



The Development of Stowage Planning Model for General Cargo Ship and Cargo Barge Vessel

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Abstract

As a maritime country whose water area is three times wider than its land, Indonesia has one of the ways to increase the logistic activities especially in adjusting to the development of the industry 4.0 by enhancing the productivity of maritime logistics in a way of streamlining the action at unit terminal containers. Stevedoring is a one of very important logistics activities in port operational ecosystem. In order to optimize the performance of the port, the efficiency of the stowage planning process is done. Some factors which can be evolved in stowage planning are processing time, ship stability, and minimum over stow. This research uses the stowage planning algorithm to develop an application in Python programming language. This application will eventually be used to create a stowage plan map for general cargo ship and cargo barge vessel in by prioritizing the ship stability, as well avoiding low over stow in a short time. With Python programming language a routine operational four hours job that used Microsoft Excel, only requires far less time with 10-15 seconds.

Keywords— stowage planning, maritime logistics, python, general cargo ship, cargo barge vessel

Abstrak

Pengembangan Model Perencanaan Stowage Untuk Kapal Kargo Umum Dan Kapal Tongkang Cargo; Pengembangan Model Perencanaan Stowage Untuk General Cargo Ship Dan Cargo Barge Vessel; Sebagai negara maritim yang wilayah perairannya tiga kali lebih luas dari daratannya, Indonesia memiliki salah satu cara untuk meningkatkan kegiatan logistik terutama dalam menyesuaikan diri dengan perkembangan industri 4.0 dengan meningkatkan produktivitas logistik maritim dengan cara mengefektifkan aksi. di unit terminal peti kemas. Bongkar muat merupakan salah satu kegiatan logistik yang sangat penting dalam ekosistem operasional pelabuhan. Dalam rangka optimalisasi kinerja pelabuhan, dilakukan efisiensi proses perencanaan stowage. Beberapa faktor yang dapat dikembangkan dalam perencanaan stowage adalah waktu proses, stabilitas kapal, dan minimum over stow. Penelitian ini menggunakan algoritma stowage planning untuk mengembangkan aplikasi dengan bahasa pemrograman Python. Aplikasi ini nantinya akan digunakan untuk membuat peta rencana stowage untuk kapal general cargo dan kapal cargo barge in dengan mengutamakan stabilitas kapal, serta menghindari *low over stow* dalam waktu singkat. Dengan bahasa pemrograman Python pekerjaan empat jam operasional rutin yang menggunakan Microsoft Excel, hanya membutuhkan waktu yang jauh lebih sedikit dengan 10-15 detik.

Kata kunci— perencanaan penyimpanan, logistik maritim, *Python*, kapal kargo umum, kapal tongkang kargo.

1. Introduction

Unwittingly, no day will pass without a logistical role in life on this earth. Logistics is not just the transfer of containers by a truck, or a package carried by a courier on a motorbike. Logistics activities according to Waters (2003) in Asian et.al (2019) is a function that involves the transfer and storage of material in its journey from the sender and regulating the movement of goods through the supply chain to the end customer (Asian, et al., 2019). Everything that is done by humans, is a process of a supply chain that requires logistical activities. As a maritime country that has a waters area three times larger than land (Pang, et al., 2017). (2017) Indonesia is the largest archipelago country in the world so that the sea becomes the main means of logistics by more than 90%. Not only the sea, Indonesia also has

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implemented various other modes of logistics transportation. According to Demir (2015) the modes of logistics transportation are divided into four, namely the road (road), rail (rail), sea (maritime), and air (water) (Demir, et al., 2015).

The smooth logistics is influenced by various aspects of interests, both from human resources, the economy, the environment, the equipment being carried out, as well as the systems implemented. In maritime logistics activities, one of the crucial things that affects the smooth logistics activities is container terminal traffic. To increase the productivity of container terminals, Stahlbock et al. (2008) provides 5 main research subjects that can be done, they are stowage planning or placement of containers on a ship, berth allocation or pier allocation, crane utilization or crane allocation optimization, transport (truck) utilization or transportation optimization, and yard management / stacking or container buildup in the land stacking area (Stahlbock, et al., 2008). Of the five topics, this research will focus on the main points that are the core of the productivity of a traffic channel, port, or company, namely stowage planning or the placement of containers on board.

Stowage planning is the activity of mapping containers to be placed on board. Stowage planning activities are important activities because the ineffectiveness of stowage planning will result in a lot of losses for both the sender, receiver, company, and from the port. Ineffective stowage planning can increase waste such as loading and unloading work hours which become longer, and the costs incurred to sanitize containers that are not in their destination by doing a reshuffle. Stowage planning has other impacts that affect the operational activities of the ship, such as for the safety of the ship, preventing the crew from injury, preventing damage to the goods transported, preventing damage to the ship's equipment, and for optimizing the container containers available on the ship. This research will be carried out by developing a stowage planning system implemented by a company, PT X.

