A GIS Based Analysis on Use of Inland Waterways for Public Transportation in the Western Province of Sri Lanka

I.P. Senanayake, T.D.C. Pushpakumara and U.G.A. Puswewala

Abstract: People in the Western Province of Sri Lanka who travel to Colombo, the commercial capital of the country, at peak hours face many hardships in transportation due to congestion of traffic. The railway network of the country seems inadequate to provide a solution to this traffic condition in Colombo City during peak hours.

Western Province of Sri Lanka located in the wet zone of the country, has a widely distributed network of inland waterways, including a colonial-era canal system, to transport commodities from inland to Colombo Port.

These canals and tributaries are sparsely used at present to transport freight such as bricks, tiles, sand and timber. However, there is potential to use these waterways as a medium of public transportation in order to reduce the road traffic, as a solution to problems of traffic congestion experienced by the commuters living in and around the Western Province.

In this work, the shortest routes connecting Colombo Fort to twenty one selected cities in the Western Province of Sri Lanka, by roads and inland waterways, were analysed on the basis of distance, time and feasibility, with the aid of GIS techniques. The methodology adopted in this research can be introduced to other areas of the island with suitable modifications based on local conditions.

Keywords: GIS, Inland Water Transportation, Network Analysis, Road Traffic

1. Introduction

Many valuable man-hours in the Western Province of Sri Lanka are wasted on the road due to the severe road traffic conditions at peak hours. The present railway system of the island appears unable to solve this problem, whilst it is also difficult to change the existing road system of Colombo. Though costly, construction of subways can provide a partial solution in the future. However, in the short-term, if a proper solution can be found to save the wasted man-hours due to the road traffic, such time may be used effectively for the development of the country.

Further, Colombo city area has a high average annual growth rate of 2.42% with a population of 642,163 in 2001 and an estimated population of 1 million in 2010 [1].

In this work, inland water transportation is suggested as an option with a high potential to provide a realistic alternative to this problem.

Approximately 90 % of the Western Province of the island lies on the wet zone, which receives over 2500mm of average annual rainfall. The drainage system of the island is mainly radial with 103 rivers starting from the central highlands [2].

Rivers Kalu Ganga and Kelani Ganga flow through the Western Province to the ocean while Maha Oya flows along the Western - North-western Provincial boundary to the ocean. During the 18th Century, the Dutch rulers of the island developed a canal system or waterways to transport the commodities such as spices and coconuts from inland to Colombo

Eng. I.P. Senanayake, B.Sc. Eng. (Hons) (Moratuwa), M.Phil (Moratuwa), AMIE(Sri Lanka), Research Engineer, Space Applications Division, Arthur C Clarke Institute for Modern Technologies, Moratuwa, Sri Lanka.

Eng. T.D.C. Pushpakumara, B.Sc. Eng. (Hons) (Moratuwa), M.Eng (Tokyo), AMIE(Sri Lanka), Senior Lecturer, Department of Civil Engineering, University of Moratuwa, Sri Lanka.

Eng. (Prof.) U.G.A. Puswewala, B.Sc. Eng. (Hons) (Moratuwa), M.Eng. (AIT, Thailand) Ph.D. (Manitoba), C. Eng., FIE(Sri Lanka), Professor at the Department of Civil Engineering and the Dean of the Faculty of Engineering, University of Moratuwa, Sri Lanka.

Port; this system extends from Kalutara to Puttalam with a total length of over 175 km [3], [4].

The waterways in the Western Province are still used sparsely in transporting commodities such as bricks, tiles, sand, timber, etc., while they have not been used in public transportation for many decades until the Sri Lanka Navy recently introduced public transportation between a few cities along inland waterways [5].

Inland water transportation is an environmental-friendly mode of transportation with a high potential to function as an alternative and a supplementary method of transportation and as an inter-modal mix of public transportation. Inland water transportation has been effectively practiced in many regions in the world for public transportation as well as transportation of commodities.

Inland water transportation is used in Europe, Asia, Africa and America in freight and passenger transportation. It represents 20% of the transport sector in Germany and 32% in Bangladesh. River ports in Bangladesh are well developed compared to rail and road transportation modes. Inland water transportation shares the second position in freight transportation in Thailand next to road transportation. Also, various types of services including express services are used in passenger transportation in and around Bangkok via inland waterways [6].

Western Province of Sri Lanka has an adequate number of inland waterways such as rivers, lakes, canals, etc. which upon development, can make an efficient network of inland water transportation.

