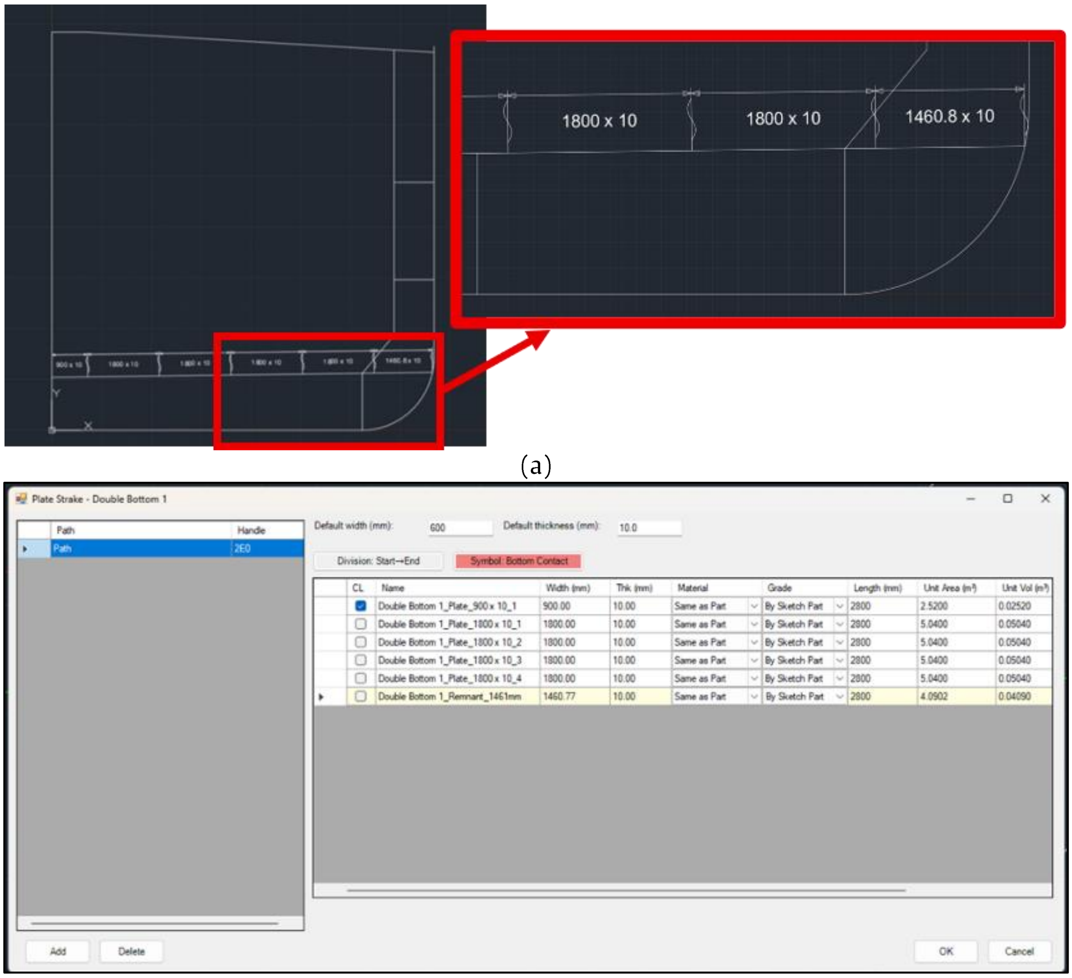


Figure 9. Example of a Structural Part Sketch and Its Entry



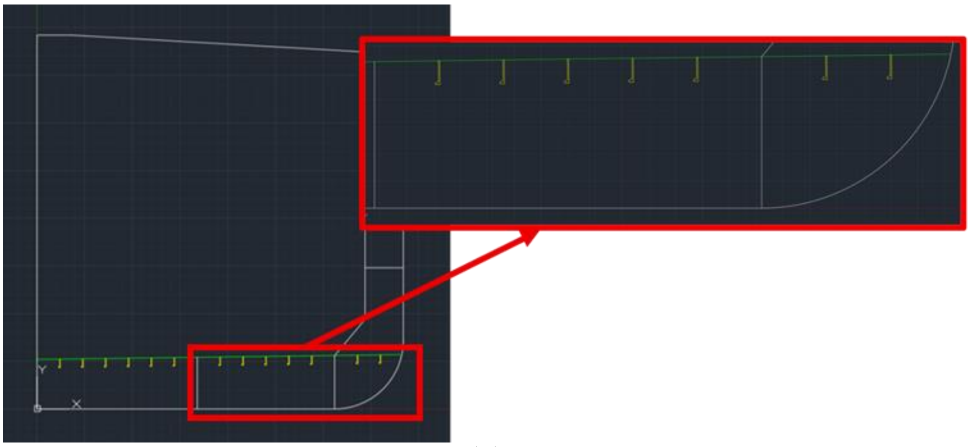
(a)

(b)

