Design of Rubbish Collecting System for Inland Waterways

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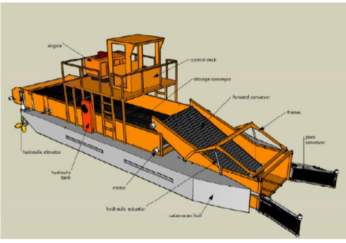
Graphical Abstract



Abstract

This paper highlights a proposed design of rubbish collecting system effective and efficient for cleaning up rubbish from rivers, canals and lakes, or known as inland waterways. The rubbish collecting system is specifically directed to application in highly maneuverable vessels equipped with means for picking up floating solid and liquid waste, storing waste on the vessel, and discharging the waste from the vessel to a storage area, either for ashore purpose or as garbage transporter. Analysis had been accomplished using Engineering Design Method to compare the present design of rubbish collecting systems, hence to propose suitable rubbish collecting system for the use of collecting rubbish in different nature of inland waterways. With the aid of Google Sketch up software, the design of the system was generated in 3D which helps to visualize all the details regarding the system.

Keywords

Waste; rubbish; inland waterways; rubbish collector boat;

Introduction

Inland waterways are crucial for human life and other living things. Their water is used for irrigation and drinking, and they maintain the moisture of the earth. Inland waterways have been contributing to transportation where many cities in the world are situated in their locality. Today, the population increases exponentially and a number of inland waterways have become a sort of sewage system. As a corollary, the cities are generating large heaps of garbage and filth, which are dumped into the inland waterways through sewers or directly from hands, worsening pollution day-to-day.

Cleaning the trashes by using manual processes would be ineffective as it often covers vast area of works and efforts. Therefore, this paper presents a proposal on rubbish collecting system for inland waterways. The system consists of a heavy duty marine work boat designed for use in inland waterways where there is a need to collect floating trashes and litters. The design will also prove instrumental in small scale oil recovery operations. The system designed will be the easiest way to manage the inland waterway environments, time saving and cost efficient, thus deemed as the most viable solution as means to clean up the mess created by human.

Type of Rubbish

The UK's Environmental Protection Act 1990 defines that waste or rubbish includes any substance which constitutes scrap material, effluent or other unwanted surplus arising from the application of any process or any substance or article, which requires to be disposed of which has been broken, worn out, contaminated or otherwise spoiled. In addition, this is supplemented with anything which is discarded otherwise dealt with as if it were waste shall be presumed to be waste unless the contrary is proved. Table 1 shows the rubbish sources.

Table 1: Major sources of rubbish [1]

Major resource	Types of area
Residential	Individual housing, apartment, flat, city houses
Commercial	House, shopping centre, warehouse, airport, restaurant
Institution	School, university, hospital, prison
Industrial	Factory disposals, toilets, wrapping components

There are many waste types defined by modern systems of waste management, and they are basically in the form of solid, liquid, and gas. Solid waste includes plastic, glass, iron or tin, paper and natural substances like wood, leafs, and seaweeds. Figure 1 shows the rubbish percentage in Malaysian rivers.

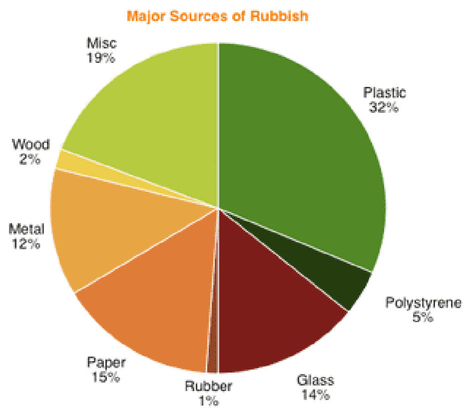


Figure 1: Types of rubbish percentage in Malaysian rivers [1]

Inland waterway in Malaysia

Inland waterway is defined as any natural water shed area that flows in a channel with defined banks. The source of inland waterway may be a lake, a spring, or a collection of small streams, known as headwaters. Malaysia's territorial waters cover an area of 549,500 km². The inland waterway systems in Malaysia are an integral part of the water resources system. There are more than 100 rivers systems in Peninsular Malaysia and more than 50 river systems in Sabah and Sarawak. River systems as a whole, with or without impounding reservoirs, are estimated to contribute about 97% of the raw water supply source. Most polluted river basins are in Peninsular Malaysia, with Johor topping the list.

Type of Rubbish Collector Boat

Nowadays, many developed countries such as Britain and United States (US) have invented various types of rubbish collector boat that could perform in several natures of inland waterway. Some of the inventions have reached global market, equipped with multifunctional criteria including harvesting agricultural plants and recreational purpose, but the major function of the boats is to collect rubbish that floats on the waterways. Some of the available types are:

Buddy Aluminium Catamaran

These innovative workboats offer an efficient solution for the removal of floating litter, debris and vegetation. The multi-purpose drop-in pod system can also accommodate oil recovery, firefighting, dispersant spraying, boom deployment and cargo hauling equipment [2]. A four stroke outboard provides economical, whisper-quiet performance, and the design of the hull ensures low wash for minimal disturbance when being underway. Flat sides and wheeled fenders make it possible to drive along dock walls. Inward flared bows force litter, debris or vegetation in the boat's path into the collection basket. A non-return gate at the rear prevents the contents from being forced out when the vessel is put into reverse. Cutaway transoms allow the Buddy to pull away from quay walls with ease, adding maneuverability when working in confined water spaces.

