Constructing a Blueprint of a Kolek

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Abstract. Kolek, a Malay Traditional Boat, is slowly forgotten by the younger generation due to several reasons. In this paper, an in-depth study was conducted to construct a Kolek blueprint for preservation using the Reverse Engineering method on the existing artifact in Malay Traditional Boat Yard located at Pulau Duyung. The study was conducted through several phases namely boat measurement, digitization, and analyses. As a result, a Kolek Lines Plan was produced using Rhinoceros 5 for reference by future generations. Then analyses were carried out using PolyCAD version 10.4 to obtain hydrostatic properties of the Kolek for its stability, and resistance to determine the power requirements needed for the Kolek. The results show the blueprint of the Kolek that can be develop as well as mechanical properties of the Kolek can be obtained using modern naval architecture techniques. This blueprint can be used to build new boats by the next generation using the hybrid method which is a combination of modern and traditional methods.

1. Introduction

The traditional Malay boat is one of the heritages slowly forgotten by Malaysians, especially the younger generation. Malay Traditional boats had existed since ancient times. There are types of boats depending on their functions and unique design. Kolek is one of the traditional Malay boats with unique art of heritage used as a fishing boat. The usage is not only for water transportation but also as symbolic of Malay thought and civilization [1]. The invention of technology and techniques in boat construction reflects Malay society intellectual thought in producing things. However, the technological progress and development of machinery propelled transport system led to the declining usage of a Kolek. [2]

Kolek, the Malay traditional boat, is made of wood and using the traditional method without any design blueprint during the construction stage and alterations made based on the rule of thumbs and trial and error [3]. It is supported by Indonesian researchers [4] that the construction of fishing boats does not use design drawings. The boat draft or design is only imagined in the boat builder's minds and verbally communicated to the boat builder assistants in the form of instructions in building fishing boats. These situations lead to difficulty for the reconstruction and identification of the traditional boat by the future generation, leading it to diminish in the future.

Moreover, the younger generation's lack of knowledge on traditional boats' construction as there is no design blueprint documentation contributed to the diminishing. Several studies on the Malay traditional boat preservation was done these few years by the researchers to resolve this situation. Most of the research focused on the art and decorations of Malay and western traditional boats. There is no
in-depth study highlighted on the blueprint of the Malay traditional boat's naval architecture and engineering design aspects. This study proposes to conduct an in-depth study of the mentioned aspect by applying the Reverse Engineering methodology from the existing artifacts. The main objective of this study is to develop a complete design blueprint on Kolek for preservation purposes.

It starts with reproducing the actual shape of the Kolek by measuring the actual boat. This blueprint is expected to support the Malaysia National Culture Policy. One of its strategies is to restore, preserve, and develop culture towards strengthening national culture through joint research, development, education, and cultural expansion and connections. The cultural heritage can enhance national identity and promote the tourism industry as a source of national income. Although few studies on the preservation of traditional boat, the research focused on the art and decoration [5] and traditional western boat, none of them highlighted traditional Malay boats from the engineering perspective.

The traditional shipbuilding in this archipelago area has already existed since the migration of Protomalay [6]. The technique is passed down from generation to generation of shipwright master. In the early days, the wooden ship was widely used to travel by the Malay communities. This seaworthy craftsmanship travelled up to Madagascar island in the west and the Polynesian islands in the east [7]. There are many types of Malay ships. Among them was a big ship or Perahu Besar that can be further categorized, such as Pinis and Bedar of Terengganu type. As Perahu Besar role conquered by the modern ship, most traditional shipyard nowadays tends to focus more on producing the smaller perahu and fishing vessels. [7]

The in-depth study of Malay traditional boats is essential to ensure the preservation of Malay maritime heritage and educate the young generation nowadays, as reported by the researcher. The study focused on Malay traditional boats' art and decoration by using the existing artifacts from the numerous museums in Malaysia [8]. The collection of these data was analyzed based on the forms, motives, and relevance inherent in the traditional Malay boat decoration components. In Malaysia, the fishing boats are the same as traditional Malay boats built without any blueprint design on the construction stage, guidance, and approval from naval architecture [9]. Any modification is only based on the trial and error method to countermeasure any technical issue. [3]

Reverse Engineering, also known as back engineering, is acquiring knowledge of design information by examining a product. For example, dismantling an automobile to study the various components and reproduce them based on the original model. Reverse Engineering is used as a tool that can preserve data by scanning the originals. Reverse Engineering applies to many areas like Architecture, works of art, and old artifacts [10]. In our engineering Industrial commercialized society, Reverse Engineering shows much promise for the application like mass production, and so forth.