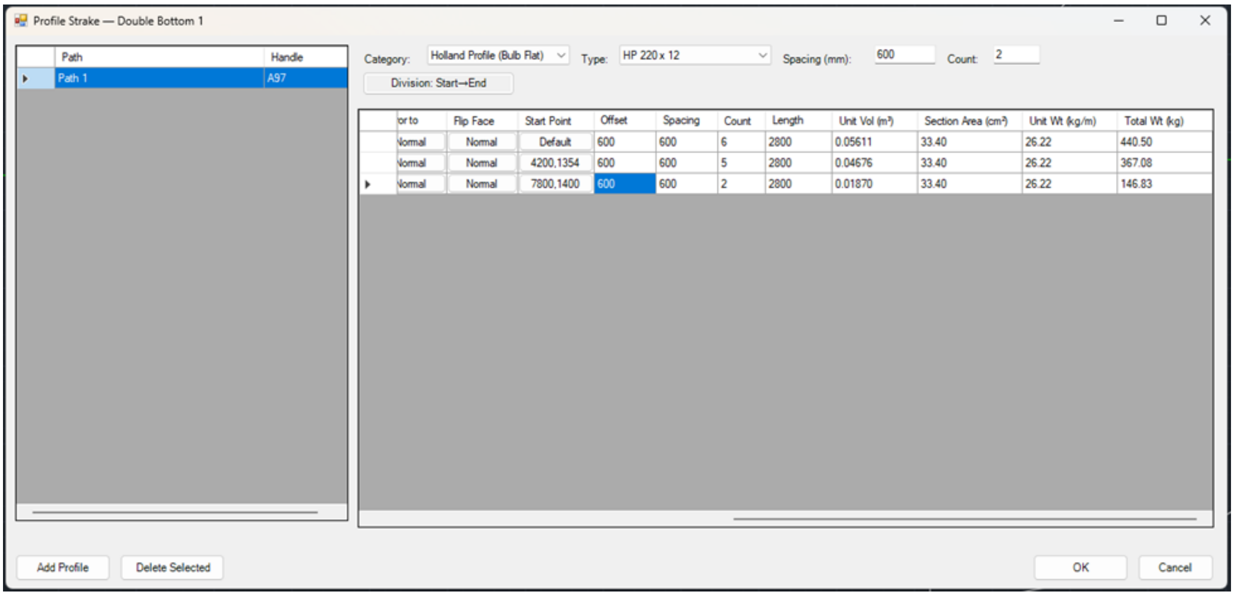
Figure 10. Example of Plate Strake Segment (a) and Its Entries (b)

Table 2. Characteristics Data of Structural Sketch Part, Plate Strakes, and Profile Components

Structural Sketch Part	Plate Strake	Profile Components
1. Select	1. Name (strake name)	1. Name
2. Show	2. Width (mm)	2. Profile Category
3. Name	3. Thickness (mm)	3. Profile Type
4. Type	4. Material (type)	4. Material (type)
5. Path Count	5. Material Grade	5. Materia Grade
6. Width (mm) - (total path length)	6. Structure Length (mm) - (Longitudinal length)	6. Spacing (mm)
7. Length (mm) - (Longitudinal length)		7. Profile Count
8. Unit Area (m^2)	7. Unit Area (m^2)	8. Length (mm) - (Longitudinal length)
9. Material (type)	8. Unit Volume (m^3)"	
10. Material Grade	9. Density (t/m^3)	9. Unit Vol (m^3)
11. Density (ton/m^3)	10. Unit Weight (ton)	10. Section Area (cm^2)
		11. Unit Weight (kg/m)
		12. Total Weight (kg)



(a)



(b)

Figure 11. Example of Profile Components (a) and Its Entries (b)

2.2.2. Part Identification Algorithm

Part Identification is a part of add-on program that aims to record information about each object generated by Drawing Tools, then attach it to each object so that it can be automatically identified as a part when an entry and image object are added by Drawing Tools. This program also includes the algorithm behind the automatic naming system for each entry. The purpose of this program is to ensure that all characteristic data within an entry is always embedded into each object generated by Drawing Tools, whether it be a structural part sketch, plate strake segment, or profile component. This way, data from each generated object can be retrieved for bill of material compilation.

2.2.3. BOM Calculation Program

From each plate strake characteristic data and profile component in the entry list, the BOM Calculation program will recapitulate all existing entries to obtain a list of plates and profiles in all objects that have been created. In the recapitulation, the program will detect several plate and profile entries that have identical characteristic data, then combine them into one new entry. The new entry will also have a new name. The criteria for plate or profile entries to be considered identical are when several entries have the same structure type, dimensions, and material type. The result of this program is a bill of material (BOM) list window, which can also be exported to Excel, as shown in Figure 12.