Recently, Sri Lanka Navy has successfully initiated a boat service to transport students and staff of the Open University at Nawala, Nugegoda to Wellawatta and extended the service from Wellawatta to Battaramulla along the Kirulapone Canal. The 45 minutes journey at peak hours from Nawala to Wellawatta via public road transportation has been shortened to a 20 minute journey through this boat service [5].

Integration of Remote Sensing and GIS techniques with the relevant data can be used to analyse the effectiveness of an inland water transportation method in public transport in

the Western Province. Remote Sensing and GIS techniques provide an updated, reliable database while significantly saving the time consumed for field work and data analysis.

2. Methodology and Results

Seven main cities from each of the three districts of Western Province were selected randomly for this study as shown in Table 1.

Table 1- Selected Cities from each District of Western Province of Sri Lanka for the analysis on inland water transportation for public transportation

Colombo District	Gampaha District	Kalutara District
Moratuwa	Negombo	Panadura
Kesbewa	Mirigama	Bandaragama
Boralesgamuwa	Ja-ela	Ingiriya
Kottawa	Gampaha	Kalutara
Kotte	Attanagalla	Maggona
Athurugiriya	Kelaniya	Matugama
Padukka	Pugoda	Baduraliya

Shortest routes from each of these cities to Colombo Fort along roads and waterways were considered for this analysis.

1: 10,000 digital data of Sri Lanka were obtained from the Survey Department of Sri Lanka. Polygonal layers demarcating Western Province and the districts in the Western Province were prepared by using ArcGIS software. Subsequently, a point feature class layer showing the selected cities was generated by using ArcGIS 9.3 software.

Network data sets for the road layer and tributaries layer were generated by using ArcGIS Network Analyst Tools and then the shortest routes from the selected cities to Colombo Fort were found along roads and waterways separately. There are no inland waterways connected to Colombo from the cities Mirigama, Negombo and Matugama, hence those cities were omitted from further analysis. Subsequently, by appending the shortest routes together by using ArcGIS software, layers showing the shortest routes via roads and waterways from the selected cities to Colombo Fort were generated separately. Figure 1 shows the two layers superimposed over the Western Province of Sri Lanka.

Figure 1- Shortest Routes to Colombo Fort via Waterways and Roads from the Selected Cities in the Western Province of Sri Lanka

The shortest distance from each city to Colombo Fort through roads and waterways was found in the attribute table of these two layers.

Subsequently, these two layers were converted to Keyhole Markup Language (KML) format using OziExplorer software and the generated files were opened in Google Earth. Existence of these routes along waterways and roads were spatially verified by visually analysing them with the existing features in the satellite imagery at Google Earth.

In order to check the average displacement between the Survey Department data and the satellite imagery data in Google Earth, distances along the shortest routes in Google Earth were measured. The mean value of the percentage increase of the distance along the

shortest routes in the Google Earth data over Survey Department data is calculated to be 1.03% with a standard deviation of 0.0926 via roads and 6.3% with a standard deviation of 0.0988 via inland waterways. Therefore, it is possible to verify that the Survey Department data is accurate spatially and on the basis of distance. For convenience in analysis, distances along the shortest routes via roads and waterways measured using Google Earth, were used in further analysis. Hence, the attribute tables of the polyline feature classes showing the shortest routes via roads and waterways were updated with the new distance values.

Subsequently, two new fields, i.e. distance via road and distance via waterways, were added to the attribute table of the point layer showing the selected cities and the fields were filled with the new distance values.

Distance along the shortest routes to each selected city from Colombo Fort via roads and waterways were then compared as shown in the graph of Figure 2. It can be clearly seen that the distance from each city to Colombo Fort via waterways is longer than the distance via roadways. The percentage increases of the shortest distance via inland waterways over roads are calculated using Equation (1) and shown in Table 2.

$$\text{i.e., } ED = \frac{(D_W - D_R)}{D_R} \times 100 \% \quad \text{----- (1)}$$

ED - Percentage of Extra Distance in km

D_W - Distance via waterways

D_R - Distance via roadways

The average increase of the shortest distance via waterways over distance via roads is calculated to be 57.98% with a standard deviation of 0.3469.