When conducting research on the stowage plan and its relationship to the stability of the ship, there are three factors that are calculated for stability of the ship (Ambrosino, et al., 2006). First is Horizontal Equilibrium, a condition where the weight of the front of the ship is the same as the back of the ship. This calculation is done to prevent trimming. According to Sihotang (2014) the difference in force moments between the front and the back of the ship is calculated as a tolerance limit (Sihotang, 2014). The second one is Cross Equilibrium, a condition where the weight of the ship's left side is the same as the ship's right side. This calculation is done to prevent the occurrence of heeling. Also, according to Sihotang (2014), the difference in force moments between the right and left side of the ship is calculated as a tolerance limit without carrying out the process of shifting containers with hill-climbing search. The last is Vertical Equilibrium, a condition where the weight of a container at a tier is greater than the container above it.

Along with the development of the industrial revolution 4.0, the small thing then integrated automation is a necessity for every company today. For companies engaged in shipping and logistics such as PT X, the application can accelerate the flow of logistics activities. The time needed in a logistics activity flow can be accelerated by replacing a manual process into automation, in this case the activity that can be implemented is the stowage planning process. During this time the mapping process stowage planning carried out by the company is mapping manually using Microsoft Excel, the average estimated workmanship for a ship is 4 hours depending on the number of containers to be transported by the ship.

There is no system or application to perform stowage planning calculations in company X, making the process of laying containers on board requires a long time. So, the application is needed to reduce the complexity of the stowage planning process, accelerate the time needed in the mapping process stowage planning without considering the number of containers to be transported, and provide more precise mapping results according to the prevailing stowage planning calculation theory. This research will focus on developing a stowage planning mapping application on both types of ships, General Cargo and Cargo Barge, by applying the stowage planning theory into a program with the Python programming language. Based on the background that has been explained before, the main problem to be explored in this study is to accelerate the mapping of stowage planning on General Cargo and Cargo Barge type ships by automation. The objectives of this research to minimize operational time for stowage planning by algorithm in Python language as adapted from Li et al. (Li, et al., 2018).

2. Methods

PT X is a company engaged in shipping, logistics and seaports located in Jakarta, Indonesia. PT X conducted a local expedition with the route Jakarta - Banjarmasin - Jakarta, Jakarta - Pontianak - Jakarta where in both routes there are different types of ships. For the Jakarta - Banjarmasin - Jakarta route, the expedition is carried out by the General Cargo ship while for the Jakarta - Pontianak - Jakarta route by the Cargo Barge ship (Hardjono, 2015).

In the implementation of stowage planning, so far PT X is still carrying out a manual process carried out by a planner from the company's Operational Team located in the port of Tanjung Priok. First, the planner collects containerized data that the lift transports by ship. Data collected consists of container number, container seal number, commodity, name of container sender, name of container owner (principal), size of container, type of container, gross tonnage of container, container status, contents of container done, loading status (stuffing), transshipment status, and additional information. After the container data to be transported by the ship has been completed, the planner then does the manual stowage planning mapping by considering the priority matters, namely the size of the container, the mass or gross tonnage of the container, the type of container, and the status of the transshipment. The mapping process for stowage planning is done using Microsoft Excel with an average estimated work time of 4 hours depending on the number of containers to be transported by the ship. When the stowage planning has been completed, the ship's chief

checks the feasibility of the stowage planning mapping which then gives approval so that the Port Team can begin laying containers on the ship.

One aspect that is prioritized in making stowage planning in this study is the aspect of ship stability. This aspect makes the container placement factor on the ship not only based on the size and status of the transshipment in its preparation, but also prioritizes the stability value of the balance from all sides of the ship. Based on the literature and previous research, there are several calculations that can be the basis for the stability assessment of a container ship. GM (Metacentric Height) is the distance between point G (Center of Gravity) and point M (Metacenter) where point M is determined by the ship's shift towards the center line or centerline. These two points determine the stability of the ship. The stability of the ship is divided into three levels of equilibrium. The following is the level of vessel balance based on GM point values. Stable Equilibrium or stable balance is a condition where Point M is above point G. Therefore, it can be concluded that the value of GM is positive and positive value is stable or $GM = (+) = \text{stable}$.