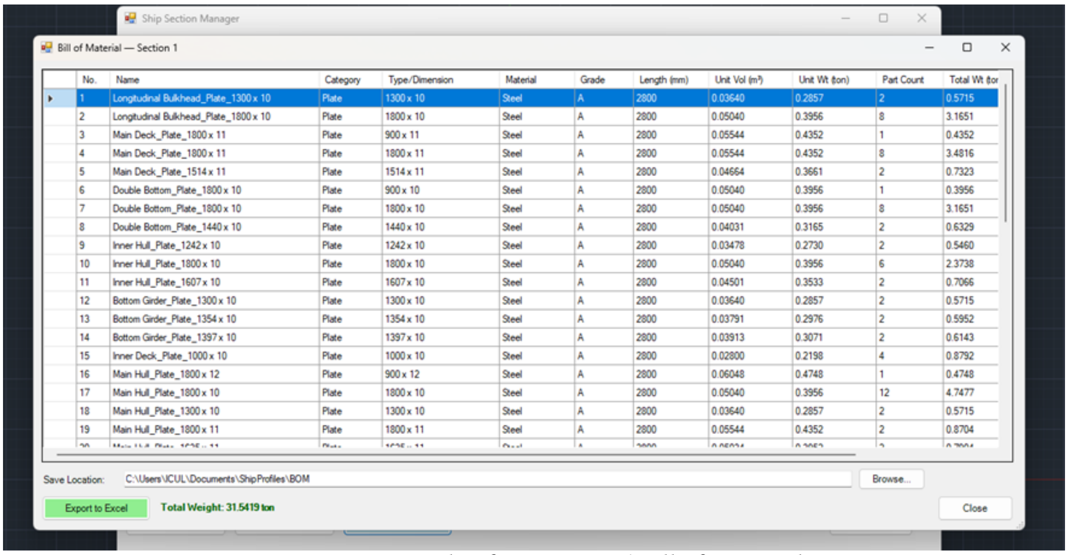


Figure 12. Example of a Generated Bill of Materials

2.3. Midship Section Remodeling using Add-on

After the development of the AutoCAD add-on was completed, the midship section of the reference product oil tanker was reconstructed using the developed program. The reconstructed structural member of the midship section is limited to the longitudinal structure members only. During this process, the structural members were recreated by selecting the appropriate plate strakes and profile sections from the material database and assigning their corresponding geometric parameters according to the reference drawing. The remodeling process was carried out to reproduce the structural arrangement of the reference ship as closely as possible while utilizing only the functions provided by the developed add-on. Once the remodeling was completed, the add-on automatically extracted the data needed to prepare the corresponding bill of materials (BOM), including information on structural components, dimensions, material specifications, quantities, and calculated weights. The generated BOM was subsequently used as the primary dataset for the validation process.

2.4. Calculation of BOM Manual

To evaluate the accuracy of the developed add-on, a reference bill of materials was prepared manually using the same midship section drawing. The manual BOM was generated by identifying each structural member from the engineering drawing, determining its dimensions, material specifications, and quantity, and subsequently calculating the weight of each component using conventional engineering calculations based on its geometric dimensions and material properties. The individual component weights were then summed to obtain the total structural weight. This manually prepared BOM served as the benchmark for validating the BOM generated automatically by the developed add-on.

2.5. Validation of the BOM Generated by the Program

The BOM obtained from the add-on program is then validated by comparing the add-on BOM with the manually calculated BOM for the reference ship structure in the same section that was created using Drawing Tools. The parameters compared are the weight data per part between the add-on BOM and the manual BOM. The purpose of this process is to ensure that the comparison results of the two methods have a minimum error value, with a target error of ≤1%.

3. Results and Discussion

The developed AutoCAD add-on was evaluated by applying it to the midship section of the reference product oil tanker introduced in Section 2. The evaluation was conducted following the same sequence as the flowchart in Figure 4, beginning with the generation of the midship section, followed by the extraction of the bill of materials (BOM), and finally the validation of the add-on generated BOM against manually prepared BOM. By using manual BOM which is prepared using existing structure design as the validation object, the accuracy of the developed add-on can be evaluated under realistic shipbuilding conditions.

The midship section of the ship was then redrawn using add-ons to resemble the original midship section drawings as closely as possible. In the add-on entry, the length value of the structure on the longitudinal axis of the ship used is 2800 mm, which is the distance between the web frames of the reference ship structure design.

3.1. Berthing Maneuver Simulation for Scenario 1

The first stage of the evaluation process was the reconstruction of the cargo hold midship section using the developed AutoCAD add-on. The structural arrangement of the generated model was created by assigning the corresponding plate strakes and profile members based on the dimensions and material data provided through the add-on. Remodeling technical process follows exactly like the process in Figure 7, starting with the generation of sketch part, then continue with determining the plate strake segment and profile strake. The result of that process would be drawings of the longitudinal structure member (plate and profile) from the reference midship section drawing, including the main hull, inner hull, longitudinal bulkhead, main deck, and the longitudinal stiffeners.

