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Research Paper

Contribution on water transportation for resilient and sustainable lowland cities

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ABSTRACT

Due to a force for development has resulted to rapid urbanization in Bangkok and its vicinities. The attractions of megacity create high number of jobs and opportunities, consequently accessibility and mobility has become super congested which has long been called for sustainable solution to tackle with this problematic of urbanization. A need to change the current supply leads to urgent need of an alternative mode choice for commuters, and adopt a new paradigm of mobilization where suburban urbanization evolves in Bangkokians' daily life. This study aimed to provide an unconventional solution to meet the current mobility needs through the introduction of water transport systems that focus on access, safety and efficiency within the larger context of reducing commuting time in Bangkok urban areas. This effort through its various initiatives to return the role of Bangkok canal network in more sustainable option include the business model option along with social engagement of community people to own their water transport. Finally, this contribution could then help Bangkok not only towards urban mobilizing, but also for resilient and sustainable lowland cities under the risk of flooding in term of mitigation and management.

1. Introduction

Bangkok Metropolitan Area (BMA) has been established since AD 2325 and it has continuously expanded into the surrounding area (Library of Congress: 2007). The urban sprawl effect consequently has occupied its growth to the greater Bangkok Metropolitan Area which extends beyond the borders of Bangkok province, spilling into the neighboring provinces of Pathum Thani, Nonthaburi, Samut Prakan, Samut Sakhorn and Nakhon Pathom. The sprawling effect has not been resulted on overconsumption of urban resources for development, the built-up area on transportation infrastructure has not been successful to create more connectivity when considering on commuting hours. Land based transportation was the key dominant on both private and public transportation, which water-based transportation has been overlooked its role and functionality (Hossain and Iamtrakul; 2007). In the past, canal transit system has been considered a backbone of transportation. However, at the present some of the

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network still has been used for transporting both goods and people as depicted in **Fig. 1**. This is due to the reason that it has various dimensions of benefits and potential for current and future use compared to other modes of transportations. Water transportation provides cheaper service in operation with less construction costs, and allow for low-to-middle income class groups to access with the reasonable transportation costs. However, the importance of the canal transit system seems to be decreasing nowadays since road transportation has become a major mode of transportation with the major impact induced on ribbon development. This situation caused an expansion of land development to suburban areas, severe traffic congestion with uncontrollable urban sprawl. Therefore, the governments must step back and rethink how to utilize the current urban water network system efficiently, instead of promoting road-based transportation, for example, the future mass transit development plan established by Office of Transportation Policy and Planning (OTP) or BMA waterways transit express service (Rockefeller, 2015). These implementation plans are important for improving the quality of transportation services in the urban area. The aims of this study are to locate possible sites for pier establishment and estimate cost and revenue for operating community-owned canal transit for the Lat Phrao canal. There are three objectives in this study: (1) to describe the present potential of the Lat Phrao canal for navigation; (2) to quantify the amount of connectivity from the local piers to other facilities based on acceptable travel time; and (3) to calculate cost and revenue from transit operations.

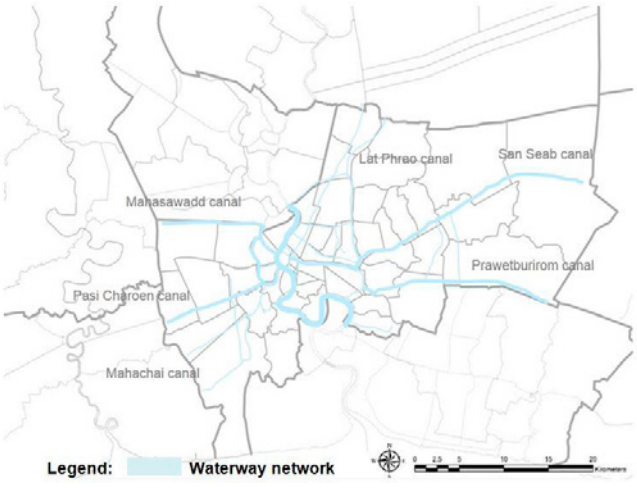

Fig. 1. Bangkok canal network.