According to figure 1, Neutral Equilibrium or neutral balance is a condition where point M is tangent to point G. Therefore, it can be concluded that the value of GM is equal to 0 or absent. If the value of GM does not exist, then the ship's equilibrium state can be called neutral or $GM = 0 = \text{Neutral}$. Meanwhile according to figure 2 Unstable Equilibrium or unstable equilibrium is a condition where Point M is below point G. Therefore, it can be concluded that the value of GM is negative and negative value is equal to unstable or $GM = (-) = \text{Unstable}$.

Heel is the difference in balance between the right and the left side of the ship. The balance between the right and left of the ship really needs to be adjusted in doing stowage planning so that heeling does not occur on the ship.

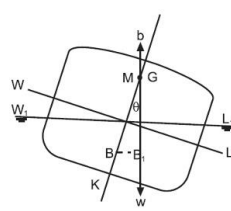


Figure 1. Neutral Equilibrium
(Source: Sihotang, 2014)

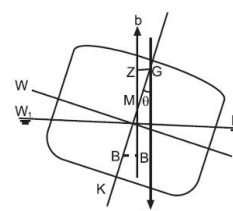
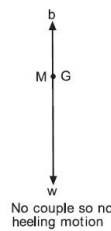
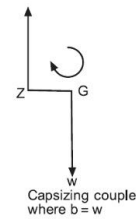


Figure 2. Unstable Equilibrium
(Source: Derret, 1999)



Trim or longitudinal stability is the state of the ship's balance against the longitudinal inclination whose value is determined by the difference in balance between the forward or draft fronts with the aft or the back of the ship. The front and rear of the ship can be stated at the same draft depth if the trim value of the ship is equal to 0. If the forward value is higher than the aft value, then trimming by the bow will occur, which is a condition where the tilt of the ship protrudes to the front. The opposite occurs when the aft value is higher than the forward value which causes the tilt of the ship to jut to the back of the ship or commonly called trimming by the stern. The equation of horizontal equilibrium is shown in equation (1)

$$Q1 = \sum_{i=a-b}^i MCi \times XCi \times g - \sum_{i=b-c}^i MCi \times XCi \times g \quad (1)$$

$$-2000 < Q1 < 2000$$

$$\text{Minimize } |Q1|$$

Where a is bay number at the front of the ship; b is number of the bay at the center of the ship; c is bay number behind the ship; I is bay number; $Q1$ is difference in force moments between the front and rear of the ship; MCi is mass of container in bay I ; XCi is distance of containers on the baby from the midpoint of the ship; g is acceleration due to gravity ($g = 10 \text{ m/s}^2$). The equation of cross equilibrium is shown in equation (2).

$$Q2 = \sum_{j=d-e}^j MCj \times XCj \times g - \sum_{j=e-f}^j MCj \times XCj \times g \quad (2)$$

$$-200 < Q2 < 200$$

$$\text{Minimize } |Q2|$$

$$Q3 = \sum Q2$$

$$-1000 < Q3 < 1000$$

Where d is front row number of the ship; e is row number in the middle of the ship; f is last row number ship; j is row number; $Q2$ is difference in force moments between the left and right sides of the ship in each bay; $Q3$ is total difference in force moments between the left and right sides of the ship in each bay; MCj is container mass in row j ; XCj is distance of container on row j from the midpoint of the ship; g is acceleration due to gravity ($g = 10 \text{ m/s}^2$). Vertical Equilibrium is a condition where the weight of a container at a tier is greater than the container above it.

Data collected by the stages of data processing is used to build a model in the form of an application. The data that forms the basis of research are secondary data. Therefore, there are several steps undertaken by researchers in determining the type of data needed before researchers make observations to the company and the Tanjung Priok port to obtain the required data. After conducting visits and observations, researchers collect data provided by the company in accordance with the needs of researchers. Data obtained included ship particular, bay plan, and container manifest summary of the two vessels. Later the data that has been collected will be the basis of the development of stowage

planning applications for both types of ships and will be a comparison for the results to be obtained from the application being built.

Ship Particular

A ship's particular is a document that contains detailed ship data as a ship's identity. Ship's particular was made with the aim to be the basic information source of the ship. In ship's particular which owned by researchers, it is divided into three major parts, namely Introduction, Main Dimension, and Engine, System & Navigation. The ship particulars discussed in this study are as follows.

For each Introduction point contains of vessel's name, ship's owner, flag, port of registry, classification, years of build, type of ship, call sign, and IMO No. For Main Dimension point contains details of the ship: LOA, LBP, breadth, depth, summer draft, speed, cargo tonnage, tonnage (DWT, GRT/NT), intake capacity, and reefer plug. While on Engine, System & Navigation point contains of main engine, auxiliary engine, and navigation aids area.