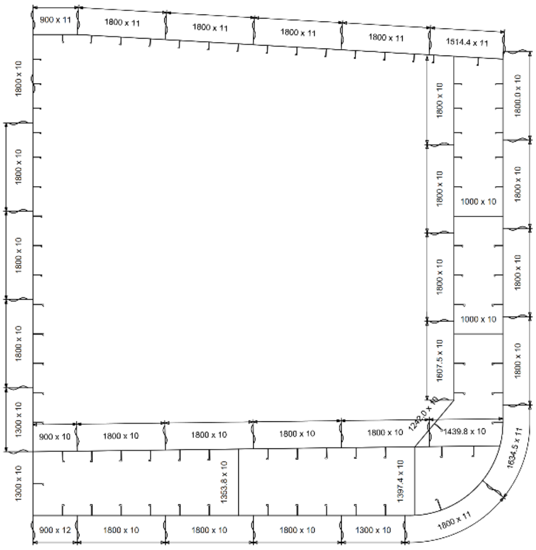


Figure 13. Redraw Result of Ship Reference' s Cargo Hold Sectional Structure Drawing

Figure 13 shows the results of generated sketch part, plate strakes, and profile strakes of the reference midship section. From that image, it can be said that the developed add-on can generate the drawing of longitudinal structural members while maintaining the geometric arrangement of the reference drawing. This result demonstrates that the implemented drawing algorithms can accurately interpret the input parameters and generate the corresponding structural geometry. Consequently, the generated drawing provides a suitable basis for the subsequent extraction of the bill of materials.

3.2. BOM Extracted from Add-on

After the midship section remodeling was completed, the add-on automatically extracted the structural information to generate a bill of materials (BOM). During this process, structural components with identical characteristics, including structure type, profile or plate dimensions, material, and longitudinal length, were consolidated into a single entry. Components located symmetrically about the centerline were automatically classified into portside (PS) and starboard (SB), while centerline components remained as individual entries. The generated BOM consists of detailed information for each structural component, including its category, dimensions, material grade, unit volume, unit weight, quantity, and total weight, as shown in the Table 3.

Table 3. Export Results of Bill of Material Generated by Add-on

No.	Name	Category	Type/ Dimension	Material	Material Grade	Length (mm)	Unit Volume (m^3)	Unit Weight (ton)	Part Count	Total Weight (ton)
1	Bottom Girder_Plate_1300 x 10_CL	Plate	1300 x 10	Steel	A	2800	0.0364	0.2858	1	0.2858
2	Bottom Girder_Plate_1354 x 10_PS	Plate	1354 x 10	Steel	A	2800	0.0379	0.2976	1	0.2976
3	Bottom Girder_Plate_1354 x 10_SB	Plate	1354 x 10	Steel	A	2800	0.0379	0.2976	1	0.2976
4	Bottom Girder_Plate_1397 x 10_PS	Plate	1397 x 10	Steel	A	2800	0.0391	0.3072	1	0.3072
5	Bottom Girder_Plate_1397 x 10_SB	Plate	1397 x 10	Steel	A	2800	0.0391	0.3072	1	0.3072
6	Double Bottom_Plate_1440 x 10_PS	Plate	1440 x 10	Steel	A	2800	0.0403	0.3165	1	0.3165
7	Double Bottom_Plate_1440 x 10_SB	Plate	1440 x 10	Steel	A	2800	0.0403	0.3165	1	0.3165
8	Double Bottom_Plate_1800 x 10_CL	Plate	1800 x 10	Steel	A	2800	0.0504	0.3956	1	0.3956
9	Double Bottom_Plate_1800 x 10_PS	Plate	1800 x 10	Steel	A	2800	0.0504	0.3956	4	1.5826
10	Double Bottom_Plate_1800 x 10_SB	Plate	1800 x 10	Steel	A	2800	0.0504	0.3956	4	1.5826
11	Inner Deck_Plate_1000 x 10_PS	Plate	1000 x 10	Steel	A	2800	0.0280	0.2198	2	0.4396
12	Inner Deck_Plate_1000 x 10_SB	Plate	1000 x 10	Steel	A	2800	0.0280	0.2198	2	0.4396
13	Inner Hull_Plate_1242 x 10_PS	Plate	1242 x 10	Steel	A	2800	0.0348	0.2730	1	0.2730
14	Inner Hull_Plate_1242 x 10_SB	Plate	1242 x 10	Steel	A	2800	0.0348	0.2730	1	0.2730
15	Inner Hull_Plate_1607 x 10_PS	Plate	1607 x 10	Steel	A	2800	0.0450	0.3533	1	0.3533
16	Inner Hull_Plate_1607 x 10_SB	Plate	1607 x 10	Steel	A	2800	0.0450	0.3533	1	0.3533
17	Inner Hull_Plate_1800 x 10_PS	Plate	1800 x 10	Steel	A	2800	0.0504	0.3956	3	1.1869
18	Inner Hull_Plate_1800 x 10_SB	Plate	1800 x 10	Steel	A	2800	0.0504	0.3956	3	1.1869

