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Research Article

Development on Water Transport System in Sri Lanka with Available Water Resources

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Abstract Traffic congestion is an enormous problem at peak hours in western province. Existing transport system is not capable to overcome these complexity situations. Therefore, Srilankan government needs to find out different mode of transport to save time and money and finally economy of the country. In the past history, there was a rich water transportation system over the country. Specially, the western province has a well-distributed network of inland waterways, comprising of main rivers, streams, canals, lakes, and tanks. Most of the time, the existing waterways were used for freight transportation (timber, sand, brick, and tiles. compare to Public transportation. The study is to determine the efficient use of waterways for the public transportation focusing the travel time and fuel consumption. The existing water way network was map and find availability of other network connectivity using ArcGIS and Google Earth Pro software. Then compare it with an existing public transportation mode (bus) and checked the suitability of usage of water transportation as an alternative to reduce the existing traffic congestion problem. And proposed water way transport system, that capable of potential and strategic way to reduce the traffic congestion problem in Colombo and its sub urban areas.

Keywords *ArcGIS; Inland Water Transportation; Public Transportation Modes; Traffic Congestion*

1. Introduction

Traffic Congestion is a massive problem in congested towns of Sri Lanka. Especially, in the western province, people lose their time and money due to traffic congestion at peak hours. The average speed of a vehicle has dropped below 10kmph in peak time. The present transport system is not sustaining congestion and traffic delay at peak hours. Several alternative policies have implemented to overcome the situation for public and private transportation. However, it was not come in to satisfactory level. On the other hand, the existing transport system can cause to increase environmental pollution. Therefore, water transportation system is a high potential and environment-friendly alternative to address the issues. It is low cost, fuel-efficient, flexible and safer transport method. The water transportation mode is remarkable solutions for most part of the world and used in Asia, Africa, America, and Europe countries. They use their inland waterways to transport passengers and freight. However, water transport is a rare In Sri Lanka (Animansa and Danimi, 2014). Approximately 90% of land lies in the wet zone in western province. The average annual rainfall is over 2500 mm (reference). There is significant waterway network Such as Canals, rivers, and tributaries in the area. The Portuguese constructed s the canal system in Colombo area for freight transport. The canals were established from Colombo to Hendala, and also linked Bolgoda Lake in the south to Kotte Lake. Dutch era has contributed to distribute the canal system in the entire country. The most well-known among these was the 02-mile long Colombo-Puttalam waterway which was constructed in 1900. They have built a Canal system and linked the old canal system in Negombo. They introduced the boat service and the boat called padda boat (reference). British time, they used waterways to transport the production of tea, coffee, rubber, and graphite (Ganga, 1981)

Colombo is the capital and largest city of Sri Lanka. Under the Megapolis project, an inland water transportation service in the western province is being developed. It is one effective solution to reduce traffic congestion in the province. Three water transport lines have been identified to develop under this project. Wellawatta- Battaramulla Line (IW1), Fort- Union Place Line (IW2) and Mattakkuliya Hanwella Line (IW3). These lines will establish on Rivers, canals, and marshes in the region. The system for traffic demand analysis (STRADA) was the transport demand model which was used for the Megapolis transport project. The boats are stopped in jetties and those are similar to bus halts in road transportation. According to the modelling, those jetties are located in places which the most demanded and suitable locations with average speed of a boat is 18km/h (Final Report, 2017). Recently, the effective boat service has been implemented by Sri Lankan Navy to transport students and staff of the Open University the route Nawala, Nugegoda to Wellawatta and extended the service from Wellawatta to Battaramulla along the Kirulupone canal (Wijayapala, 2010)

Although, the water transportation is considered as an environment-friendly transport mode, it might be badly affected for the environment such as solid waste disposal, air pollution, operational oil pollution. The solar powered and electric boat can be used to minimize the pollution that occurred by the inland water transportation system. It may be possible to introduce some limitation such as number of boat enters to the system and introduce speed limits to ensure safety of the passengers. In other hand water turbulence and disturbance of inland fishing activities need to be carefully considered before planning of water transport system (Sulaiman et al., 2011). There were few guidelines and methods to design the navigational channel. Among those, mostly used guidelines are introduced by PIANC (Permanent International Association of Navigation Congresses). There are several factors will consider before design a channel.