General Cargo and Cargo Barge ship had Indonesia's flag. General Cargo's port of registry is Jakarta, meanwhile the Cargo Barge is Batam. General Cargo was built in 2004 and has classification from CCS. The General Cargo was built in 2015 and has classification from BKI. The LOA of General Cargo and Cargo Barge are 100,00 mtr and 89,90 mtr, the LBP are 103,03 mtr and 84,80 mtr, the breadth is 19,70 mtr and 21,60 mtr, the depth are 8,50 mtr and 6,40 mtr, the summer draft are 6,50 mtr and 5,00 mtr, the speed are 11,5 knots and 9,5 knots, the cargo tonnage are 6,000 tons and 3,800 tons. For the Tonnage, General Cargo's DWT and GRT/NT are 7,633 tTons and 5,650 tTons / 2,976 Tons meanwhile the Cargo Barges are 5,300 tTons and 2,997 tTons / 900 Tons. Their intake capacity is 562 TEU's for General Cargo and 364 TEU's for Cargo Barge.

General Cargo's main engine is 2 x MAN B&W 8L23/30A 1280kW and Cargo Barge's is 2 x Guangzhou Diesel 6320ZCd 1103kW428 rpm/ The auxiliary engine for both General Cargo and Cargo Barge are 3 x WD615.68CD 165kW and 3 units Cummins 6CTA8.3 120 kw 1500rpm. And the last detail of the ship's particular is navigation aids area, General Cargo has A1 + A2 + A3 while Cargo Barge only has A1 + A2.

Bay Plan

A Bay Plan is a document that contains a chart or plan mapping the available space of a ship to be filled by containers in a longitudinal, transverse, and upright manner. Later the ship's cargo planning is calculated based on the size, weight, type, destination of delivery, and the volume of carrying capacity that will be loaded. Generally, a bay plan is made by the shipowner to find out the capacity that can be accommodated by the ship (Yuliani, 2011). The following are the two bay plan formats for the vessels obtained from the company adapted from (Sciomachen, et al., 2007).