No.	Name	Category	Type/ Dimension	Material	Material Grade	Length (mm)	Unit Volume (m³)	Unit Weight (ton)	Part Count	Total Weight (ton)
19	Longitudinal Bulkhead_Plate_1300 x 10_CL	Plate	1300 x 10	Steel	A	2800	0.0364	0.2858	1	0.2858
20	Longitudinal Bulkhead_Plate_1800 x 10_CL	Plate	1800 x 10	Steel	A	2800	0.0504	0.3956	4	1.5826
21	Main Deck_Plate_1514 x 11_PS	Plate	1514 x 11	Steel	A	2800	0.0466	0.3662	1	0.3662
22	Main Deck_Plate_1514 x 11_SB	Plate	1514 x 11	Steel	A	2800	0.0466	0.3662	1	0.3662
23	Main Deck_Plate_1800 x 11_CL	Plate	1800 x 11	Steel	A	2800	0.0554	0.4352	1	0.4352
24	Main Deck_Plate_1800 x 11_PS	Plate	1800 x 11	Steel	A	2800	0.0554	0.4352	4	1.7408
25	Main Deck_Plate_1800 x 11_SB	Plate	1800 x 11	Steel	A	2800	0.0554	0.4352	4	1.7408
26	Main Hull_Plate_1300 x 10_PS	Plate	1300 x 10	Steel	A	2800	0.0364	0.2858	1	0.2858
27	Main Hull_Plate_1300 x 10_SB	Plate	1300 x 10	Steel	A	2800	0.0364	0.2858	1	0.2858
28	Main Hull_Plate_1635 x 11_PS	Plate	1635 x 11	Steel	A	2800	0.0503	0.3952	1	0.3952
29	Main Hull_Plate_1635 x 11_SB	Plate	1635 x 11	Steel	A	2800	0.0503	0.3952	1	0.3952
30	Main Hull_Plate_1800 x 10_PS	Plate	1800 x 10	Steel	A	2800	0.0504	0.3956	7	2.7695
31	Main Hull_Plate_1800 x 10_SB	Plate	1800 x 10	Steel	A	2800	0.0504	0.3956	7	2.7695
32	Main Hull_Plate_1800 x 11_PS	Plate	1800 x 11	Steel	A	2800	0.0554	0.4352	1	0.4352
33	Main Hull_Plate_1800 x 11_SB	Plate	1800 x 11	Steel	A	2800	0.0554	0.4352	1	0.4352
34	Main Hull_Plate_1800 x 12_CL	Plate	1800 x 12	Steel	A	2800	0.0605	0.4748	1	0.4748
35	Bottom Girder_HP 220 x 12_CL	Profile	HP 220 x 12	Steel	A	2800	0.0094	0.0734	1	0.0734
36	Double Bottom_HP 220 x 12_PS	Profile	HP 220 x 12	Steel	A	2800	0.0094	0.0734	13	0.9542
37	Double Bottom_HP 220 x 12_SB	Profile	HP 220 x 12	Steel	A	2800	0.0094	0.0734	13	0.9542
38	Inner Hull_HP 160 x 9_PS	Profile	HP 160 x 9	Steel	A	2800	0.0050	0.0391	5	0.1955
39	Inner Hull_HP 160 x 9_SB	Profile	HP 160 x 9	Steel	A	2800	0.0050	0.0391	5	0.1955
40	Inner Hull_HP 180 x 10_PS	Profile	HP 180 x 10	Steel	A	2800	0.0063	0.0494	2	0.0988
41	Inner Hull_HP 180 x 10_SB	Profile	HP 180 x 10	Steel	A	2800	0.0063	0.0494	2	0.0988
42	Inner Hull_HP 220 x 12_PS	Profile	HP 220 x 12	Steel	A	2800	0.0094	0.0734	4	0.2936
43	Inner Hull_HP 220 x 12_SB	Profile	HP 220 x 12	Steel	A	2800	0.0094	0.0734	4	0.2936
44	Longitudinal Bulkhead_HP 160 x 9_CL	Profile	HP 160 x 9	Steel	A	2800	0.0050	0.0391	6	0.2346
45	Longitudinal Bulkhead_HP 180 x 10_CL	Profile	HP 180 x 10	Steel	A	2800	0.0063	0.0494	3	0.1482
46	Longitudinal Bulkhead_HP 220 x 12_CL	Profile	HP 220 x 12	Steel	A	2800	0.0094	0.0734	5	0.3670
47	Main Deck_HP 160 x 9_PS	Profile	HP 160 x 9	Steel	A	2800	0.0050	0.0391	15	0.5865
48	Main Deck_HP 160 x 9_SB	Profile	HP 160 x 9	Steel	A	2800	0.0050	0.0391	15	0.5865
49	Main Hull_HP 160 x 9_PS	Profile	HP 160 x 9	Steel	A	2800	0.0050	0.0391	5	0.1955
50	Main Hull_HP 160 x 9_SB	Profile	HP 160 x 9	Steel	A	2800	0.0050	0.0391	5	0.1955
51	Main Hull_HP 180 x 10_PS	Profile	HP 180 x 10	Steel	A	2800	0.0063	0.0494	2	0.0988
52	Main Hull_HP 180 x 10_SB	Profile	HP 180 x 10	Steel	A	2800	0.0063	0.0494	2	0.0988
53	Main Hull_HP 220 x 12_PS	Profile	HP 220 x 12	Steel	A	2800	0.0094	0.0734	15	1.1010
54	Main Hull_HP 220 x 12_SB	Profile	HP 220 x 12	Steel	A	2800	0.0094	0.0734	15	1.1010
55	Main Hull_HP 240 x 12_PS	Profile	HP 240 x 12	Steel	A	2800	0.0104	0.0820	1	0.0820
56	Main Hull_HP 240 x 12_SB	Profile	HP 240 x 12	Steel	A	2800	0.0104	0.0820	1	0.0820
	TOTAL								**150**	**32.9930**