Such as, the dimension and speed of the ship, maneuvering characteristics, allowances of sedimentation and shoaling etc. ArcGIS and Google earth pro software can be used acquire more accurate and reliable data for analyzing and designing waterway works. These techniques can have used to update data time to time.

2. Methodology and Results

The digital data of Sri Lanka were found from the Survey Department of Sri Lanka. By using ArcGIS software, Separated the western province polygonal layers including the existing waterways and land usage layers (Figure 1). The study area of 10km radius from Colombo fort was taken as case study due to more traffic congested and it can be simplifying to other area as well (Senanayake et al., 2013).

The study selected bus routes which operate in the study area and proposed the terminal point of the waterway network considering lad usage of the area and developed the existing waterway network by adding the connectivity. Some of the small new waterway paths need to be added to increase the path between selected terminal. Shorted path between those terminals will be considering when selecting waterway network.

Some canals' widths are small and not able to travel a boat. Therefore, these kinds of waterway need to be modified. Mostly the adding segments were created on the lake, paddy field, and none build-up area. However, in some places, to create the connectivity of waterway, the small segments had to be placed on the building area.

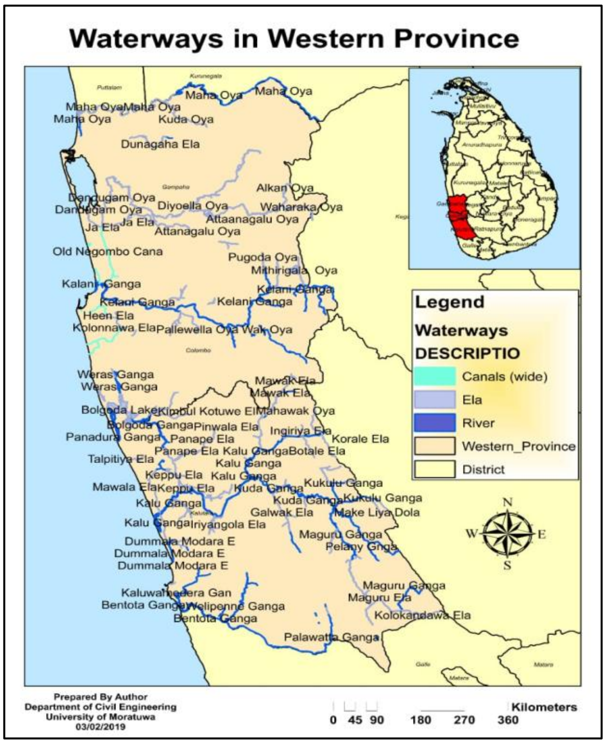

Figure 1: *Existing Waterways in Western Province*

Subsequently, these layers were converted to Keyhole Markup Language (KML) format using ArcGIS software and the generated files were opened in Google Earth Pro software. The existence of these routes along waterways was spatially verified and modified by visual analysis with existing features in the satellite imagery at Google Earth Pro. Then compare travel time via inland waterways and existing public transport mode (buses). During peak hours, the study found the travel time via the public road transportation system between selected terminal stations in the study area (Table 1).

Table 1: *Average Travel Time by Public Transport (Bus) in Peak hour in Some Selected Routes*

Starting Station	Ending station	Peak Hours 7.30-8.30 a.m. Minutes	Peak hour 530-6.3p.m Minutes	Average Travel Time in Minutes
Fort	Narahenpita	40	40	40
Fort	Elakanda	52	55	53
Kotahena	Maharagama	62	65	63
Pettah	Elakanda	45	48	46
Kollupitiya	Wellampitiya	50	55	52
Wellawatta	Narahenpita	36	40	38
Pettah	Kaduwela	70	74	72

To find the travel time via waterways, firstly, waterways were divided into a small segment and measure each segment distance (Figure 2).

Secure speed for all ships that are used in inland water transport must be maintained, sufficient and successful steps taken to prevent a collision are taken and stopped within the same range as the prevailing circumstances and conditions (Navigation Rules and Regulation Handbook, 2014).