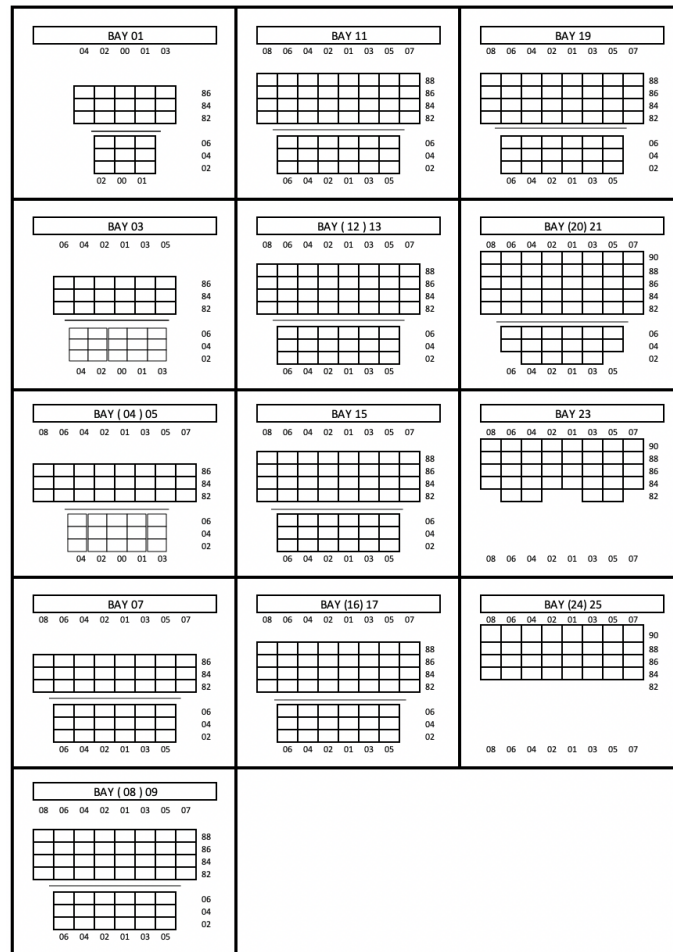


Fig 3. General Cargo Bay Plan

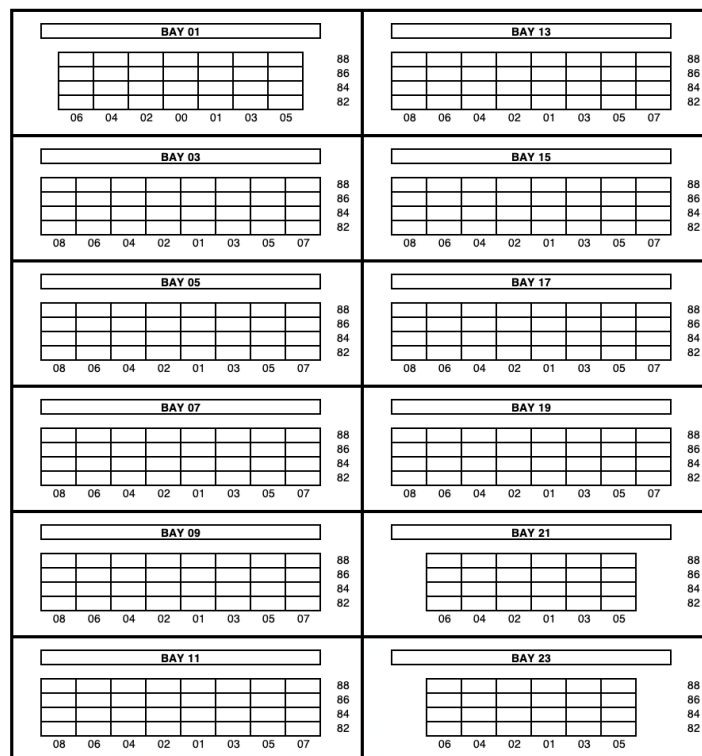


Fig 4. Cargo Barge Bay Plan

3. Analysis and Discussion

General Cargo

After doing the calculations and getting each value for Q1, $\Delta Q1$, Q2, and $\Delta Q2$ in equations (1) and (2) the researchers made a comparison. Comparisons are divided based on the method used. Delta value is close to the tolerance limit value, where the tolerance value can be positive and negative, then the value shows a good level of stability according to table 3.

Ship stability is achieved when the three ship stability factors, horizontal equilibrium, vertical equilibrium, and cross equilibrium are met. Therefore, in the table below it can be seen that although the two Q values generated by stowage planning with the manual method are higher, the two Q deltas owned by the application have smaller numbers and are closer to the tolerance limit point. Then it can be concluded temporarily that the application that was built to make stowage planning on general cargo type ships, runs properly and has a high level of stability of the ship as mentioned by Imai et.al. (2006) (Imai, et al., 2006).

Table 3. Comparison of Q1 and Q2 in the Two Methods in General Cargo

Information	Manual Method	Application
Q1	220.200	37.920
Q1 MAX		2000
Q2	3.744	1.872
Q2 MAX		200

Cargo Barge

Cargo barge is a form of container ship where containers are stacked on barges. After doing the calculations and getting each value for Q1, $\Delta Q1$, Q2, and $\Delta Q2$ the researchers made a comparison. Comparisons are divided based on the method used. Delta value is close to the tolerance limit value, where the tolerance value can be both positive and negative, then the value indicates a high level of ship stability. Therefore, it can be seen through the following table that the Q1 value generated by the manual method far exceeds the tolerance limit, while in the Q1 application it is still within the tolerance range of $-2000 < Q2 < 2000$.

However, even though the Q2 value generated by stowage planning with the manual method is closer to the tolerance limit point, the Q2 delta owned by the application has a small number and is still quite close to the Q2 value of the manual method. Then it can be concluded temporarily that although each method has a better value than each balance factor, when combined the balance value of the stowage plan produced by the application is much better in handling the stability of ships on cargo barge type vessels according to table 4.

Table 4. Comparison of Q1 and Q2 in the Two Methods in Cargo Barge

Information	Manual Method	Application
Q1	128.940	540
Q1 MAX		2000
Q2	7.085	9.792
Q2 MAX		200

Experiment Analysis Results

Based on research that has been done, the application of containers laying on ships starting from the center of the ship is one of the strategies to improve the stability of the ship. This is also supported by the stowage planning algorithm that does not include the mass in the center of the ship in the calculation of the ship's balance.

After doing various calculations, doing stowage planning using a Python language program has a higher chance of ship stability compared to the manual method performed by the company's operational team using Microsoft Excel. This is caused by using the application, focusing on the stability of the ship can be done for four sides, namely the front and rear and the left and right of the ship. The balance of the four sides of the ship is needed for safety and reduces the possibility of heeling and trimming on the ship.