3.3. Preparation of the Manual Bill of Materials

Using the same midship section drawing that served as a reference for the remodeling, a manual BOM was then created separately for the identified longitudinal structural components. The identified components were then organized into separate lists of structural plates and profiles. Next, based on the geometric dimensions of each structural component, the weight of each entry in the list was calculated. The calculated manual BOM can be seen in Table 4 and Table 5.

Table 4. Manual BOM (Plates)

No	Name	Structure Part	Position	Width (mm)	Thickness (mm)	Material	Length (mm)	Unit Volume (m³)	Unit Weight (ton)	Qty	Total Weight (ton)
1	Bottom Girder_1300 x 10_CL	Bottom Girder	CL	1300	10	Steel	2800	0.036	0.286	1	0.286
2	Bottom Girder_1354 x 10_PS	Bottom Girder	PS	1354	10	Steel	2800	0.038	0.298	1	0.298
3	Bottom Girder_1354 x 10_SB	Bottom Girder	SB	1354	10	Steel	2800	0.038	0.298	1	0.298
4	Bottom Girder_1397 x 10_PS	Bottom Girder	PS	1397	10	Steel	2800	0.039	0.307	1	0.307
5	Bottom Girder_1397 x 10_SB	Bottom Girder	SB	1397	10	Steel	2800	0.039	0.307	1	0.307
6	Double Bottom_1440 x 10_PS	Double Bottom	PS	1441	10	Steel	2800	0.040	0.317	1	0.317
7	Double Bottom_1440 x 10_SB	Double Bottom	SB	1441	10	Steel	2800	0.040	0.317	1	0.317
8	Double Bottom_1800 x 10_CL	Double Bottom	CL	1800	10	Steel	2800	0.050	0.396	1	0.396
9	Double Bottom_1800 x 10_PS	Double Bottom	PS	1800	10	Steel	2800	0.050	0.396	4	1.583

No	Name	Structure Part	Position	Width (mm)	Thickness (mm)	Material	Length (mm)	Unit Volume (m³)	Unit Weight (ton)	Qty	Total Weight (ton)
10	Double Bottom_1800 x 10_SB	Double Bottom	SB	1800	10	Steel	2800	0.050	0.396	4	1.583
33	Side Girder_1000 x 10_PS	Side Girder	PS	1000	10	Steel	2800	0.028	0.220	2	0.440
34	Side Girder_1000 x 10_SB	Side Girder	SB	1000	10	Steel	2800	0.028	0.220	2	0.440
11	Inner Hull_1242 x 10_PS	Inner Hull	PS	1242	10	Steel	2800	0.035	0.273	1	0.273
12	Inner Hull_1242 x 10_SB	Inner Hull	SB	1242	10	Steel	2800	0.035	0.273	1	0.273
13	Inner Hull_1607 x 10_PS	Inner Hull	PS	1607	10	Steel	2800	0.045	0.353	1	0.353
14	Inner Hull_1607 x 10_SB	Inner Hull	SB	1607	10	Steel	2800	0.045	0.353	1	0.353
15	Inner Hull_1800 x 10_PS	Inner Hull	PS	1800	10	Steel	2800	0.050	0.396	3	1.187
16	Inner Hull_1800 x 10_SB	Inner Hull	SB	1800	10	Steel	2800	0.050	0.396	3	1.187
17	Longitudinal Bulkhead_1300 x 10_CL	Longitudinal Bulkhead	CL	1300	10	Steel	2800	0.036	0.286	1	0.286
18	Longitudinal Bulkhead_1800 x 10_CL	Longitudinal Bulkhead	CL	1800	10	Steel	2800	0.050	0.396	4	1.583
19	Main Deck_1514 x 11_PS	Main Deck	PS	1514	11	Steel	2800	0.047	0.366	1	0.366
20	Main Deck_1514 x 11_SB	Main Deck	SB	1514	11	Steel	2800	0.047	0.366	1	0.366
21	Main Deck_1800 x 11_CL	Main Deck	CL	1800	11	Steel	2800	0.055	0.435	1	0.435
22	Main Deck_1800 x 11_PS	Main Deck	PS	1800	11	Steel	2800	0.055	0.435	4	1.741
23	Main Deck_1800 x 11_SB	Main Deck	SB	1800	11	Steel	2800	0.055	0.435	4	1.741
24	Main Hull_1300 x 10_PS	Main Hull	PS	1300	10	Steel	2800	0.036	0.286	1	0.286
25	Main Hull_1300 x 10_SB	Main Hull	SB	1300	10	Steel	2800	0.036	0.286	1	0.286
26	Main Hull_1634 x 11_PS	Main Hull	PS	1634	11	Steel	2800	0.050	0.395	1	0.395
27	Main Hull_1634 x 11_SB	Main Hull	SB	1634	11	Steel	2800	0.050	0.395	1	0.395
28	Main Hull_1800 x 10_PS	Main Hull	PS	1800	10	Steel	2800	0.050	0.396	7	2.769
29	Main Hull_1800 x 10_SB	Main Hull	SB	1800	10	Steel	2800	0.050	0.396	7	2.769
30	Main Hull_1800 x 11_PS	Main Hull	PS	1800	11	Steel	2800	0.055	0.435	1	0.435
31	Main Hull_1800 x 11_SB	Main Hull	SB	1800	11	Steel	2800	0.055	0.435	1	0.435
32	Main Hull_1800 x 12_CL	Main Hull	CL	1800	12	Steel	2800	0.060	0.475	1	0.475
	Total									**67**	**24.9578**