The Buddy is manufactured from high quality 4mm marine grade aluminium for low maintenance, durability and strength [2]. The sealed hulls offer excellent buoyancy, stability and carrying capacity. Safety handrails and operator canopies are easily removable for added versatility. Drop in deck plates provide 13m² of working space – ideal for work platform, personnel transport or safety support roles. The Buddy also features built-in lifting points for easy handling and can be transported by road on a custom built launch and recovery trailer.

Water Witch

A true multi-purpose Water Witch provides ultimate flexibility and maximum reliability, combined with easy maintenance for quick and effective marine pollution solutions [2]. The water witch usually works together with Skipper Barge, which functions as a rubbish container during debris collection or oil-recovery process.

The unique Water Witch features a powerful front end loader which can lift up to 1000kg and reach 3.65m below the waterline. A quick-release system ensures a range of loader attachments can be easily fitted in seconds. Attachments available include dredge buckets, log grapples, weed cutters/rippers, access platforms, cranes and more. It offers reliable, powerful performance in the harshest of conditions. Designed using the latest 3D CAD systems and manufactured from the highest standards of 6mm Lloyds Grade 'A' plate, the craft is designed to offer maximum versatility, ease of use and minimum maintenance.

Skipper Barge

Skipper Barge is essentially developed to team up with Water Witch workboat [2]. It allows recovered debris and waste to be stored and transported using transfer skips, and is currently employed by waste removal contractors' world-wide. It's loading and discharging fully-laden skips is fast, without any manual handling, enabling Water Witch operators to immediately resume work. Each barge features quick-connect couplings to allow additional units to be connected to suit capacity requirement.

Cataglop

The main function of this type of vessel is to collect floating solid and liquid waste. From the demand and need of cleaning pollutants in the waterways area, the vessel has been developed to suit the requirement of working at places other than offshore area, giving more choices for the use of cleaning rubbish and waste from the water environment. Its strong points include improved V hull design for vessel speed, combined with stability, integrated wheels allowing launching by only one person, recovery of hydrocarbons and macro waste, and easily transportable on its road gauge trailer. The Cataglop uses turbine pull system to pull a stream of water through a tank with a mesh to filter out solid waste. The stream is then separated into two: Firstly, the turbine pumps away the clean water. Then, the surface water, polluted with oil and hydrocarbons, is channeled into a hydrocarbon separator, where the hydrocarbons are held floating without any emulsion.

Trash Hunter

The Trash Hunter is a heavy duty marine work boat designed for use in rivers, lakes, ports, harbors, marinas or any place with a need to collect floating trash and litter [3]. It is designed to pick up a wide variety of flotsam and jetsam, including floating litter, garbage, logs, discarded tires and others. After unwanted debris is collected, it is conveyed on board and stored in the generous storage hold area. Complete instrumentation and hydrostatic hydraulics enable a single operator to manage all functions of the Trash Hunter without coming into direct contact with the refuse.

DESIGN METHODOLOGY

The comprehensive methodology for the design is based on system engineering design and analysis approach. While giving due regard to the importance of the system design procedure, the methodology also draws on reliability study where the process will enhance the dependency on the system applied adequately in removing rubbish from inland waterway.

Particular attention is given to present design of boats since it is the most crucial phase in determining the overall configuration, and because of its added importance with the current emphasis of concurrent engineering. The information obtained can be further analyzed for improvised design of rubbish collecting system for rivers and canals.

Engineering Design

The main emphasis of the engineering design method is on the design of products that has an engineering content, although most of the principles and approaches that it teaches are relevant to the design of all kind of products. It means that the method can also be applied in designing a new system, which in this case is designing rubbish collecting system for the waterways. The selected set is detailed as follows, with the stage in the design process shown on the left, and the method relevant to this stage on the right, as subjected by Cross [5].

1. Clarifying objective - Objectives Tree Method
2. Establishing functions - Function Analysis Method
3. Setting requirements - Performance Specification Method
4. Determining characteristics - Quality Function Deployment Method
5. Generating alternatives - Morphological Chart Method
6. Evaluating alternatives - Weighted Objective Method
7. Improving details - Value Engineering Method

Objective Tree Method

The study aims at proposing and designing a new rubbish collecting system that is effective and efficient for cleaning up rubbish from inland waterway, with objectives as follow:

1. To compare the proposed design of rubbish collecting system by performing engineering design methods.
2. To design intended system for actual operation.
3. To verify the design by expert inputs.