Figure 2: *Segment-Wise Divided Waterway Network*

When concern about low water levels and the risks involved, the speed will be reduced to 5 knots or less (Transport Safety Victoria, 2019). Regarding all these aspects, the average speed of vessels used in inland water bodies is selected as 7 knots (13km/h). Therefore, the time to be travelled through the inland waterway between the selected terminals was determined by estimating the average speed of vessels as 13 km / h (Table 2).

Table 2: *Travel Time through Waterway Network*

Starting Station	Ending station	Distance trough water way(Km)	Travel Time Minutes
Fort	Narahenpita	10.3	48
Fort	Elakanda	10.2	47
Kotahena	Maharagama	18.15	84
Pettah	Elakanda	10.2	47
Kollupitiya	Wellampitiya	11.8	54
Wellawatta	Narahenpita	4.4	20
Pettah	Kaduwela	20.6	95

Subsequently, by comparing the travel times via waterways and public road transportation, selected the waterways which could be saved more than 10 minutes compared to public road transportation system (Table 3).

After that, compared the boat fare and bus fare. The fuel consumption was found to be 4.8 l / h for the speed 13 km/h and the power requirement 5.5 hp/ t by assuming the engine burns 0.25 l / h for each horsepower for a boat with an 8 m waterline length and a 3175 kg service condition displacement (Gulbrandsen, 1982). The fuel consumption can be estimated to travel between the selected terminals by using the diesel value in December 2019 (SL Rs.104). Since calculating the cost of transporting the fuel between each terminal, the researcher calculated the passenger's boat charges for transport between each Terminal by adding 30 % to the fuel consumption. Then, separately calculated the boat fare for a Passenger, when the boat capacities are 10, 15 and 25 passengers. The present bus fare between each bus terminal could be finding out by the National Transport Commission (NTC). Table 4 shows a significant reduction of the boat fare per passenger when the number of passengers accommodated by a boat is increased. Further, the boat fare of the passenger is raised relative to the bus fare, when the distances between the start station and end station are increased. In addition to that, the researcher needed to get a rough idea about the initial cost that has to be paid to develop the existing waterways according to the travel requirement. Assuming the boat beam is 3m, the minimum canal width was calculated to travel along the waterway.

$$W_T = 2W_{BM} + 2\sum W_i + W_{Br} + W_{Bg} + \sum W_p \qquad (1)$$

W_T is the final width of the channel, W_{BM} is required channel width for maneuvering of the sail safety in favorable environmental an operational condition, W_i are additional channel widths due to ship speed and wave, W_{Br} and W_{Bg} are the ban clearance sides of navigational channel and W_p is the passing distance. Considering all these factors, final canal's width would be 33m (El-Sersawy and Ahmed, 2005)

Subsequently**,** the canal width was widened along the proposed waterway paths included in the waterway network (Figure 3) then, to get an idea about initial construction cost; the land area that has to be acquired for the proposed waterways was measured by using existing satellite imagery at Google Earth Pro. Mainly, the researcher has divided those lands into with buildings and without buildings. After, the rough idea can be getting by concerning the percentages of those areas from the total canal area (Table 5)

Table 3: *Comparison the Travel Time between Public Transport and Water Transport*

Starting Station	Ending station	Travel Time by public Transport (P T)	Travel Time by Water Transport (WT)
Wellawatha	Narahenpita	10.30	48.0
Pettah	Abatale	10.20	47.0
Borella	Jayawwrdanapura	18.15	84.0
Battaramulla	Mattakuliya	10.20	47 0
Pettah	Kaduwela	20.6	95.0

Table 4: *Bus Fares in December 2019 with the suggested Boat Fares and Distance between among each Selected Terminal in the Study Area*