A safe speed has to be maintained for all the vessels used in inland water transportation, thus appropriate and effective actions can be taken to avoid accidents by adopting an appropriate stopping distance in any such circumstance [7]. When, in cases involving doubt regarding low water levels and submerged hazards, the speed is recommended to be reduced to 5 knots or less [8]. Concerning all these factors the average speed of vessels used in inland water bodies is selected as 7 knots (i.e. 12.96 km/h).

Hence, by assuming the average speed of vessels as 13 km/h, time duration to travel via inland water bodies from Colombo Fort to each of the selected cities were calculated.

Questionnaires and interviews were carried out among 500 people in the selected cities who travel to Colombo for work by public road transportation (buses), inhabitants and bus drivers in order to find the realistic data on the time duration and the cost for travelling at peak traffic hours. The average time durations for travel via public road transportation were calculated and interpreted in the graph in Figure 3 with time durations for travel via inland water bodies.

Figure 3 clearly shows that the time duration for travelling to Colombo Fort from selected cities via inland water bodies is longer than the time duration for travelling via roads by buses during peak hours except for Kotte City.

Displacements from the selected cities to Colombo Fort were determined by using Hawth's Analysis extension in ArcGIS software, and the percentage extra travel times to travel from the selected cities to Colombo Fort via inland waterways over the travel time via public road transportation services (buses) during peak hours were calculated except for Kotte City. For Kotte, the percentage extra travel time to travel via public road transportation services in peak hours over the travel time via inland waterways was calculated, and above calculated data are interpreted by the graph of Figure 4.

Figure 2- Comparison of the Shortest Routes to Colombo Fort, Sri Lanka from the Selected Cities via Roads and Inland Waterways on the Basis of Distance

Table 2- Percentage Increase of Distance to Colombo Fort via Inland Waterways over Distance via Roads of the Selected Cities in the Western Province of Sri Lanka

Districts	City	Percentage increase of distance via inland waterways over roads
Colombo	Athurugiriya	55.80
	Boralesgamuwa	91.28
	Kesbewa	129.54
	Kottawa	84.94
	Kotte	26.06
	Moratuwa	112.98
	Padukka	38.22
Gampaha	Attanagalla	48.69
	Gampaha	38.75
	Jaela	12.55
	Kelaniya	19.31
	Pugoda	27.62
Kalutara	Baduraliya	48.19
	Bandaragama	40.45
	Ingiriya	125.30
	Kalutara	47.41
	Maggona	41.29
	Panadura	55.24

Figure 4 shows that when the displacement from the selected cities to Colombo Fort is shorter, percentage extra time duration for travelling via inland waterways becomes shorter; for Kotte City which is located adjacent to the Colombo City area, the time duration for travelling in the peak hours via inland water bodies becomes shorter than the time duration for travelling via public road transportation. Considering total and extra travel times taken, it can be seen that implementation of an inland water transportation system within a radius of 10 km from Colombo Fort is more viable.

Then a feasibility analysis was carried out for the two modes of transportation during peak hours from the selected cities to Colombo Fort. The data on cost of travelling from selected cities to Colombo Fort was collected through questionnaires and interviews carried out among inhabitants of the selected cities and bus drivers.

By assuming that the engine burns 0.25 Litres/h for each horsepower for a boat with 8 m waterline length and displacement in service condition of 3.5 tonnes, the fuel consumption was found to be 4.8 l/h for the speed of 7 knots and a power requirement of 5.5 hp/t [9]. Thus, the fuel consumption to travel from each selected city to Colombo Fort can be calculated by using the time duration to travel as shown in Figure 3. Subsequently, by using the current price of kerosene in March 2012 (SL Rs. 106),

Figure 3- Comparison of the Average Time Durations to Travel via Public Road Transportation and Inland Waterways to Colombo Fort from the Selected Cities in the Western Province of Sri Lanka

Figure 4- Distribution of Percentage Extra Time Taken to Travel from the Selected Cities in the Western Province of Sri Lanka to Colombo Fort During Peak Hours with respect to the Displacement of the Cities from Colombo Fort.

the costs of fuel to travel from each of the selected cities to Colombo Fort were calculated. Then, by adding 25% profit margin, boat fares for a passenger to travel from each city to Colombo Fort in boats which can transport 10, 15 and 25 passengers were calculated separately.

Average bus fares in March 2012 to the selected cities from Colombo Fort were found out through the questionnaires and interviews carried out among inhabitants of those cities. Bus fares from each of the selected cities to Colombo Fort were listed with the suggested boat fares to transport 10, 15 and 25 passengers in the Table 3, assuming the fuel consumption is constant when transporting 10, 15 and 25 passengers.