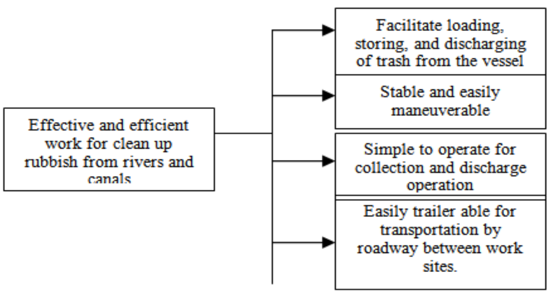


Figure 2: Objectives for rubbish collecting system design for inland waterway

Function Analysis Method

The aim of function analysis method is to establish the functions required by the rubbish collecting system to perform the desired task which is to collect rubbish from inland waterways. Figure 3 shows how a rubbish collecting system should perform in the desired manner. It begins with waste collecting process, to collect both solid and liquid waste. The collection of both wastes may be simultaneous or independent from each other, depending on what kind of collecting method has been adopted by the system. Next, the collected waste should be stored appropriately in the storage container to ensure the effectiveness of the system at the highest level.

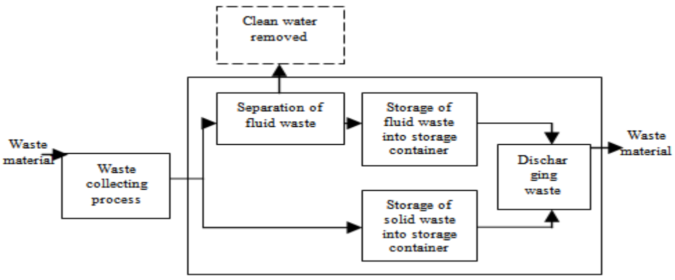


Figure 3: Analysis of principal function for the collection of rubbish

There may be a requirement for the system to have a system that can separate the fluid waste from the water surface or the one that contained in the water rather than collecting the whole contaminated water in the storage container. The filled container should be emptied by discharging the waste to other location or container as to ensure the function of the system can be repeated for collecting waste that floats on the waterway.

Each function of the current system was evaluated according to function analysis criteria, and the system that matches most of the feature can be concluded as the most functional system among others. The characteristic of the function is shown in Table 2. To determine the system that fulfils function criteria the most, each evaluation should be assessed based on these requirements. The criteria of the function analysis is shown in Table 3.

Cataglop is a vessel that comprises all the evaluation criteria for the function analysis. The Cataglop rubbish collector is installed with a turbine pull type collecting system, which can collect both solid and fluid waste at a time. For the fluid waste separation process, the vessel is capable of separating the waste using its own installed separation system, called as hydrocarbon separation unit. All collected waste can be stored in a suitable manner, assuring a high effectiveness of working ability. Cataglop, however, does not possess the ability to discharge the collected waste using the installed system of its own, and this happens to be a major disadvantage in the function evaluation. Among all of the systems, only Trash Hunter possesses the capability to discharge the collected waste using its own installed system, which is conveyor system. This has raised the issue of selecting the best system to adopt for the final design of rubbish collecting system for waterways.

Table 2: Evaluation of function for each design of rubbish collecting system

Characteristics		Buddy Aluminium Catamaran	Water Witch Workboat	CATAGLOP	TrashCatTM
Collecting System	Solid Waste	Multipurpose drop-in pod system -litter collection basket	Quick release system -mesh scoop -log grapple -weed cutter/ripper	Turbine pull system	Conveyor system
	Fluid Waste	Multipurpose drop-in pod system -oil recovery skimmer	Hydraulic system -oil recovery skimmer	Hydrocarbon separator unit	Not available
Fluid Waste Separation Process		Oil is separated by oil recovery skimmer and stored in the storage containment system	Oil is separated by oil recovery skimmer and stored in the storage tank	Oil is separated by the hydrocarbon separator unit and stored floating in storage reservoir	Not available
Waste storage	Solid Waste	Stored in litter collection basket	Stored in skipper barge	Hydraulic powered basket is emptied to bulk bag storage container	Stored in storage conveyor positioned approximately amidships
	Fluid Waste	Stored in storage containment system	Stored in storage tank	Stored floating in storage reservoir and transferred to floating bladder	Not available
Discharging method	Solid Waste	Via crane from litter collection basket	Via crane from skipper bag	Via crane	Via storage to skipper barge or rubbish truck
	Fluid Waste	Via pump from storage containment system	Via pump from storage tank	Via pump to bulk bag storage container	Not available

Table 3: The evaluation criteria for the function analysis

Characteristic	Criteria
Collecting system	Capable of collecting waste using the collecting system of its own
Fluid waste separation process	Capable of separating fluid waste using the separation system of its own
Waste storage	Capable of storing waste in the installed container of its own
Discharging method	Capable of discharging the collected waste using the discharging system of its own.