Starting Station	Ending station	Distance Between each Station (km)	Bus Fair Sri Lankan rupees (Rs)	Suggested boat fare (SL Rs.) with a 30% profit from Fuel consumption to transport		
				10 Passengers	15 Passengers	25 Passeng
Fort	Narahenpita	10.30	19.0	52.0	34.0	21.0
Fort	Elakanda	10.20	32.0	51.0	34.0	20.0
Kotahena	Maharagama	18.15	47.0	91.0	61.0	36.0
Pettah	Elakanda	10.20	32.0	54.0	34.0	20.0
Kollupitiya	Wellampitiya	11.80	28.0	59.0	39.0	24.0
Wellawatta	Narahenpita	4.40	14.0	22.0	15.0	9.0
Pettah	Kaduwela	20.60	39.0	103.0	69.0	41.0
Fort	Rajagiriya	8.98	19.0	45.0	30.0	18.0
Seemamalakaya	Mattakuliya	8.98	32.0	45.0	30.0	18.0
Kalanimulla	Seemamalakaya	14.66	36.0	73.0	49.0	29.0
Pettah	Abatable	10.54	32.0	53.0	35.0	21.0
Pettah	Gothatuwa	9.81	23.0	49.0	33.0	20.0
Kiribathgoda	Angulana	30.07	52.0	151.0	100.0	60.0
Mattakuliya	Soysapura	22.35	47.0	112.0	75.0	45.0
Town Hole	Salmal Uyana	12.35	39.0	62.0	41.0	25.0
Slave Island	Angoda	12.00	32.0	60.0	40.0	24.0
Kotahena	Nugegoda	15.10	39.0	76.0	50.0	30.0

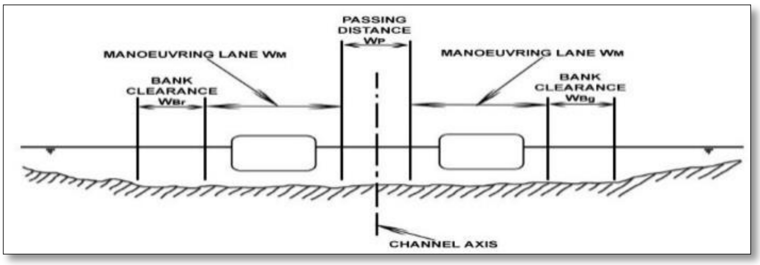

Figure 3: *Element of Channel Width*

Table 5: *The building area and without buildings area measuring and it is comparison with total required waterway area*

Starting Station	Ending station	Total waterway area	Land with building area as a percentage from the total area(%).	Land without Building Area as a percentage from the total area (%).
Fort (Colombo)	Narahenpita/ Borella	339900	18.12	15.04
For	Elakanda	336600	16.25	9.27
Kotahena	Maharagama	598950	9.25	10.34
Pettah	Elakanda	336600	16.25	9.27
Kollupitiya	Welampitiya	389400	11.82	8.48

3. Discussion and Recommendation

According to the comparison of travel time through waterways and public transportation (bus), water transportation is effective than the existing public transportation. In here, the boat speed was taken as 13km/h for safe travel. But it can be increased. Due to the manoeuvring effect, the researcher has limited the boat speed to 13km/h. But when it moves freely (no boat crossing), the boat speed can be increased over 13km/h. So it would be caused to reduce travel time furthermore. As the researcher found, there are few waterway routes that can be used to save the travel time more than 10 minutes at peak time. Therefore, if there is an idea to implement the water transportation system in the Colombo area, it is better to consider these waterway routes as an initial step. Here the boat fares were calculated, considering fuel consumption as 4.8 l / h for the speed of 13 km/h and adding the 30% by the cost of fuel consumption. Table 3 shows, when the number of passengers accommodated by a boat is increased, the boat fares are reduced. It is suitable to accommodate more passengers. Here the Table 6 shows, these waterway routes save travel cost more than Rs.15.00 than the existing public transport mode. Furthermore, boat fares can be reduced by using fuel saving boats. And also, if the electrical boat can be used, the negative effect for the environment due to boat transportation can be minimized and it would be a cost-effective and environment friendly method. Furthermore, compared to the Bus service, the maintenance cost of boat service is low and the initial cost of boat service is lower than the bus service. Subsequently, the researcher has measured the land that has to be acquired for water way to get the draft idea about the initial construction cost. According to that, table shows, the coverage of built-up area is below 25% (1/4) from the total land area which is about to expand (for the expansion of canal width) by the proposed waterway network. The remaining land area (75% - 3/4) comprises from canal (above 50% - 2/4) and non-built-up area (below 25% - 1/4) (Figure 4). Since the built-up area is comparatively low (1/4); the land acquisition process, demolishing process and compensation process are effective in terms of cost and time. Hence the proposed waterway network can be positioned as a feasible project. According to the comparison of travel time and travel cost between the existing public transport method (bus) and waterway transport method, Table 7 shows the significantly effective waterways that can be used to travel among those terminals and it can save time and cost. If water transportation will be added to the transport method in the western province to reduce traffic congestion at peak hours, these waterways can be effectively used.