1.1 Challenges of Waterborne Transit Planning in Bangkok

When considering an urban waterway system, we must look at important features supporting urban activities such as a water supply for daily consumption, cultivation, drainage system, fortification, aesthetic layout and transportation. Effects of rapid urbanization have been occurring for centuries. It has driven on demanding more land to develop and access by road network due to a limitation of the canal system as well as geographic conditions. Water transportation shapes urban structure especially on commercial corridor development through its network before road development and urban sprawl (UITP, 2013). An advantage of water transport system is based on its geographic potential lead to lower construction and operating cost of transport system with economy fare compared to others. Furthermore, it could be used for promoting tourist activities, and help to stimulate physical and social integration in the city or country (IWTDC, 2015). For navigation purpose, it must provide services as a mean of city logistics with high quality, reasonably priced delivery in congested urban areas. The fundamental concepts of city logistics seek to maintain sustainable development of the urban area, increase efficiency of network usage, maximize profits and minimize the adverse effects from transportation and its activities. City logistics recently became a prominent issue in terms of planning, operation, and management (Tadic et al., 2015). Based on Taniguchi (2014) who wrote the book titled “City Logistics: Mapping the Future,” three challenges of city logistic development schemes could be considered the following issues of; 1) how to balance the efficiency and the environmental friendliness, safety, and saving energy associated with urban freight transport; 2) possibilities to establish sustainable urban freight transport system in megacities to maintain the higher number of demand; and 3) the considerable features of sustainable urban freight transport system in an aging society (Taniguchi, 2014: 4).

The major consideration in transit planning should be able to quantify the cost and revenue from services. However, other factors such as pleasure variables or satisfaction factors should be addressed and included into the analysis, especially for public transit commuters in their daily life (Hanson, 2004 :4). Good network planning and design is a critical issue for public transport success. The important issues in transit planning are network integration of all public transport modes and operation, high frequency services to serve a large demand, capacity improvements, cost efficiency, energy consumption, safety and service quality improvement. (Federal Highway Administration; n.d.:32).

A public transit system should consistently be improving which should be able to persuade passengers to choose public transit for their trip instead of using

private vehicles (Nelsen et al., 2005:8). Based on a previous study entitled of “Hybrid Canal-Rail Connectivity: Linking Bangkok’s Canal Networks to Mass Rapid Transit Line”, there are four routes operating at present (Chao Phraya River, Phra Kanong canal, Pasi Charoen canal, and Saen Saeb canal) (Rockefeller, 2015). The results from prior analysis showed that the 108 canal routes in Bangkok could be classified into three categories; (1) canals with navigation potential, (2) canals to be improved for navigation, and (3) canals without navigation potential. The prior results also reviewed that Lat Phrao canal is one of the potential canals in the first category as depicted in **Figs. 2, 3 and 4**. (Rockefeller, 2015).

Fig. 2. Current water transportation services in Bangkok Metropolitan Area.

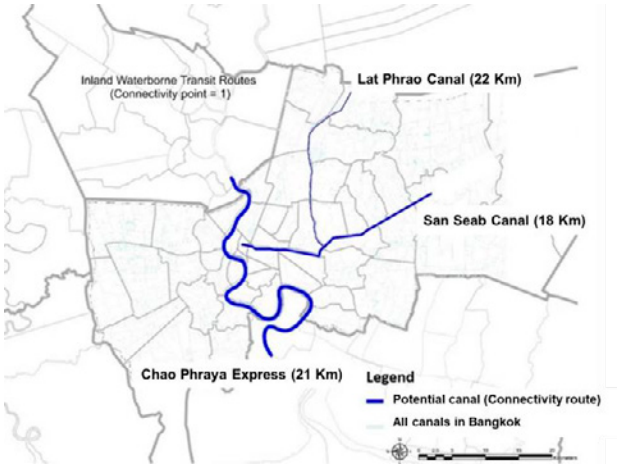

Fig. 3. Inland waterborne transit route in Bangkok Metropolitan Area.