Calculation of the stability of cargo barge ships has more difficulty compared to the stability of general cargo type vessels. As can be seen from the above calculation results, in the calculation of cargo barge type ships the level of balance of the left-right side of the ship by the application is no better than the balance of the left-right side provided by the manual method. This might occur because in cargo barge type ships, transshipment often occurs. The existence of transshipment makes the placement of containers to be lowered first, namely containers that have transshipment status, are prioritized, and placed in a special bay on the ship. This serves to facilitate the loading and unloading of containers without requiring container reshuffle on the ship because of the lack of even no overstay. In addition, the process of placing containers in a bay is placed in order from right to left. So that the number of bays that are filled before being full because of the special bay for containers that will carry out transshipment, makes the possibility of

mass margins on the left and right sides of the cargo barge ship being greater than the general cargo ship. The layout algorithm used in the construction of the general cargo ship stowage planning application: 1) Sort containers by weight, starting from the heaviest to the lightest; 2) Place containers from the middle bay, starting from the bottom row; 3) Keep placing containers until one row is fulfilled and then place another container on top of that row; 4) This is done until the bay is filled, then proceed to the next bay in front of the bay; 5) Repeat process 2-4 until the second bay is filled; 6) Repeat process 2-4 on the bay that is behind the first filled bay. It can be concluded that processes 1-6 are processes 1-4 which are carried out in opposite bays alternately and 7) Do the process 1-6 until all the chests are on the ship

The algorithm that has been compiled as presented above, is then implemented in a function in the Python language. The display in the above process will look like the figure 5.

```
def fill_bay_with_container_theory(containers):
    bay = 6
    row = 8
    col = 8
    count = 0
    for index, container in containers.iterrows():
        match = False
        b, r, c = bay, row, col

        while not match:
            print("iter {}, {}, {}".format(bay, row, col))
            count += 1
            if ship[bay][row][col] == '--':
                if container.SIZE == 20:
                    ship[bay][row][col] = "{}({},{})".format(container.SIZE, container['K/P'], container.CONTAINER)
                    match = True
            else:
                if bay < 12 and ship[bay+1][row][col] == '--':
                    ship[bay][row][col] = "{}({},{})".format(container.SIZE, container['K/P'], container.CONTAINER)
                    ship[bay+1][row][col] = '+'
                    match = True
                if c < 8:
                    bay, row, col = b, r, c+1
                else:
                    bay, row, col = b, r, c
                    if ship[bay][row][col] == 'XX':
                        break

        if row < 1 and bay < 7:
            bay = get_next_bay(bay)
            row = 8
            col = 8
        else:
            bay = get_pair_bay(bay)
            if count == 2:
                if col > 0:
                    col -= 1
                    count = 0
                else:
                    if row > 0:
                        col = 8
                        row -= 1
                        count = 0
                    else:
                        break
            elif count > 2:
                count = 0
```

Figure 0. The Implementation of the Construction Stage of the Container Stowing Function on Ship

After the algorithm is applied, the Jupyter Notebook environment will display an algorithm that is arranged according to the type of ship shape. After structuring the stowage plan, the researcher saves the results of the compilation program in an .xlsx file which can then be accessed via Microsoft Excel. The following is an example of the results of a container preparation program in .xlsx format in Microsoft Excel for each type of ships as shown in figure 6 and 7.

08	06	04	02	00	01	03	05	07	row
XX	XX	XX	XX	XX	XX	XX	XX	XX	90
XX	XX	XX	XX	XX	XX	XX	XX	XX	88
XX	XX	--	--	--	--	--	XX	XX	86
XX	XX	--	--	--	--	--	XX	XX	84
XX	XX	--	--	--	--	--	XX	XX	82
XX	XX	XX	--	--	--	XX	XX	XX	06
XX	XX	XX	--	--	--	XX	XX	XX	04
XX	XX	XX	--	--	--	XX	XX	XX	02
08	06	04	02	00	01	03	05	07	3
XX	XX	XX	XX	XX	XX	XX	XX	XX	90
XX	XX	XX	XX	XX	XX	XX	XX	XX	88
XX	--	--	--	XX	--	--	--	XX	86
XX	--	--	--	XX	--	--	--	XX	84
XX	--	--	--	XX	--	--	--	XX	82
XX	XX	--	--	--	--	--	XX	XX	06
XX	XX	--	--	--	--	--	XX	XX	04
XX	XX	--	--	--	--	--	XX	XX	02
08	06	04	02	00	01	03	05	07	5
XX	XX	XX	XX	XX	XX	XX	XX	XX	90
XX	XX	XX	XX	XX	XX	XX	XX	XX	88
--	--	(20,3,TAKI (20,3,TAKI XX			(20,3,TAKI (20,3,TAKI (20,3,TAKI (20,3,TAKI				86
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Figure 6. Storage Stage Results in .xlsx Format on General Cargo Ships