Reverse engineering is not only applied to the engineering design aspect; it also further utilizes on the old artifacts, for example, monuments and various musical instruments from the past. The digitalization of cultural heritage with R.E (reverse engineering) methodology has piqued the interest of many researchers from a different field, especially the archaeologist. Digitization helps preserve and can also make digital copies and store the digital data at various locations at a minimal cost, which is not possible with the original.

With the advancements of computer technologies, their applications are used to virtualize the cultural heritage to make digital copies of the models showing its shapes, texture, and type of material used and the reverse engineering methodology to reconstruct the objects lost. The process allows for the reconstruction and preservation of objects that are lost due to unexpected events. [11] As reported by the researchers [12], there are several different methods to record individual ship timbers and ship timber assemblies applied by marine archaeologists. The current ship timber recording methods generally fall under one of four categories, which are 2D scaled drawings, 2D tracing, 3D contact digitizing, and 3D scanning.
2. Research Method
The study was conducted through several phases namely boat measurement, digitization, and analyses. In analyses phase, hydrostatic, stability and resistance analysis were analyzed.

In the boat measurement phase, the activity was conducted manually at a known boat maker yard owned by Haji Abdullah Muda, in Pulau Duyung, Terengganu for the existing Kolek. The Kolek needed to be measured in several parts: stem profile, stern profile, and cross-sections at 5 location as shown in figure 1.

![Figure 1: Measurement plan of Kolek](image)

In the digitization phase, the shape of the Kolek hull was drawn using 3-D modeling software called Rhinoceros 5. The Kolek was modelled in the 3-D. The re-drawing process began by placing the stem and stern profiles in the profile view to get the overall length of the Kolek. Next, the 5 measured cross-sections were then positioned along the Kolek length as shown in figure 1. After that, the deck line can be produced by connecting the edges of each cross-section and ending at the stem and stern as shown in figure 2. Then a surface was lofted along those measured cross-sections as shown in figure 3. From this surface, the actual 10 stations were generated using an automatic function in the software.

![Figure 2: 3-D wireframe modelling of Kolek](image)  ![Figure 3: 3-D surface modelling of Kolek](image)

3. Results and Discussion
From the 3-D modelling in digitization phase, a 2-D drawing known as Lines Plan has been produced. This Lines Plan modelling consists of 3 projections: Body Plan, Profile, and Half Breath Plan, to visualize a ship's shape. Figure 4 shows the replica of the Kolek Lines Plan. This Lines Plan helps the younger generation who have carpentry skills to visualize the shape of a Kolek. Today, the skills to visualize the shape of the Kolek are found in the minds of highly skilled boat makers where they are becoming less and less.
Figure 4: Replica of Kolek Lines Plan

The accuracy of this Lines Plan drawing is essential to ensure that it represents the Kolek that has been measured. Table 1 shows the difference between the measured curves and the curves drawn for the 5 cross sections. It was found that there was a small difference between them where the average was 1.83%. These small differences indicate that the Kolek has been drawn almost identical to the one measured.

Table 1: Cross sections comparison

| Height (m) | 1st Cross Section - 2.12 m | 2nd Cross Section - 3.14 m | 3rd Cross Section - 4.25 m | 4th Cross Section - 5.17 m | 5th Cross Section - 6.19 m |
|------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
|            | Measured (m) | 3D model (m) | Diff. | Measured (m) | 3D model (m) | Diff. | Measured (m) | 3D model (m) | Diff. | Measured (m) | 3D model (m) | Diff. | Measured (m) | 3D model (m) | Diff. |
| 0.15       | 0.17          | 0.17          | 0.02  | 0.48          | 0.48          | 0.03  | 0.56          | 0.56          | 0.02  | 0.34          | 0.34          | -     | 0.20          | 0.11          | 0.11  |
| 0.30       | 0.38          | 0.38          | 0.00  | 0.68          | 0.68          | -0.01 | 0.75          | 0.75          | -0.02 | 0.60          | 0.60          | 0.16  | 0.22          | 0.24          | 11.85 |
| 0.45       | 0.54          | 0.54          | 0.22  | 0.78          | 0.78          | 0.03  | 0.84          | 0.84          | 0.02  | 0.72          | 0.72          | 0.05  | 0.33          | 0.37          | 11.92 |
| 0.60       | 0.64          | 0.64          | -0.09 | 0.84          | 0.84          | -0.01 | 0.88          | 0.88          | -0.01 | 0.78          | 0.78          | 0.03  | 0.44          | 0.48          | 10.05 |
| Deck Edge  | 0.74          | 0.74          | 0.06  | 0.88          | 0.88          | 0.06  | 0.90          | 0.90          | 0.08  | 0.84          | 0.84          | 0.08  | 0.60          | 0.65          | 6.79  |