Table 5. Manual BOM (Profiles)

No.	Name	Structure Part	Position	Profile type	Section Area (cm²)	Material	Length (mm)	Unit Volume (m³)	Unit Weight (kg/m)	Qty	Total Weight (ton)
1	Bottom Girder_HP 220 x 12_CL	Bottom Girder	CL	HP 220 x 12	33.4	Steel	2800	0.009	26.22	1	0.073
2	Double Bottom_HP 220 x 12_PS	Double Bottom	PS	HP 220 x 12	33.4	Steel	2800	0.009	26.22	13	0.954
3	Double Bottom_HP 220 x 12_SB	Double Bottom	SB	HP 220 x 12	33.4	Steel	2800	0.009	26.22	13	0.954
4	Inner Hull_HP 160 x 9_PS	Inner Hull	PS	HP 160 x 9	17.8	Steel	2800	0.005	13.97	5	0.196
5	Inner Hull_HP 160 x 9_SB	Inner Hull	SB	HP 160 x 9	17.8	Steel	2800	0.005	13.97	5	0.196
6	Inner Hull_HP 180 x 10_PS	Inner Hull	PS	HP 180 x 10	22.46	Steel	2800	0.006	17.63	2	0.099
7	Inner Hull_HP 180 x 10_SB	Inner Hull	SB	HP 180 x 10	22.46	Steel	2800	0.006	17.63	2	0.099
8	Inner Hull_HP 220 x 12_PS	Inner Hull	PS	HP 220 x 12	33.4	Steel	2800	0.009	26.22	4	0.294
9	Inner Hull_HP 220 x 12_SB	Inner Hull	SB	HP 220 x 12	33.4	Steel	2800	0.009	26.22	4	0.294
10	Longitudinal Bulkhead_HP 160 x 9_CL	Longitudinal Bulkhead	CL	HP 160 x 9	17.8	Steel	2800	0.005	13.97	6	0.235
33	Longitudinal Bulkhead_HP 180 x 10_CL	Longitudinal Bulkhead	CL	HP 180 x 10	22.46	Steel	2800	0.006	17.63	3	0.148
34	Longitudinal Bulkhead_HP 220 x 12_CL	Longitudinal Bulkhead	CL	HP 220 x 12	33.4	Steel	2800	0.009	26.22	5	0.367
11	Main Deck_HP 160 x 9_PS	Main Deck	PS	HP 160 x 9	17.8	Steel	2800	0.005	13.97	15	0.587
12	Main Deck_HP 160 x 9_SB	Main Deck	SB	HP 160 x 9	17.8	Steel	2800	0.005	13.97	15	0.587
13	Main Hull_HP 160 x 9_PS	Main Hull	PS	HP 160 x 9	17.8	Steel	2800	0.005	13.97	5	0.196
14	Main Hull_HP 160 x 9_SB	Main Hull	SB	HP 160 x 9	17.8	Steel	2800	0.005	13.97	5	0.196
15	Main Hull_HP 180 x 10_PS	Main Hull	PS	HP 180 x 10	22.46	Steel	2800	0.006	17.63	2	0.099
16	Main Hull_HP 180 x 10_SB	Main Hull	SB	HP 180 x 10	22.46	Steel	2800	0.006	17.63	2	0.099
17	Main Hull_HP 220 x 12_PS	Main Hull	PS	HP 220 x 12	33.4	Steel	2800	0.009	26.22	15	1.101