Table 3 shows that when the number of passengers which can be accommodated by a boat increases, the boat fare per passenger can be reduced drastically. Further, it can be seen that, when the displacements from the selected cities from Colombo Fort are decreased (i.e. when the cities are closer to Colombo), the suggested boat fare significantly decreases compared to the bus fare. According to Table 3, when a boat transports 25 passengers from the cities Kotte and Kelaniya, which is located at a displacement of 12.9 km and 6.9 km from Colombo Fort, the suggested boat fare can be reduced below the bus fare.

Subsequently, a GPS survey has been carried out to spatially verify the digital data.

A comparison of some basic factors between vessels which can be utilized in an inland water transportation system in the Western Province of Sri Lanka and buses commonly used in public road transportation system in the area is shown in Table 4.

According to Table 4, it can be seen that the initial capital cost and the maintenance cost for boats are drastically low compared with buses, whilst the number of passengers who can travel in a bus are higher than in a boat.

The percentage extra boat fare to travel from the selected cities to Colombo Fort by a 25 passenger boat over the travel time by public road transportation services (buses), except for Kotte and Kelaniya cities were calculated. For Kotte and Kelaniya, the percentage extra bus fare over the 25 passenger boat fare were calculated, and plotted against the displacement from Colombo Fort in Figure 5. Graph in Figure 5 shows that inland water transport could be cost effective when displacement is less than 10 km.

Table 3 - Bus Fares in March 2012 with the Suggested Boat Fares and Displacement to Colombo Fort from the Selected Cities in the Western Province of Sri Lanka (Fares as per March 2012)

Districts	City	Displacement from Colombo Fort (km)	Bus Fare to Colombo Fort in SL Rs.	Suggested boat fare (SL Rs.) with a 25% profit from Fuel consumption to transport		
				10 passengers	15 passengers	25 passengers
Colombo	Athurugiriya	18.9	38	150	100	60
	Boralesgamuwa	12.1	38	127	84	51
	Kesbewa	18.8	25	202	134	81
	Kottawa	16.7	34	176	117	70
	Kotte	12.5	30	68	45	27
	Moratuwa	17.9	38	169	113	68
	Padukka	27.7	60	223	148	89
Gampaha	Attanagalla	37.7	60	326	217	130
	Gampaha	24.2	45	199	133	80
	Jaela	17.3	34	106	70	42
	Kelaniya	6.9	23	55	37	22
	Pugoda	30.8	60	224	149	90
Kalutara	Baduraliya	64.2	120	611	407	244
	Bandaragama	29.1	49	234	156	94
	Ingiriya	42.8	130	544	363	218
	Kalutara	40.6	60	305	203	122
	Maggona	49.7	69	347	232	139
	Panadura	25.7	32	206	137	82

3. Discussion and Recommendations

Above results clearly show that travelling in the peak hours via inland waterways does not have an advantage over travelling via public road transportation on the basis of travel time except in the cities closer to Colombo. But, travel time in the peak hours from the cities such as Kotte can be significantly shortened compared to the travel time via public road transportation. Hence, there is a high potential for reducing the travel time drastically by introducing a network of inland water transportation to the Colombo city area and adjacent urban centres within 10 km radius area from Colombo Fort as shown in Figure 6. The reduction of the travel time from Nawala to Wellawatta from 45 minutes to 20 minutes by the boat service introduced by Sri Lanka Navy can be considered as a good example for this.

Bathymetric surveys can be carried out followed by trials for the recommended routes, prior to the actual implementation of the service. A short sea shipping system can be collaborated with inland water transportation

for the cities in the coastal belt of Sri Lanka to link with Colombo.

An inland water transportation network inside Colombo city and the adjacent urban centres will help in reducing the road traffic density during peak hours which can be identified as 7.00am to 9.00am and 4.30pm to 6.30pm, according to the questionnaires and interviews carried out among the people. Further, this service can be used to transport school children at the end of school hours around 1.30pm to 2.30pm. Also, it can be successfully employed in the transportation of freight between the cities in the Western Province and extending up to Colombo Harbour.