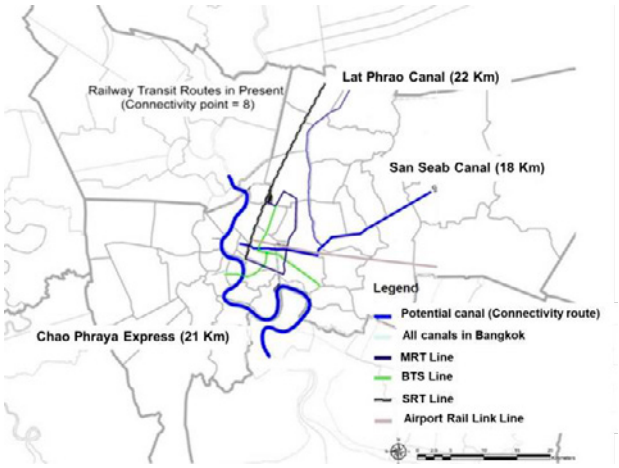

Fig. 4. Present urban rapid transit routes.

Based on primary data, this canal had been used for transit operation throughout history. The service route was started in the Ying Charoen Market in Saphan Mai District and run through Phra Kanong Bridge. The operation time was during 05:30 – 19:30 hrs. daily. The travel fees were approximately 7 to 15 THB based on distance travel. The former operator was Nawa Numchoke Co.Ltd. There are 15 piers in the service line; Tha Saphan Mai, Tha Changwattana, Tha Bang Bua, Tha Senanikom, Tha Arpapirom, Tha Wat Lat Phrao, Tha Saphan Song, Tha Sutthisan, Tha Pracha Uthit, Tha Thai-Yipun (Thai-Japan), Tha Khlong Tan, Tha Sukhumvit 71, Tha Mahabut and Tha Phrakanong. The Office of Transport and Traffic Policy and Planning (OTP) initiated the transit development projects entitled “Mass Rapid Transit Master Plan in Bangkok Metropolitan Region” (M-Map) (OTP, 2001).

This plan contributed to the potential of public transit connectivity along the Lat Phrao canal. There are five routes of mass rapid transit lines crossing the Lat Phrao canal. This intersection creates seven points of connectivity which are shown in **Fig. 5**. The network of future mass transit will pass through the proximity of Lat Phrao canal which include the following link. First, the yellow line and the grey line are intended for completion and ready for service in 2020. Orange Line (Taling Chan - Minburi) is intended for completion in 2022, and Pink Line (Khae Rai - Minburi) is intended for completion in 2023. Those transit lines can easily connect to the Lat Phrao canal in the future.

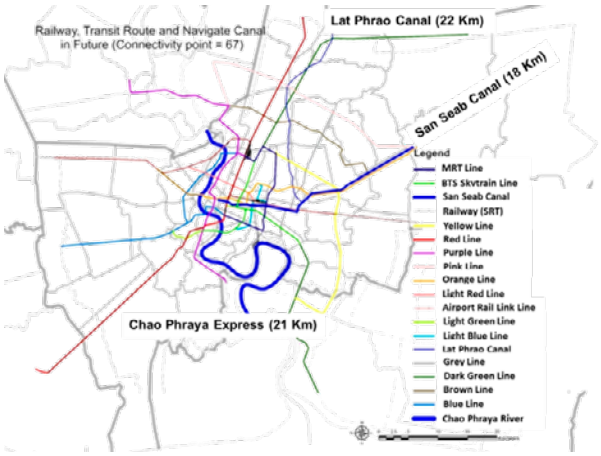

Fig. 5. Urban rapid transit routes in future.