No.	Name	Structure Part	Position	Profile type	Section Area (cm²)	Material	Length (mm)	Unit Volume (m³)	Unit Weight (kg/m)	Qty	Total Weight (ton)
18	Main Hull_HP 220 × 12_SB	Main Hull	SB	HP 220 x 12	33.4	Steel	2800	0.009	26.22	15	1.101
19	Main Hull_HP 240 × 12_PS	Main Hull	PS	HP 240 x 12	37.29	Steel	2800	0.010	29.27	1	0.082
20	Main Hull_HP 240 × 12_SB	Main Hull	SB	HP 240 x 12	37.29	Steel	2800	0.010	29.27	1	0.082
21	Bottom Girder_HP 220 × 12_CL	Bottom Girder	CL	HP 220 x 12	33.4	Steel	2800	0.009	26.22	1	0.073
22	Double Bottom_HP 220 × 12_PS	Double Bottom	PS	HP 220 x 12	33.4	Steel	2800	0.009	26.22	13	0.954
	Total									**139**	**8.0365**

3.4. Validation of the Generated Bill of Materials

The accuracy of the developed add-on was evaluated by comparing the automatically generated BOM with a manually prepared BOM for the same sectional structure. The comparison was performed separately for plate components, profile components, and the total structural weight. The comparison results can be seen in Table 6.

Table 6. Comparison Results of Add-on Generated BOM and Manual Prepared BOM

Item	Weight (ton)		Difference (%)
	Add-on BOM	Manual BOM	
a	*b*	*c*	*d = (b-c)/c*
Plate components	24.9580	24.9578	0.0010%
Profile components	8.0350	8.0365	-0.0191%
Overall components	32.9930	32.9943	-0.0039%

Based on the comparison results, the calculated differences are only 0.0010% for plate components, -0.0191% for profile components, and -0.0039% for the total structural weight. Among the components compared, the largest deviation is observed in the profile components, where the add-on generates total weight approximately 1.5 kg lower than the manual BOM. When compared to profile components total weight of the add-on BOM, it can be determined that for every ton of profile weight calculated with the add-on, there is a deviation of 0.187 kg. Although the deviation is relatively small in practical terms, it is noticeably higher than that of the plate components. This difference is attributable to the profile weight calculation method, which relies on unit weight data obtained from various structural profile manufacturer catalogs. Since slight differences may exist among product catalogs and reference data, further investigation of the profile database and alternative weight calculation methods is recommended to further improve the accuracy of the generated BOM.

In contrast, the difference in plate component weight between the add-on BOM and the manual BOM is relatively small, only about 0.0002 tons or 0.2 kg. When measured by the deviation ratio per ton of weight, every ton of plate would result in deviation of about 0.008 kg per ton or 8 grams per ton. This minor difference is primarily attributed to the different levels of numerical precision between BOM from add-on and manual BOM. The manual BOM is derived from engineering drawings, where dimensions have generally been rounded during the drafting process, whereas the developed add-on extracts geometric information directly from the digital drawing model with a higher level of decimal precision. Consequently, the calculated plate weights from the add-on are expected to exhibit slightly different values while remaining in close agreement with the manually calculated results.

Overall, the validation results show that the developed add-on can accurately generate bill of materials data for ship structural components, with only negligible deviations from conventional manual calculations. These findings are consistent with previous studies reporting that automated BOM generation improves data consistency and reduces manual processing while maintaining engineering accuracy, thereby supporting the applicability of the developed add-on for practical ship structural design.

4. Conclusion

An add-on was successfully developed in this study as an alternative way to enhance the data consistency and efficiency to prepare bill of material of in design stage, by using cargo oil tank longitudinal structure member in midship area as study case and reference. The add-on is developed to integrates midship section structural drawing with automatic Bill of Materials (BOM) generation. The main idea of the add-on is to embed geometrical and material information to the geometry object of midship section drawing created by the add-on. By utilizing the information embedded in the structural model, the developed add-on is capable of automatically extracting structural component data, calculating material quantities, and exporting a standardized BOM. This integrated workflow eliminates repetitive manual data transcription during BOM preparation, thereby improving data consistency and reducing the potential for human error associated with conventional BOM transformation between engineering and downstream shipyard divisions. The developed add-on was validated using manually prepared BOM based on information of longitudinal structure members from midship section of an existing product oil tanker. Comparison between the automatically generated BOM and manually prepared BOM demonstrated excellent agreement, with deviations of only 0.0010% for plate components, -0.0191% for profile components, and -0.0039% for the total structural weight. These results confirm that the developed add-on can reliably generate accurate BOM data while significantly simplifying the BOM preparation process compared with conventional manual methods. Although the proposed approach demonstrates satisfactory performance, the accuracy of profile weight calculations remains dependent on the quality and consistency of the profile database. Future research should therefore focus on improving the profile database, investigating geometry-based profile weight calculation methods, and extending the developed add-on to support additional structural configurations and broader ship design applications.

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