08	06	04	02	00	01	03	05	07	row	
XX	--	--	--	--	--	--	--	XX	88	
XX	--	--	--	--	--	--	--	XX	86	
XX	--	--	--	--	--	--	--	XX	84	
XX	--	--	--	--	--	--	--	XX	82	
08	06	04	02	00	01	03	05	07	3	
--	--	--	--	XX	--	--	--	--	88	
--	--	--	--	XX	--	--	--	--	86	
--	--	--	--	XX	--	--	--	--	84	
--	--	--	--	XX	--	--	--	--	82	
08	06	04	02	00	01	03	05	07	5	
--	--	--	--	XX	--	--	--	--	88	
--	--	--	--	XX	(20,2,3,nan,	(20,2,3,nan,	(20,2,3,nan,	(40,4,6,nan,	86	
(40,4,6,nan,	(40,4,6,nan,	(20,2,3,nan,	(20,2,3,nan,	XX	(20,2,3,nan,	(20,2,3,nan,	(20,2,3,nan,	(20,2,3,nan,	84	
(20,2,3,nan,	(20,2,3,nan,	(20,2,3,nan,	(20,2,3,nan,	XX	(20,2,3,nan,	(20,2,3,nan,	(20,2,3,nan,	(40,4,6,nan,	82	
08	06	04	02	00	01	03	05	07	7	
(20,2,3,nan,	(20,2,3,nan,	(20,2,3,nan,	(20,2,3,nan,	XX	(20,2,3,nan,	(20,2,3,nan,	(20,2,3,nan,	(20,2,3,nan,	88	
(20,2,3,nan,	(20,2,3,nan,	(20,2,3,nan,	(20,2,3,nan,	XX	(20,2,3,nan,	(20,2,3,nan,	(20,2,3,nan,	++	86	
++	++	(20,22,0,nar	(20,22,0,nar	XX	(20,22,0,nar	(20,22,0,nar	(20,22,0,nar	(20,22,0,nar	84	
(20,22,0,nar	(20,22,0,nar	(20,22,0,nar	(20,22,0,nar	XX	(20,22,0,nar	(20,22,0,nar	(20,22,0,nar	++	82	
08	06	04	02	00	01	03	05	07	9	
(20,22,0,nar	(20,22,0,nar	(20,22,0,nar	(20,22,0,nar	XX	(20,22,0,nar	(20,22,0,nar	(20,22,0,nar	(20,22,5,nar	88	
(20,22,5,nar	(20,22,5,nar	(20,22,5,nar	(20,22,5,nar	XX	(20,22,5,nar	(20,22,5,nar	(20,22,5,nar	(20,22,5,nar	86	
(20,22,5,nar	(20,22,5,nar	(20,22,5,nar	(20,22,5,nar	XX	(20,25,0,nar	(20,25,0,nar	(20,25,0,nar	(20,25,0,nar	84	
(20,25,0,nar	(20,25,0,nar	(20,25,0,nar	(20,25,0,nar	XX	(20,25,0,nar	(20,25,0,nar	(20,25,0,nar	(40,30,0,nar	82	
08	06	04	02	00	01	03	05	07	11	
--	--	--	--	XX	--	--	--	(40,4,6,JICT,	(20,22,5,JICT	88
(20,22,5,JIC	(20,23,0,JIC	(20,23,0,JIC	(20,23,0,JIC	XX	(20,23,0,JIC	(20,23,0,JIC	(20,23,0,JIC	(20,25,0,JIC	86	
(20,25,0,JIC	(20,22,5,JIC	(20,22,5,JIC	(20,22,0,JIC	XX	(20,22,0,JIC	(20,22,0,JIC	(20,22,0,JIC	(20,22,5,JIC	84	
(20,22,5,JIC	(20,22,5,JIC	(20,22,5,JIC	(20,22,5,JIC	XX	(20,22,5,JIC	(20,22,5,JIC	(20,22,5,JIC	++	82	
08	06	04	02	00	01	03	05	07	13	
--	--	--	--	XX	--	--	++	(20,22,5,JIC	88	
(20,22,5,JIC	(20,22,5,JIC	(20,23,0,JIC	(20,23,0,JIC	XX	(20,23,0,JIC	(20,23,0,JIC	(20,23,0,JIC	(20,25,0,JIC	86	
(20,25,0,JIC	(40,30,0,JIC	(40,30,0,JIC	(20,22,5,JIC	XX	(20,22,0,JIC	(20,22,0,JIC	(20,22,0,JIC	(20,22,0,JIC	84	
(20,22,5,JIC	(20,22,5,JIC	(20,22,5,JIC	(20,22,5,JIC	XX	(20,22,5,JIC	(20,22,5,JIC	(20,22,5,JIC	(40,30,0,JIC	82	