2. Processes and Methodology

This study aims to emphasize the potential of local canal transit in consideration of transit operations, connectivity, and the number of demand sites. The survey was done in December 2016, and was based on the 29 survey spots along the the Lat Phrao canal. The three processes applied in this study are: (1) Site observation – the study team performed observation by riding a boat from Wat Lat Phrao to the Community Organizations Development Institute (CODI) housing project; (2) Estimation of operation cost – the team interviewed the local transit operator for data related to operating site such as the number of boats, engine, fuel cost, and boat capacity; and (3) Analysis of local connectivity – the study team applied results from the questionnaire towards the estimated acceptable travel times from the local pier to nearby facilities.

In conducting the research project, the four-step conceptual framework and procedures, along with the methodologies are presented in **Fig. 6**, which containing 4 main steps of the research process.

Step 1: Site selection. Site selection is aimed primarily to identify suitability of the Lat Phrao canal for establishing a community-owned canal transit system. In the phase of site selection, three sequential methods are used to filter areas into macro, meso, and micro scales by integration of Geographic Information System (GIS) and spatial multivariate analysis. The 22 kilometers in service with 29 potential locations for local piers along the Lat Phrao canal are analyzed based on their spatial characteristics of development under the constraints of the availability of land and transit services as well as the social resources in terms of number of boats available, staff, and maintenance spots. The analysis was performed within a limit of community budgets by considering physical factors of urban expansion area and density, alignment of MRT projects, and availability of land. The suitable pier locations are Wat Lat Phrao pier, Lotus Wang Hin pier, Wat Bang Bua pier, and CODI Housing project pier.

Step 2: Data collection. After identifying the potential catchment area of the Lat Phrao canal, a survey was conducted to understand the mobility pattern of Bangkok commuters. Based on the collected data, the mobility pattern in terms of behavior and spatial mobility was influenced by two categories of mobility indicators; (1) Demographic and socio-economic: personal characteristics of trip makers, (2) Commuting behavior: travel patterns of commuters within their social environment, urban mobility, job accessibility, and personal preferences. Also, the community and related stakeholders were included in the data collection process in order to meet the challenge of establishing community owned canal transit within a radius of system service while maintaining a multi-community scale enterprise along the canal in the study area.

Step 3: Demonstrating future mobility demand. To develop transportation network based on community-owned transport perspective, the questionnaire survey was conducted through 1,200 people who live nearby the nodes, within 500 m. and 2 km. along the Khlong respectively. A face to face interview by using questionnaire was employed for analyzing and evaluating travel behaviors of Lat Phrao canal commuters which was performed in conjunction with the quantitative approach from different stakeholders. The collected data explains existing travel behaviors and shifting trends of water-based transport commuters. Attitudes and opinions from respondents will be used as an input to predict the demands of an unconventional service. Future transit demands could be determined based on the following approach; (1) Macro analysis: the growth of urban economic change on mobility patterns; (2) Water transportation service: focusing on system management aspects from the view point of community-owned business; (3) Access to a water transportation service: the connectivity to community owned infrastructure and its service quality.

Step 4 Conclusions and Recommendation The site survey and investigation were done to acquire data which will be used for site analysis. This step is aimed to identify potential concepts for development of the proximity area of the Lat Phrao canal. This was done by collecting in-depth information of various factors as follows: (1) Physical factor: Land use and building use, transportation characteristics, landscape and image of the city; (2) Socio-cultural factors: Community and their socio-demographic characteristics.