Also, the information in the Table 4 proves that when the cities are closer to Colombo, boat fare can be reduced compared to the bus fare from those cities to Colombo Fort. Hence, Colombo City area and the adjacent urban centres such as Kotte, Nugegoda, Kelaniya and Dehiwala can be identified as the most suitable area to implement an inland water transportation network on the basis of feasibility and it can be

identified as an economical mode of transportation to move possible commodities within Colombo city area and adjacent urban centres.

According to the results of this study, Kotte and Kelaniya can be identified as the suitable cities to implement an effective inland water transportation system to transport passengers and freight to Colombo Fort area. Trial rides have to be carried out between Colombo Fort and the above two cities in order to practically verify the results followed by necessary infrastructure development and awareness programmes prior to the actual implementation of an inland water transportation system. Further, in view of the above factors, it can be seen that, there is a high potential to implement an effective inland water transportation system within Colombo city area, hence a detailed research is highly recommended to be carried out focused on Colombo City area and adjacent urban centres, based on the methodology utilized here, in order to identify the suitable

routes to design an effective inland water transportation system. According to the results of this analysis, such a detailed study can be suggested for the area within 10 km radius from Colombo Fort as shown in Figure 4 and Figure 5.

Further, an inland boat service can be utilized in the development of local and international tourism in the country with recreation facilities such as city tours, leisure activities, pleasure rides, water sports, boat parties, etc. in the off-peak hours. This will also assist to cover the initial capital cost of vessels.

18 ft (5.5m) outboard powered fibre reinforced plastic (FRP) boats with 7hp and 12-15hp kerosene outboard engines and 28 ft (8.5m) inboard powered boats with diesel engine developing 30 hp at 2200 rev/mm are the two most common types of boats used in Sri Lanka in fisheries [9].

Table 4 - Comparison of Basic Factors between Vessels which can be Utilized in an Inland Water Transportation System and Buses Commonly used in Public Road Transportation System in the Western Province of Sri Lanka (Fuel prices and capital costs as per March 2012)

Description	Buses	Inland water vessels
Common types	40-60 seat Ashok Leyland and Tata bus models	18 ft (5.5m) outboard powered FRP boats with 7hp and 12-15hp kerosene outboard engines 28 ft (8.5m) inboard powered FRP boats with diesel engine developing 30 hp at 2200 rev/mm Vessels designed based on the local conditions
No. of passengers	40-60 seated + around 25 passengers standing	10-35 passengers depending on the design
Fuel price	Diesel: SL Rs. 115	Kerosene: SL Rs. 106 Diesel: SL Rs. 115
Fuel consumption	4.2 km/ l	2.71 km/l
Initial capital cost	About SL Rs. 5,000,000	18 ft FRP boat with 15hp Suzuki kerosene outboard Engine SL Rs. 400,000 28ft FRP boat with 30hp Suzuki Diesel inboard engine SL Rs. 2,300,000
Maintenance cost	High	Low

Figure 5- Distribution of Percentage Extra Travel Fare to Travel from the Selected Cities in the Western Province of Sri Lanka to Colombo Fort with respect to the Displacement of the Cities from Colombo Fort.

Figure 6 - Colombo City Area and Adjacent Urban Centres with Inland Waterways

These fibreglass boats can be used also in inland water transportation after suitable modifications. Sri Lanka Navy has employed boats which can carry 12 persons on board with lagoon craft which can carry 35 persons onboard in their inland water transportation

works [10]. Suitable vessels can be manufactured locally for these inland water transportation projects relating to the factors such as number of passengers, bathymetry and width of the canals, fuel consumption and feasibility, etc. in order to employ the vessels with maximum passenger transportation capacity and efficiency in the inland water transportation system.

Infrastructure development is crucial for a proper inland water transportation system. Construction of new jetties and ports to receive and discharge passengers and freights between cities, widening and deepening the waterways as necessary, construction of linking canals and starting shuttle bus services to connect the ports and jetties with desired locations in the city which facilitates easy access for the people, can be identified as the most important factors in infrastructure development.

Through the questionnaires and interviews with people, it was found that easy access, safety and cleanliness of the waterways as the commonly related factors next to comparatively low cost and travel time over public road transportation.

Safety measures can be identified as one of the most important factors when designing an inland water transportation system. Therefore, trained professionals on boating safety and life

saving have to be employed as boat drivers. Also, boats used in inland water transportation have to be equipped with safety jackets, life saving equipment and first aid kits. In addition, special consideration has to be made on important factors such as removing hazards in lakes, rivers and canals whilst maintaining safe bathymetry and width in every season of the year. The boats and vessels must undergo tests for buoyancy to prevent unexpected accidents. Also, it is recommended to prepare a set of safety rules for boat transportation to ensure passenger safety by the relevant local authority. International Safety rules and handbooks such as Victorian Recreational Boating Safety Handbook [8] and International Inland Navigation Rules prepared by the U.S. Department of Transportation [11] can be used as guidelines in preparation of safety rules and regulations for inland water transportation.