Figure 7. Storage Stage Results in .xlsx Format on Cargo Barge Ships

Apart from the level of the ship's balance, the efficiency of the work time needed to do stowage planning is also prefer using the application rather than manually. According to data obtained from the company, the operational team needed about 4 hours to work on the stowage planning process from collecting data to making a ship's bay plan. Meanwhile, by utilizing the application, stowage planning only takes about 10 to 15 seconds by using existing data into the application and running the program. The use of this type of hardware affects the time needed to make stowage planning by utilizing applications that have been built. As for application development, this study uses an APPLE MacBook Pro laptop with 13.3-inch MLH12 Touch Bar / Dual Core i5 / 8GB / 256GB.

4. Conclusions and Recommendations

Based on research conducted, Using Python programming language to solve the problem of stowage planning with applications takes time less than 15 seconds whilst company's operational team using Microsoft Excel took 4 hours.

Research on stowage plans is still very broad to be developed since it has a high level of complexity, some suggestions for the implementation of similar studies further are the planning stowage generated by the application is not yet within the maximum range of the Equilibrium opening up space for further research. The applications can also be developed to carry out stowage planning on previously filled ships. Furthermore, the application development is expected to be able to handle containers with more diverse needs such as reefer containers or containers that carry hazardous chemicals.

Declarations

Author contribution

All authors contributed equally as the main contributor of this paper. All authors read and approved the final paper.

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References

- Ambrosino, D., Sciomachen, A., & Tanfani, E. (2006). A decomposition heuristics for the container ship stowage problem. *Journal of Heuristics*, 12(3), 211-233. doi:10.1007/s10732-006-5905-1
- Asian, S., Pool, J. K., Nazarpour, A., & Tabaeian, R. A. (2019). On the importance of service performance and customer satisfaction in third-party logistics selection An application of Kano model. *Benchmarking: An International Jurnal*, 26(5), 1550-1564. doi:10.1108/BIJ-05-2018-0121

- Demir, E., Huang, Y., Scholts, S., & Van Woensel, T. (2015). A selected review on the negative externalities of the freight transportation: Modeling and pricing. *Transportation research part E: Logistics and transportation review*, 77, 95-114. doi:10.1016/j.tre.2015.02.020
- Hardjono, S. (2015). Analisa Ukuran Utama Kapal General Cargo yang Sesuai dan Aman untuk Gelombang Tinggi di Perairan Indonesia. *Warta Penelitian Perhubungan*, 27(3), 167-180. doi:10.25104/warlit.v27i3.782
- Imai, A., Sasaki, K., Nishimura, E., & Papadimitriou, S. (2006). Multi-objective simultaneous stowage and load planning for a container ship with container rehandle in yard stacks. *European Journal of Operational Research*, 171, 373–389. doi:10.1016/j.ejor.2004.07.066
- Li, J., Zhang, Y., Ma, J., & Ji, S. (2018). Multi-Port Stowage Planning for Inland Container Liner Shipping Considering Weight Uncertainties. *IEEE Access*, 6, 66468-66480. doi:10.1109/ACCESS.2018.2878308
- Pang, G., & Gebka, B. (2017). Forecasting container throughput using aggregate or terminal-specific data? The case of Tanjung Priok Port, Indonesia. *International Journal of Production Research*, 55(9), 2454-2469. doi:10.1080/00207543.2016.1227102
- Sciomachen, A., & Tanfani, E. (2007). A 3D-BPP approach for optimising stowage plans. *European Journal of Operational Research*, 183, 1433–1446. doi:10.1016/j.ejor.2005.11.067
- Sihotang, R. (2014). *Perancangan Algoritma Penempatan Peti Kemas di Kapal Pengangkut Peti Kemas yang Menjaga Stabilitas Kapal dan Menghindari Overstow dengan Pendekatan Heuristik*. Depok: Universitas Indonesia.
- Stahlbock, R., & Voß, S. (2008). Operations research at container terminals: a literature update. *OR spectrum*, 30, 1-52. doi:10.1007/s00291-007-0100-9
- Yuliani, A. (2011). Evaluasi Penerapan Next Generation Terminal Managementsystem (NGEN) Dalam Mendukung Kelancaran Penanganan petikemas Pada PT. JICT di Pelabuhan Tg. Priok. *Warta Penelitian Perhubungan*, 23(4), 349-361. doi:10.25104/warlit.v23i4.1090