The proposed waterway network has potential to reduce the traffic congestion in Colombo and its sub urban areas. And also inland water transportation network can be mentioned as a city beautification element. It can attract local and foreign tourists and the water network can be promoted for tourism related activities. The infrastructure facilities of the city area and its sub urban areas will develop in accordance with the initiation of proposed waterway transportation network. The proper maintenance of the water transportation network can preserve the environmental condition and eco system of the canal network by preventing the garbage disposal and wastewater disposal to the canal network.

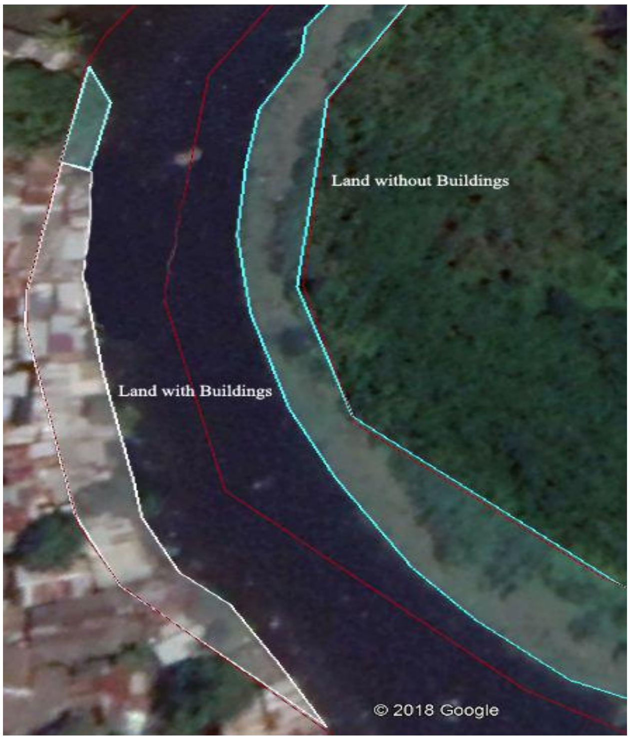

Figure 4: *The Building area and without Building Area*

Table 6: *Comparison between Bus and Boat Fare*

Starting Station	Ending Station	Bus Fare(SL Rs)	Boat Fare 25 passenger	Difference Between Bus and Boat Fare
Battaramulla	Pettah	39.0	23.0	16.0
Battaramulla	Mattakuliya	42.0	24.0	18.0

Table 7: *Comparison of Travel Time and Travel Cost between existing Public Transport Method and Waterway Transport Method*

Starting Station	Ending Station	Travel Time Difference	Travel Fare Difference
Wellawatta	Narahenpitiya	18.0	60.0
Pettah	Ambatale	11.0	11.0
Borella	Jayawadanagama	16.0	12.0
Battaramula	Mattakuliya	12.0	17.0

4. Conclusion

Considering the travel time and travel cost, it is effective to do a detailed study for the area within a 10km radius from the Colombo fort to propose an inland water transportation network. The selected bus routes which operate in the study area was used to get the terminal point of the waterway network and then considering these points and land usage of the study area and developed the existing waterway network by increasing the connectivity. Therefore, some small new waterway paths had to be added. The existence of these routes along waterways was spatially verified and modified by visual analysis them with existing features in the satellite imagery at Google Earth Pro.

The analysis of travel time comparisons, fuel consumption rate comparisons and fare comparisons the proposed project has more advantages and a considerable level of feasibility. As well as the land acquisition and upgrades of the existing waterway network recorded a less amount of impact. Overall, the proposed waterway transportation can be found as a potential and strategic way to reduce the traffic congestion problem in Colombo and its sub urban areas.

Apart from the solution for the traffic congestion, the inland waterway network is an element of city beautification, magnet for tourist attraction and motivation for environmental preservation.

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