Average 0.04  Average 0.02  Average 0.02  Average 0.02  Average 9.07  
Total Average 1.83
Once the lines plan is produced, the analysis phase can be performed. The first analysis performed was hydrostatics. The hydrostatics analysis is done using an open-source software known as PolyCAD version 10.4. Table 2 shows the results of hydrostatics analysis of the Kolek at various water levels. These hydrostatics data describe the geometric properties of the Kolek. These hydrostatic data are important so that they can be used in stability, and resistance analysis.

| T [m] | Disp [Tonnes] | LCB [m] | VCB [m] | KM [m] | WPA [m²] | LCF [m] | TPC [Tonne s/cm] | Cₗ | Cₚ | Cwp | Cₘ | BMₜ [m] | BMₗ [m] | WSA [m²] | MCT [Tonne s-m] |
|-------|----------------|---------|---------|--------|-----------|---------|------------------|----|----|------|----|---------|---------|---------|----------------|
| 0.000 | 0.000          | 0.000   | 0.000   | 0.000  | 0.15      | 4.025   | 0.000            | 0.000| 0.000| 0.000| 0.000| 0.000   | 0.000   | 0.000   | 0.000          |
| 0.050 | 0.016          | 4.149   | 0.028   | 0.043  | 0.39      | 4.151   | 0.000            | 0.739| 0.917| 0.959| 0.806| 0.015   | 47.202  | 0.700   | 0.002          |
| 0.100 | 0.095          | 4.039   | 0.072   | 1.086  | 2.33      | 3.999   | 0.020            | 0.198| 0.482| 0.499| 0.411| 1.014   | 25.692  | 2.858   | 0.005          |
| 0.150 | 0.241          | 4.016   | 0.105   | 1.051  | 3.33      | 4.005   | 0.030            | 0.251| 0.481| 0.535| 0.522| 0.946   | 16.784  | 4.035   | 0.007          |
| 0.200 | 0.435          | 4.017   | 0.136   | 1.008  | 4.13      | 4.008   | 0.040            | 0.285| 0.492| 0.554| 0.579| 0.871   | 12.816  | 5.049   | 0.010          |
| 0.250 | 0.664          | 4.015   | 0.167   | 0.982  | 4.82      | 4.012   | 0.050            | 0.305| 0.495| 0.567| 0.616| 0.814   | 10.746  | 5.989   | 0.012          |
| 0.300 | 0.931          | 4.018   | 0.198   | 0.955  | 5.43      | 4.016   | 0.060            | 0.322| 0.501| 0.577| 0.642| 0.757   | 9.354   | 6.888   | 0.014          |
| 0.350 | 1.223          | 4.017   | 0.229   | 0.933  | 5.96      | 4.016   | 0.060            | 0.335| 0.505| 0.585| 0.664| 0.704   | 8.388   | 7.733   | 0.016          |
| 0.400 | 1.541          | 4.018   | 0.259   | 0.911  | 6.41      | 4.018   | 0.070            | 0.346| 0.507| 0.590| 0.682| 0.652   | 7.642   | 8.550   | 0.018          |
| 0.450 | 1.881          | 4.019   | 0.289   | 0.894  | 6.82      | 4.019   | 0.070            | 0.356| 0.509| 0.595| 0.698| 0.605   | 7.038   | 9.365   | 0.020          |
| 0.500 | 2.243          | 4.021   | 0.319   | 0.880  | 7.18      | 4.021   | 0.070            | 0.365| 0.512| 0.600| 0.714| 0.562   | 6.538   | 10.164  | 0.022          |
| 0.550 | 2.619          | 4.021   | 0.349   | 0.873  | 7.52      | 4.022   | 0.080            | 0.374| 0.513| 0.605| 0.728| 0.524   | 6.148   | 10.955  | 0.024          |
| 0.600 | 3.017          | 4.023   | 0.378   | 0.867  | 7.82      | 4.025   | 0.080            | 0.382| 0.516| 0.610| 0.741| 0.489   | 5.802   | 11.757  | 0.026          |