Table 4: Evaluation of performance specification

Specification		8 m Buddy Aluminium Catamaran	Mk3 Water Witch Workboat	CATAGLOP ® CG-92	MS16-12000B TrashCat™
Hull form		Catamaran	Barge	Catamaran	Catamaran
Hull material		5083 Aluminium	6 mm Lloyd's Grade 'A' plate	5083 Aluminium	5083 Aluminium
Length overall		8 m Buddy Aluminium Catamaran	8.2 m	9.2 m	15.24 m
Breadth		2.3 m	2.95 m	2.5 m	4.88 m
Depth		0.7 m	4.55 m	3.6 m	4.27 m
Draught	lightweight	0.2 m	0.9 m	1.35 m	0.43 m
	deadweight	0.5 m	0.9 m	1.5 m	0.66 m
Displacement unladed		1200 kg	12500 kg	3000 kg	10884 kg
Max load capacity		1500 kg	1000 kg	1200 kg (solid) 2700 L (fluid)	5442 kg
Max speed		7 knots	8.5 knots	6 knots	6 knots
Operating speed		2-3 knots	2-3 knots	0-2 knots	1-2 knots
Estimated area covers in an hour		10000 m^2	20000 m^2	8000 m2	50000 m2
Engine options		Outboard petrol engine, 25-40 hp high thrust	Inboard diesel engine engine 140kW (185 hp)	Inboard diesel engine engine 75 hp	Cummins Diesel engine, liquid cooled

Performance Specification Method

The aim of setting the performance specification is to make an accurate specification of the performance required by the rubbish collecting system for the waterway. It is important to have the specific requirements of performance for the rubbish collecting system to fulfil demand and need. Initially, all specifications of the current model are tabulated in a proper manner as to simplify the analysis of the requirements of the system. Since there are several models for a single type of rubbish collecting system, the tabulated specification is only made for determining the maximum size for each system. This is to ensure that each model can be distinguished according to their maximum performance. In addition, the specification will only consider the most significant criteria that contribute to the performance of the system.

The comparison in Table 4 can help consumer to deduce the final performance specification that should be occupied by the system for collecting rubbish in rivers and canals. Each criteria of specification had been evaluated to determine the custom nature for the system, thus the performance specification could be set and made as principle for the final system design. The initial characteristic for performance requirements is as in Table 5:

Table 5: Initial deduction for performance specification

Specification		Characteristic
Hull form		Catamaran
Hull material		5083 Aluminium
Length overall		8 m (min) – 15 m (max)
Breadth		3 m (min) – 5 m (max)
Depth		3 m (min) – 5 m (max)
Draught	Lightweight	0.2 m (min) – 1.4 m (max)
	Deadweight	0.5 m (min) – 1.5 m (max)
Displacement (unladed)		1200 kg (min) – 12 500 kg (max)
Max load capacity		1000 kg (min) – 5500 kg (max)
Max speed		6 – 9 knots
Operating speed		0 – 3 knots
Estimated area covered in an hour		10 000 m^2 (min) – 50 000 m^2 (max)
Engine option		Optional

Following the initial deduction was the finalized performance specification for rubbish collecting system for rivers and canals. The specification was selected by considering various factors that may affect the overall performance of the system. Practically, the factors involved are related to the operation environment for the system which would be rivers and canals. It is important to consider the nature of operation environment on behalf of ensuring that the system is not defective when operating at the working site. The consideration should be determined in the moment of planning to adopt the system for the use of collecting rubbish in the waterway. Since this study is based on established model, there is no requirement to analyze the factor. Thus, the maximum characteristic selection would be the final specification performance guidelines for the final design of rubbish collecting system and the model which matches most of the criteria. From Table 6, it can be concluded that MS16-12000B TrashCat™ fulfills all the final performance specification. This means that this kind of model can perform at the highest level among others with all its comprised specification. However, this model still cannot be the best reference for the final design of rubbish collecting system since there are still some considerations needed to take into account, which will be explained in the next section.

Table 6: Final performance specification

Specification		Characteristic	MS16-12000B TrashCat™
Hull form		Catamaran	Catamaran
Hull material		5083 Aluminium	5083 Aluminium
Length overall		15 m	15.24 m
Breadth		5 m	4.88 m
Depth		5 m	4.27 m
Draught	Lightweight	1.4 m	0.43 m
	Deadweight	1.5 m	0.66 m
Displacement (unload)		12 500 kg	10 884 kg
Max load capacity		5500 kg	5442 kg
Max speed		9 knots	6 knots
Operating speed		3 knots	1-3 knots
Estimated area covered in an hour		50 000 m^2	50 000 m^2
Engine option		Optional	Cummins Diesel engine, liquid cooled

From Table 6, it can be concluded that MS16-12000B TrashCat™ fulfills all the final performance specification. This means that this kind of model can perform at the highest level among others with all its comprised specification. However, this model still cannot be the best reference for the final design of rubbish collecting system since there are still some considerations needed to take into account, which will be explained in the next section.

Determining characteristics (Quality Function Deployment Method)

The aim of the quality function deployment method is to set targets to be achieved for the engineering characteristics of a product, to satisfy customer requirements. Surveys should be done to determine this necessity but unfortunately, the rubbish collecting system for rivers and canals is not a mass production type of invention, hence it is not very popular or well known, and only recognized by certain organization or people. Therefore, market research survey is not compulsory and only estimation can be made to establish the requirements.