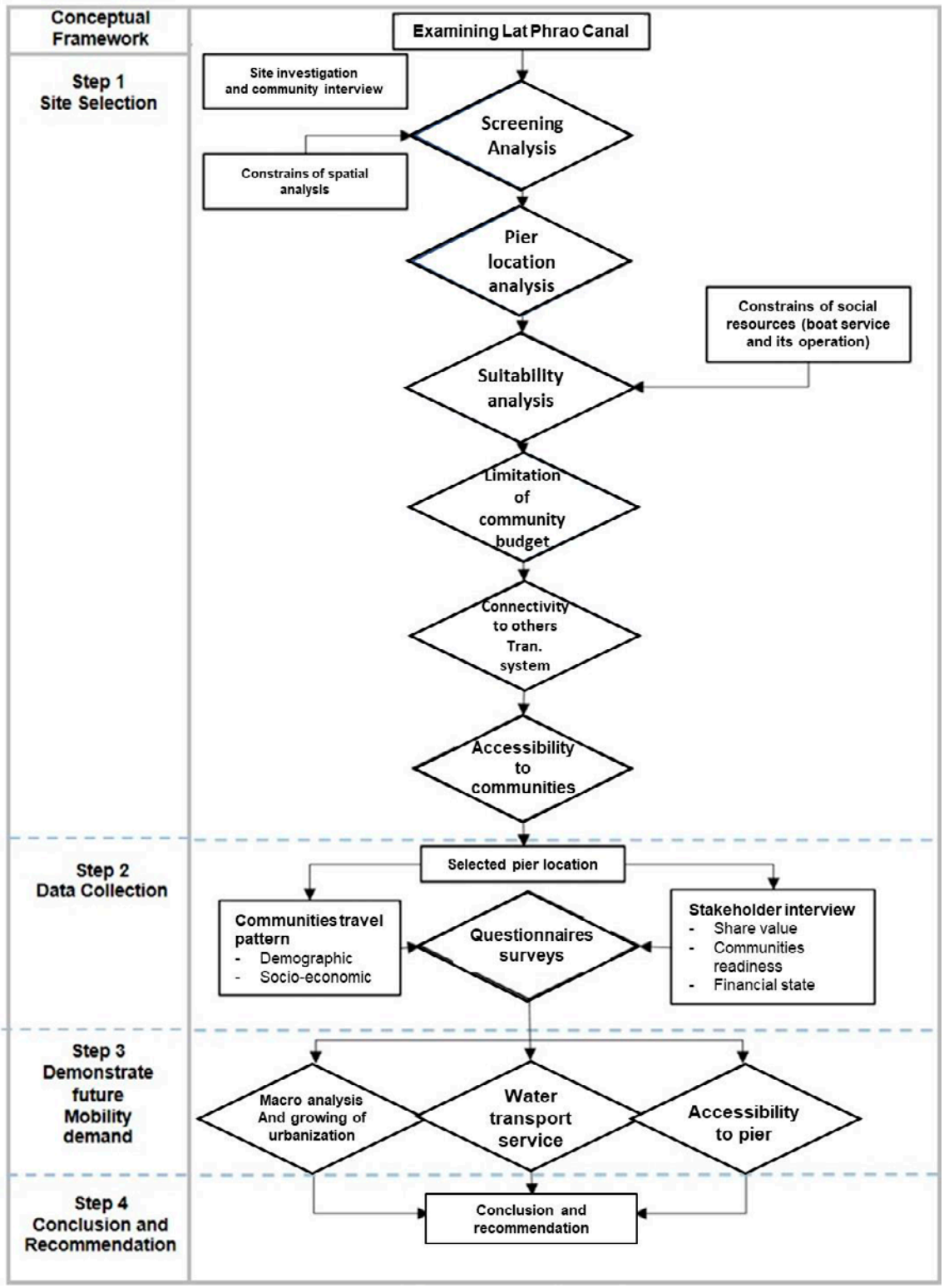

Fig. 6. Framework of analysis.

(3) Stakeholders factor: Stakeholder characteristics and their political influence within different contexts. Developmental limitations were analyzed and applied in making conceptual plans which do not only reflect the existing contexts but also propose an efficient water-based transportation development design.

3. Potential of the Lat Phrao Canal for Local Transit Improvement

During data gathering process based on observations by boat, there are 29 suitable points for establishing local piers alongside the Lat Phrao canal. Mostly, the suitable

points are located in small vacant areas which are only accessible on foot. For emphasis on the number of passengers, however, the research team selected four locations to construct piers as an initial phase of development; Wat Lat Phrao, Lotus Wang Hin Pier, Wat Bang Bua Pier, and the CODI Housing Project site. It took approximately seventy-five minutes from Wat Lat Phrao (first pier) to the CODI Housing Project Site (last pier). Those four sites share a common characteristic and the buildings in the surrounding area are mostly residential units. However, some areas have specific facilities nearby (e.g., airport, universities and mass transit stations). The potential of pier establishments alongside the Lat Phrao canal are on the east side rather than the west side. Result from network analysis was applied to analyze the potential of the Lat Phrao canal for supporting urban mobility and future connectivity between the Lat Phrao canal and MRT stations as demonstrated in **Fig. 7**.