Legend:
- **T** Draft
- **Disp** Mass Displacement
- **LCB** Center of Buoyancy (longitudinal direction)
- **VCB** Center of Buoyancy (vertical direction)
- **KM** Distances from Keel to Transverse Metacentres
- **WPA** Waterplane Area
- **LCF** Center of floatation (longitudinal direction)
- **TPC** Tonne per centimeter immersion
- **Cₗ** Block coefficient
- **Cₚ** Prismatic coefficient
- **Cwp** Water-plane area coefficient
- **Cₘ** Midship section area coefficient
- **BMₜ** Distances from Centre of Buoyancy to Transverse Metacentres
- **BMₗ** Distances from Centre of Buoyancy to Longitudinal Metacentres
- **WSA** Wetted Surface Area
- **MCT** Moment to Change Trim one Centimeter

The measured boat has already been painted with a red underwater coating to indicate the sinking level of the boat. This is done by the boat builder through his many years of experience in the traditional boat building industry. The height of this waterline design when measured is 0.5 meters from the keel as shown in figure 5. Table 3 shows the geometric properties of the Kolek on the waterline design. These data have been taken from table 2 at T=0.5 m.
**Table 3: Hydrostatics data of Kolek at design draft**

| Hydrostatic Particulars | Value | Hydrostatic Particulars | Value |
|-------------------------|-------|-------------------------|-------|
| T [m]                   | 0.500 | C_b                     | 0.365 |
| Disp [Tonnes]           | 2.243 | C_p                     | 0.512 |
| LCB [m]                 | 4.021 | C_wp                    | 0.600 |
| VCB [m]                 | 0.319 | C_m                     | 0.714 |
| KMr [m]                 | 0.880 | BMr [m]                 | 0.562 |
| WPA [m²]                | 7.18  | BM_r [m]                | 6.538 |
| LCF [m]                 | 4.021 | WSA [m²]                | 10.164|
| TPC [Tonnes/cm]         | 0.07  | MCT [Tonnes-m]          | 0.022 |

**Table 4: Compliance of stability criteria**

| Criteria | Calculate d | IMO Requirement | Compliance |
|----------|-------------|-----------------|------------|
| A0-30    | 0.0643      | > 0.055         | comply     |
| A0-40    | 0.1075      | > 0.090         | comply     |
| A30-40   | 0.0433      | > 0.030         | comply     |
| GZmax    | 0.2620      | > 0.200         | comply     |
| Angle of | 50°         | > 25°           | comply     |
| GZmax    | GMawal      | 0.464           | > 0.150    | comply     |

The boat is Stable

The last analysis in the analyses phase is resistance analysis. The Kolek resistance analysis was also performed using PolyCAD version 10.4. The resistance curve, as in figure 7, has been successfully produced. This analysis has been done based on the Delft Systematic Yacht Hull Series (DSYHS). From figure 7, it is found that at low Froude numbers (<5 Knots), the frictional resistance is the major component and is dependent on the wetted surface area of the hull (and inherent roughness). While, at higher Froude numbers, the residuary resistance becomes the primary drag component.

The resistance curve can be used to estimate the Effective Power of the Kolek by multiplying R Total [N] and the desired speed. The sail of the Kolek must be able to produce the same number of forces as the Effective Power to keep the boat moving at the desired speed. If you want to modernize the Kolek by installing an engine, the effective power must be multiplied by the loses factor occurs throughout the power train such as loses caused by gearbox, shaft, quasi propulsive coefficient, sea margin and maximum continuous engine rating (MCR) to determine the engine brake horsepower needs to be installed.
4. Conclusion
Kolek is a significant Malay traditional boat that has been slowly forgotten by Malaysians, mostly the young generation. As a symbol of Malay thought and civilization, she is supposedly preserved. The study has successfully produced a Lines Plan drawing for the Kolek that can be made as a reference for future generations. From the Lines Plan drawing, stability analysis has been done which shows that the Kolek has good stability. The resistance analysis has also been performed to show the power requirements for the Kolek. The results of this resistance analysis can be used to determine the prime mover to be used for the Kolek. Therefore, the objective for constructing a blueprint utilizing modern naval architecture techniques can be achieved to support the preservation of a historical Malay traditional boat.

It is proposed to produce the new construction method of the Kolek using this blueprint. The traditional method of building the Kolek needs to be changed a bit by applying modern methods so that the younger generation can build the new Kolek in the future. This is because, the traditional method of building the Kolek without drawing is quite difficult for the younger generation to master the method.

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