Table 7: Interactions between customers attribute with engineering characteristics

Customer attribute	Engineering characteristic
Able to store rubbish onboard	Designed draught achieved at maximum load
High capacity of rubbish storage	Installation of storage system
Able to discharge rubbish from vessel	Installation of discharge system
Easy to control vessel	Highly maneuverable characteristic
Easy handling of collecting system	Simple control and handling requirement
Good collecting mechanism	Installation of effective collecting system
Good stability	Effective hull design
Can be transported via land	Lightweight (material selection)
Comfortable operator station	Systematic control system arrangement
Able to operate at shallow water	Low operating draught
Low cost of operation and maintenance	Highly cost effectiveness
Attractive appearance	Antifouling paint and material selection

Since the survey is not compulsory and this method is rather complex to be employed, determining the interactions between customer attribute with engineering characteristics was performed by comparing both criteria. The relationship between both criteria was made based on assumptions to determine which requirements should be concentrated on for the design.

The engineering characteristics based on engineering knowledge are more precise. Table 7 shows the interactions between customers attribute with engineering characteristics supposedly evaluated using house of quality method. However, lack of information restricted the method to be performed, hence deduction was made based on the tabulated criteria to verify that engineering characteristics should be focused more to determine the best characteristics for the rubbish collecting system for rivers and canals.

The first criterion was to achieve the desired draught at maximum load. This is basically related to hull form design procedure, where the design must follow the rules established by Lloyds Register. The maximum load required for the design is approximately 11 000 kg, thus the hull design should be able to withstand that load capacity while maintaining the maximum draught. Apart from that, a storage system that can accommodate high capacity of storing waste and the requirement to install discharge system that can transfer the waste from the vessel without any external support should be installed.

The Morphological Chart Method

The morphological chart method functions to present complete range of alternative design solutions for a product, and hence to widen the search for potential new solutions. This method requires a list of features that are essential to the rubbish collecting system. Each feature will be compared to select the intended objective and a chart is drawn to include all the possible sub-solutions for the system. This usually concerns with the form arrangement or configuration of the essential basic elements of the rubbish collecting system, and represents the alternative configurations in purely graphical term. The essential generic features are as follows:

1. Means of collecting rubbish
2. Means of storing rubbish
3. Means of discharging rubbish
4. Means of moving the vessel
5. Means of support to increase stability
6. Means of system to assist the overall function
7. Location for operator

Table 8: Morphological chart for comparison of rubbish collecting system for rivers and canals

Feature	Means					
Collecting system	Multipurpose drop-in-pod system	Quick release system	Turbine pull system	Conveyor system	Oil recovery skimmer	Hydrocarbon separator unit
Storing system	Litter Collection basket	Skipper barge	Hydraulic powered basket	Storage conveyor	Storage tank	Floating bladder
Discharging system	via crane	via conveyor	via pump			
Propulsion system	Fix propeller	Adjustable elevation screw propeller	Water jet	Screw propeller	Hydraulic motor	
Powering system	25-40 HP high thrust, 4 stroke outboard diesel engine	185 HP inboard diesel engine	75 HP inboard diesel engine	Cumin diesel engine, liquid cooled		
Hull form	Catamaran	V-shape hull	Barge	Trimaran		
Operator	Seated at forward	Seated at amidships	Seated at aft	Standing		
Lifting	Hydraulic	Robotic	Crane			

Table 9: Best characteristics for rubbish collecting system for waterway based on morphological chart in Table 7

Feature	Means	Justification
Collecting system	Conveyor system + hydrocarbon separator unit	The system will be able to collect both solid and liquid waste. The system will be able to extract liquid waste from polluted water.
Storing system	Conveyor storage + storage tank + floating bladder	The system will be able to store both solid and liquid waste onboard before discharging them onshore.
Discharging system	Via conveyor + via pump	The system will be able to transfer waste without external assistance.
Propulsion system	Adjustable elevation screw propeller + hydraulic motor	Permits vertical position of the propeller to be adjusted to control the depth of the propeller during operation at shallow water.
Powering system	Cumin diesel engine, liquid cooled	Efficient and reliable
Hull form	Catamaran	Good stability characteristic
Operator	Seated at amidship	Facilitates clearer view
Lifting	Hydraulic	More effective than mechanical lifting

Some new functional alternatives have been added to the conventional alternatives, as in Table 8. Table 8 shows various rubbish collecting systems for rivers and canals designs. Of course, some of these are not practicable solutions, or else they imply incompatible options, for example, a rubbish collecting system for rivers and canals would be impractical if employing robotic system for lifting collected waste as it will be very expensive to imply.

Additionally, some of the solutions involve more than one feature for generating a multipurpose function. A conventional rubbish collecting system for rivers and canal would best comprise the following set of option from the chart as shown in Table 9.

The Weighted Objectives Method

The aim of the weighted objective method is to compare the utility value of alternative design proposals, on the basis of performance against differentially weighted objective. The general purpose for rubbish collecting system for rivers and canals is of course to collect rubbish that floats on rivers and canals. However, when it comes to specifying the overall functions, it is important to realize that floating rubbish is categorized into two major types which are solid waste and fluid waste; hence requiring the system to possess the ability to collect both kinds of waste.

The design may require a combination of various sub-systems. In this study, from the QFD analysis, each current design was compared by setting a datum of most possible design to be developed. The datum was based on result from the QFD analysis.