According to Sri Lanka Navy, one of the main problems in inland water transportation through canals in Colombo is dumping of garbage and polythene to the canals by the people living around the waterways [5]. By awareness programmes to educate the people who live along canals to prevent dumping of garbage in to canals, and dredging the canals with the aid of the Land Reclamation and Development Corporation of Sri Lanka and relevant Municipal Councils, a pleasant environment can be maintained along the canals in order to transport passengers while making an environmental friendly surrounding in the Colombo city.

4. Conclusion

Seven cities from each of the 3 districts in the Western Province of the country were selected for this study with a total number of 21 cities. The shortest routes from Colombo Fort to these cities via roads and inland waterways were found by integrating digital data of the area with GIS techniques. Questionnaires and interviews were carried out among the inhabitants of these areas, people who travel from these cities to Colombo for work and bus drivers in order to gather realistic data on public road transportation during peak hours.

It is found by analysis of data that, Kotte and Kelaniya are the suitable cities to implement an inland water transportation system connected to Colombo, among the 21 selected cities for this study. Further, there is a high potential to shorten the travel time significantly during

peak hours by introducing an inland water transportation system in Colombo city and adjacent urban centres, while concurrently reducing the road traffic density. Travelling cost by inland water transportation system can be reduced by implementing it to transport passengers and freights within short distances; hence Colombo city and adjacent urban centres is the most suitable region to introduce such a transportation system combining roadways with inland waterways.

A detailed analysis is recommended focused on Colombo city and adjacent urban centres (within an area of 10 km radius from Colombo Fort as demarcated in Figure 6) with the aid of the methodology described in this work to design an effective inland water transportation network. It is recommended to popularize this system among school children and for leisure activities during off-peak hours.

Though an inland water transportation system is not preferable for passenger transportation from the cities far from Colombo city limits due to long travel time, it can still be used in freight transportation between the cities in the Western Province and other linked cities as well as to Colombo harbour.

It is prudent that special attention be paid to aspects such as infrastructure development, safety measures, public awareness and cleanliness of the inland waterways prior to the actual implementation of an inland water transportation system.

5. References

1. Ariyawansa, R.G., Udayanthika, A.G.P.I., "Living in High-Rise: An Analysis of Demand for Condominium Properties in Colombo", *International Journal of Sociology and Anthropology*, Vol 4(1), pp. 31-37, 2012.
2. Survey Department of Sri Lanka, *The National Atlas of Sri Lanka*, 2nd ed., Survey Department of Sri Lanka, 1988.
3. Perera, R., "Problems and Prospects of Utilizing Canal Banks to Enhance the Built-Environment in Colombo", *Built-Environment-Sri Lanka*, Vol 3 (2), pp. 75-81, 2003.
4. Priscoli, J.D., Moon, J., Von Groen, P., Bradley, J., Fujii, C., *Report of the Inland Waterway Transport (IWT) Mission*,

- Economic and Social Commission for Asia and the Pacific, 1985.
5. www.defence.lk/new.asp?fname=20101012_02, Visited, 16th February 2012.
 6. Rangaraj N. and Raghuram G., *Viability of Inland Water Transport in India*, INRM Policy Brief No. 13, Asian Development Bank, 2007.
 7. U.S. Department of Transportation, *Navigation Rule, International - Inland*, U.S. Department of Transportation United States Coast Guard, 1995, p. 14.
 8. Transport Safety Victoria, *Victorian Recreational Boating Safety Handbook*, Transport Safety Victoria, A Victorian Government Initiative, Australia, November 2011.
 9. Gulbrandsen, O., *Reducing the Fuel Cost of Small Fishing Boats*, Development of Small-Scale Fisheries - Bay of Bengal Programme, Madras, India, July 1986.
 10. <http://www.development.lk/news.php?news=572>, Visited, 1st March 2012.
 11. U.S. Department of Transportation, *Navigation Rules, International - Inland*, U.S. Department of Transportation, United States Coast Guard, Washington, DC, USA, October 1995.