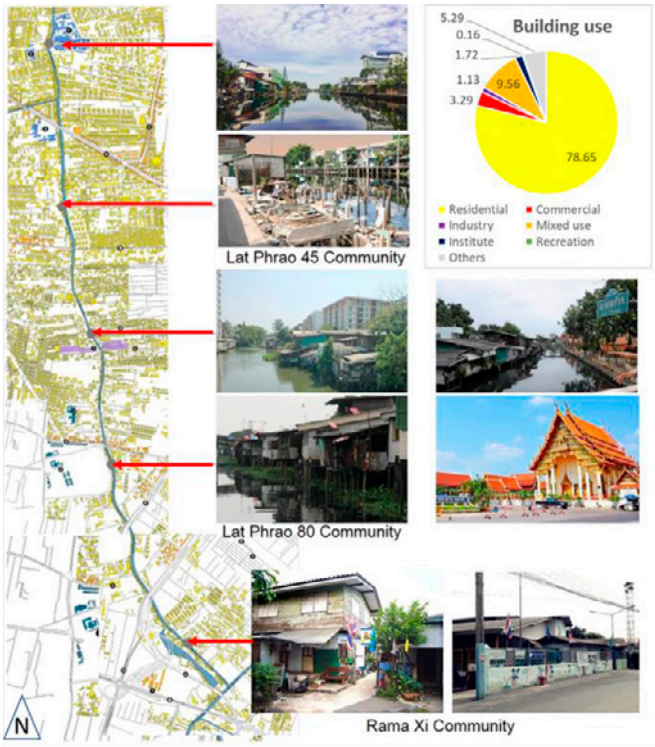

Fig. 7. The Lat Phrao canal.

The catchment of five-kilometer network service areas of the piers located on the Lat Phrao canal are shown in red on the analysis maps. It should be noted that if governments or local communities' members who are interested in revitalizing the Lat Phrao canal for navigating passengers or goods, other local modes of transportation must be efficiency provided such as local motorcycles services, small vans or pick-up, or taxis. The feeder systems from the canal to other destinations are very essential such as shopping centers, institutional places, medical service centers, living units, workplaces or other transit stations. The results of the analysis showed that if the Lat Phrao canal were fully operated for community-owned canal transit, it could be help to connect to other modes of public transportation. Consequently, it could reduce approximate travel distance from the eastern side of the Lat Phrao canal to the existing mass rapid transit lines **(Fig. 8)**.

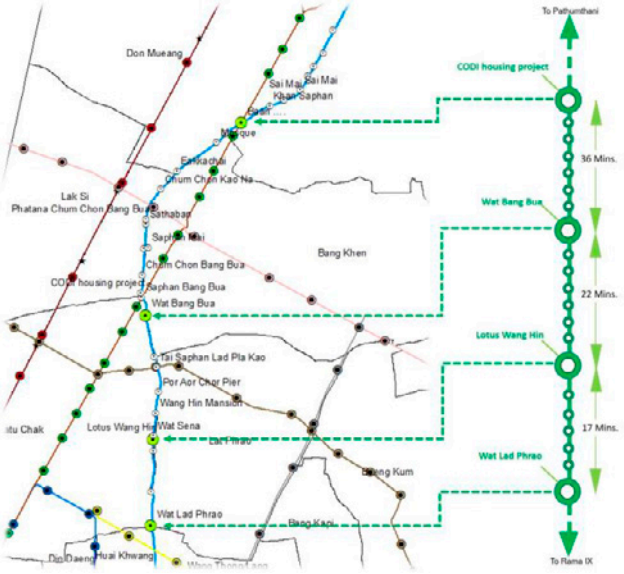

Fig. 8. The survey route and the selected location of future pier services.