1. Designed draught achieved at maximum load
2. Installation of storage system
3. Installation of discharge system
4. Highly maneuverable characteristic
5. Simple control and handling requirement
6. Installation of effective collecting system
7. Effective hull design
8. Lightweight (material selection)
9. Systematic control system arrangement
10. Low operating draught
11. High cost effectiveness
12. Antifouling paint and material selection

For each objective, each established design was then judged as either better (+), worse (-) or the same (S), in comparison to the datum. Total for the (+) sign and (-) sign was given for each of each concept at the bottom of the matrix. The current designs are as follows:

i. Design I - 8m Buddy Aluminium Catamaran
ii. Design II - Mk.3 Water Witch Workboat
iii. Design III - CATAGLOP ® CG-92
iv. Design IV - MS16-12000B TrashCat™
v. Datum - The final design which comprise the requirement in Table 9

Table 10: Evaluation chart for the final concept

Engineering characteristic	I	II	III	IV	D
Designed draught achieved at maximum load	-	-	-	S	A
Installation of storage system	-	-	-	-	T
Installation of discharge system	-	-	-	-	U
Highly maneuverable characteristic	S	-	S	S	M
Simple control and handling requirement	S	S	S	S	
Installation of effective collecting system	-	-	-	-	
Effective hull design	S	-	+	S	
Lightweight (material selection)	S	-	S	S	
Systematic control system arrangement	-	S	-	S	
Low operating draught	S	-	-	S	
Highly cost effectiveness	+	S	S	S	
Antifouling paint and material selection	-	S	-	S	
Total +	1	0	1	0	
Total -	6	8	7	3	
Overall total	-5	-8	-6	-3	

From Table 10, design IV was chosen as the best among the others, as all other designs possess lots of negative values for the total evaluation. This is because the generated datum had been particularly comprised with the entire requirements. Concept IV therefore was selected as the best design of all, and preferred as the alternative concept for the rubbish colleting system for rivers and canals.

Improving details (The Value Engineering Method)

The aim of the value engineering method is to increase or maintain the value of a product to its purchaser while reducing its cost to its producer [6]. This method needs specific information about the price of the current rubbish collecting system for rivers and canals as to estimate the cost for developing the new system. Unfortunately, lack of information on the price restricted the method to be completed accordingly. Rather than analyzing the value in term of price, which may need elimination of some of the systems function to reduce cost, this method can also be performed by evaluating in term of its functional value. It is acceptable to increase the cost for the system development, as long as there is value added to the rubbish collecting system for rivers and canals.

Table 11: Functional value analysis

Attributes	Current design	Improvement
Utility	• Able to collect, store, and discharge floating solid waste in rivers and canals using the same system of operation (conveyor system). • No system to collect, store, and discharge fluid waste. • Powered by Cummins Diesel engine, liquid cooled. • 2 hydraulically driven, independently bi-directional and variable speed propellers	• Able to collect, store, and discharge floating solid waste in rivers and canals using the same system of operation (conveyor system). • Installed with hydrocarbon separator unit, provided with storage tank and floating bladder for storing waste. • Powered by Cummins Diesel engine, liquid cooled. • Propelled by adjustable elevation propeller, powered by hydraulic motor.
Reliability	• Catamaran hull • 50 000m^2 covered in an hour	• Catamaran hull • 50 000m^2 covered in an hour
Safety	• No auxiliary portion of the hull • Operator at amidship	• Provided with removable auxiliary portion for the hull • Operator at amidship
Maintenance	• Depends on hours of operation	• Depends on hours of operation
Lifetime	• Estimated 20 years	• Estimated 20 years
Pollution	• Gas emission from power plant	• Gas emission from power plant

There is a considerable body of knowledge in the field of ergonomics which can be applied to the system design. The attributes that can contribute to the quality or value of the system are as follows:

1. **Utility** - Performance on aspect such as capability, power, speed, accuracy or versatility.
2. **Reliability** - Freedom from breakdown or malfunction; performance under varying Environmental condition.
3. **Safety** - Secure, hazard-free operation
4. **Maintenance** - Simple, infrequent or no maintenance requirements
5. **Lifetime** - Except for disposable products, a long lifetime which offers good value for the initial purchase price
6. **Pollution** - Little or no unpleasant or unwanted by-products, including noise and heat

After much deliberation, finally, a whole class of value attributes related to aesthetics was obtained. This includes not only the appearance of the rubbish collecting system but also aspects such as surface finish and the arrangement of the sub-systems.

From the deduction made during Evaluating Alternatives (The Weighted Objectives Method), concept IV; MS16-12000B TrashCat™ had been selected to be the best alternative concept for reference in designing the rubbish collecting system for rivers and canals. The attributes to the quality of the design are tabulated as shown in Table 11.

Design Development

The design for rubbish collecting system for rivers and canals was completed using Google Sketch Up software, and a 3D model had been generated for the purpose of visualizing the requirements and specification that had been determined throughout the analysis. The details regarding to the design will be mentioned in the discussion chapter. Five drawings are previewed (Figure 4 to Figure 8) with different angles of view; isometric view, plan view, side view, stern view and bottom view; whereas several other views that show the specific sub-system and components consisted in the overall system will be attached in the appendices. Lines plan and general arrangement drawing were not required for this study as they were not in the scope of study. Hence, only 3D drawing was acknowledged.

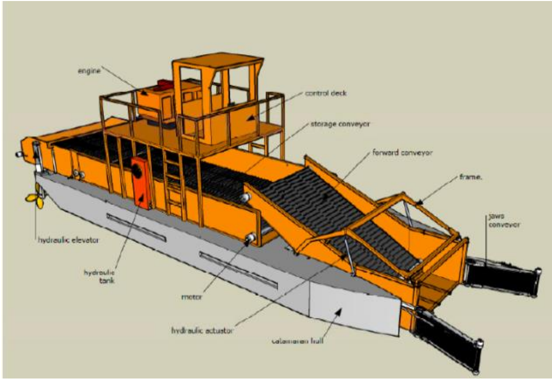


Figure 4: Isometric view

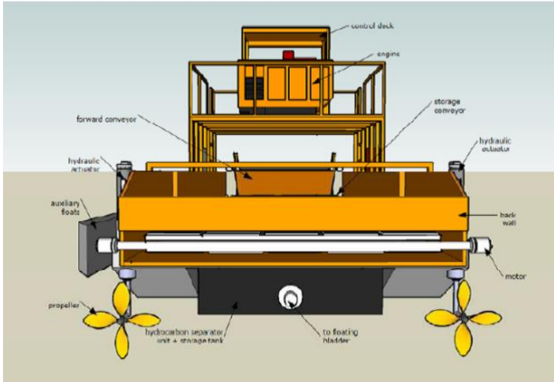


Figure 5: Stern view

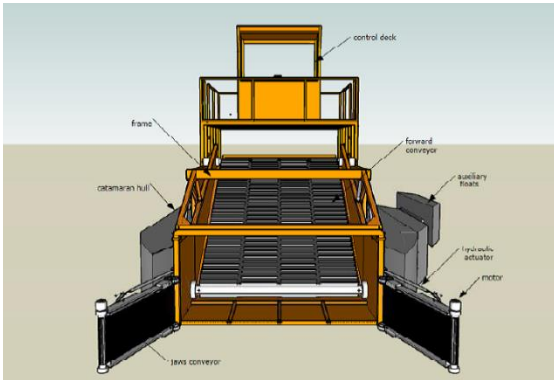


Figure 6: Front view

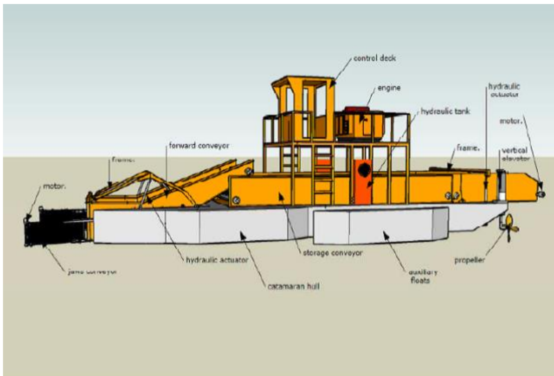


Figure 7: Side view

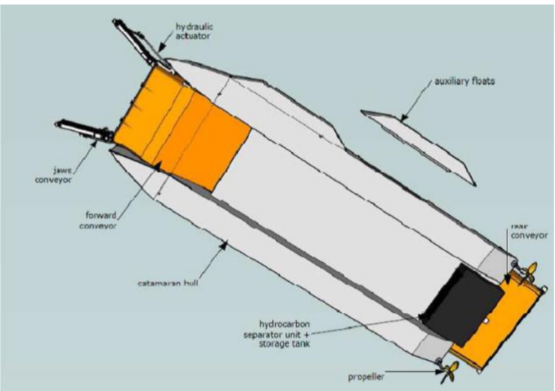


Figure 8: Bottom view

Discussion

The study is not precisely to design a vessel for collecting rubbish that floats in the river, but it intended to evaluate available systems of the current vessel designs for collecting rubbish using a suitable methodology. To achieve the objective, an analysis using engineering design method had been performed and accomplished. The analysis essentially concerned with problem formulation and the conceptual and embodiment stages of design, rather than proposing the best detail design which is the concern of most engineering design methods. The systematic analysis of engineering design method had successfully generated a potential and feasible concept of rubbish collecting system for rivers and canals.

This design relates to skimmer boats, or in other manner, refers to working boats for collecting and disposing floating solid materials in rivers and canals. Several modifications have been performed for the purpose of equipping the vessel with additional system able to collect fluid waste that floats on the water.

The invention is more specifically directed to highly maneuverable vessels equipped with means for picking up floating solid and liquid waste, storing the waste on the vessel, and discharging the waste from the vessel to a storage area, either for ashore or as other vessels such as barge [5].

MS16-12000B TrashCat™ has been selected to be the model reference where several additional features and modification were made for the purpose of fulfilling the design requirements of the system. The adjustments that had been made to the alternative design are based on engineering requirements and knowledge, also with the aid of facts from several trusted resources. The final detailed specification of the rubbish collecting system for rivers and canals are as follow:

Table 12: Detailed specification of rubbish collecting system for rivers and canals

Specification	MS16-12000B TrashCat™	
Hull form	Catamaran	
Hull material	5083 Aluminium	
Length overall	15.24 m	
Breadth	4.88 m	
Depth	4.27 m	
Draught	Lightweight Deadweight	0.43 m 0.66 m
Displacement (unladed)	10 884 kg	
Max load capacity	5442 kg	
Max speed	6 knots	
Operating speed	1-3 knots	
Estimated area covered in an hour	50 000 m^2	
Engine options	Cummins Diesel engine, liquid cooled	

In this design, one or more hydraulically powered open mesh conveyors are positioned between the catamaran hulls. Twin over-the-rear propellers are used to propel and maneuver the vessel, and these can be tipped up for cleaning weeds and waste from the propeller blades. A main pickup conveyor extends off the front end, and extends into the water to catch the floatables, by picking up and carrying them back to main storage conveyor. When the storage conveyor is completely loaded, the boat is taken to a discharge position where the waste can be transferred into a truck or barge or other facility. A rear conveyor at the stern of the vessel carries the waste from the storage conveyor up and backdrops it into the barge or on-shore facility. As alternative, a separate on-shore conveyor can be used to pick up the trash discharged from the vessel.

Forward conveyor working mechanism

A forward conveyor is mounted at the bow portion of the hull and is used for picking up trash from the body of the water and transferring it to the storage conveyor. The forward conveyor is also used to discharge the trash stored on the skimmer boat to a discharge station. A frame of the forward conveyor extends past the bow of the trash skimmer. The frame is mounted to the hull so that it can be tilted at range of angles, up and down, and so that the proximal end of the forward conveyor can be positioned above or below the distal or forward end of the storage conveyor. The forward conveyor favourably has an open mesh web, and fore and aft rollers over, for which the web travels and defines the distal and proximal ends of the forward conveyor [5].

Jaw conveyor working mechanism

At the front end of the forward conveyor, there is preferably also pair of supplemental conveyors. These shall be carried on the left and right jaw members. These jaw members are articulated so that they can open and close laterally. This enables the front conveyor to pick up rubbish or waste from a wide area at the front of the vessel. The jaws can be narrowed when loading from a narrow area [5].

Amidships conveyor working mechanism

A storage conveyor is positioned on the boat hull, approximately amidships and along the center line. In a favourable embodiment, the storage conveyor has an open mesh web that travels over forward and aft rollers, defining the forward and aft ends of the storage conveyor. The storage conveyor is mounted to the hull on a slide or track arrangement that permits motion fore and aft for a limited distance relative to the hull [5].

Rear conveyor working mechanism

The rear conveyor is functional for discharging process. It is mounted with a frame that can be lifted up and down to the same level of storage conveyor by a pair of synchronized hydraulic actuator. At the rear end of the conveyor is a wall which avoids the collected rubbish from getting outside the vessel [5].

Oil separator unit working mechanism

As the vessel moves forward, the forward conveyor is elevated by hydraulic actuators positioned at the port and starboard of the vessel. Fluid waste flows below the main deck between the hulls, hence collected in the hydrocarbon separator unit. The system separates fluid waste from the contaminated water and stores the fluid waste in the storage tank, or transferred to floating bladder via flexible pipe [5].

Propulsion and maneuvering working mechanism

Propulsion and maneuvering are achieved with a pair of screw drives, each positioned at the stern of the vessel at port and starboard sides, with each screw drive having respective hydraulic motor for powering it. Each screw drive is mounted on a respective elevator at the stern of the vessel that permits vertical position or the drive to be adjusted to control the depth of the screw propeller. Each elevator has an associated hydraulic actuator [5].

Recommendation

The design is not final since this study only presents comparison on the specifications and functions of the system and the sub-systems. Nevertheless, several recommendations are included for further study in the future, as follows:

1. The hull form design should be further evaluated for generating a reliable performance of the system.
2. General arrangement for the system should be drawn in a proper manner to ensure the systematic design of the system is complied.
3. All estimation calculations regarding the structural strength, stability, power estimations should be performed according to Lloyd's Register and IMO Regulations.
4. Fabrication process should be completed to generate a reliable model to be tested and evaluated, for the purpose of determining the reliability and the effectiveness of the system.

References

[1] *Suhai, S., 2007. Development of Rubbish Collector Boat. Thesis UTM.*

[2] *Water Witch Workboats- Multi purpose pollutuion control, marina, & waterway maintenance. www.waterwitch.com*

[3] *Aquarius Systems, 2007. On the cutting edge of water management technology http://www.aquarius-systems.com/*

[4] *Archer, L.B., 1984. Systematic Method for Designers. In: N. Cross (Ed.), Developments in Design Methodology, Wiley, Chichester.*

[5] *Walczyk, S.L., 2006. Trash Collection Skimmer Boat. United States Patent.*

[6] *Cross, N., 1942. Engineering design method: strategies for product design. 3rd ed.John Wiley & Sons, Ltd*