4. The determination of Water Transit Service of Lat Phrao Canal

4.1 The Demand Estimation

The estimated number of passengers is derived by calculating the number of buildings through the application of GIS and then multiplying by the average household size (4.29 persons per household). Results from the calculations showed that the number of people who may use Lat Phrao canal for their trips are approximately 69,000 persons per day (estimated at 5% of use), and would increase to 138,279 persons (estimated at 10% of usage). The result of these calculations is demonstrated as shown in **Table 1**.

Operation analysis was done in this step to quantify the amount of expenditure spent and revenue gained in local transit operation at the community level. Consequently, the evaluation of operation costs of canal transit service at present can be performed. Thus, the research team interviewed boat drivers in the community to determine four aspects of operation costs: number of boat in services, wage of boat drivers, driving period, and

fuel cost per day **(Table 2)**. Furthermore, the cost of water transit operation is provided as shown in **Table 3**.

Table 2. Assumption in calculation.

Fuel consumption		Operation time		
Approximate fuel cost per month	500 THB/month	Morning peak	06:00-09:00	3 Hrs/day
Fuel consumption	40 Litre for 20 km.	Evening peak	15:00 18:00	3 Hrs/day
Approx. Fuel cost per month	2 Litre per km.			
Distant travel)Observed(	15.56 km.			

Remarks: Estimated fuel consumption 31.12 Liter/day

4.2 Revenue of the Water Transit Operation

Regarding the revenue from transit operations, there is a variance based on each boat's capacity and the service times in morning and evening. The operation cost was derived from the hiring of personal cost and fuel cost which vary from the distance of service. This study selected only 4 pier locations for the analysis and the result was demonstrated as shown in **(Table 4)**. Results from analysis shows that the estimated revenue from service operations are 6,650 THB per day or 200,000 THB per month, while the estimated operation cost is equal to 9,600 THB per day or 288,000 THB per month. Therefore, subsidization from other institutions or value-added services are needed to balance the operation costs and revenue to operate a community-driven canal transit system. This calculation is based on the interview data from the boat drivers, current performance of operation (old engine or new boat). Other services such as increasing seats for service, launching on-demand transit (especially in small boats), and engine improvement, are needed for improving the current service.

Improving services for serving specific purposes such as medical transportation in peak hour, supply goods from market to waterfront communities, tourist transportation and on-demand transit should be addressed and mentioned in further considerations to improve the service of a community canal transit system. Regarding service issues, existing resources such as local boats, boat drivers, maintenance spots and local piers are limited. It is necessary for them be supported by other groups of interests if the local community would like to operate a canal transit for commuters. Therefore, the first step of a community owned canal transit service system should be implemented as an "On-Demand Service" to support the community-owned specific purpose such as local tour trips or delivery services from department stores near the Lat Phrao canal. These activities should be implemented as an initial step of community-owned canal transit.

Table 3. Estimated cost of service operation.

Boat	Operation cost)Estimated(							
	Hiring				Fuel cost			Total
	Operator)Persons(	Time shift)hours(	Wage per shift)THB/hr(	Payment)THB/Day(	Fuel cost)THB/Day(	Trips travelled)Times(	Total	
no.1	1	6	150	900	500	4	2,000.00	
no.2	2	6	150	1,800	500	4	2,000.00	
no.3	1	3	150	450	500	2	1,000.00	
no.4	1	3	150	450	500	2	1,000.00	
	Total cost of staff hiring			3,600	Total cost of fuel consumption		6,000.00	9,600.00

Table 4. Estimation of revenue derived from service operation.

Boat	Revenue for operation							
	Capacity)Persons(	No.of unit	Max. passenger carried	Fixed fare rate	Revenue per trip service	No. of service trip)Morning(	No. of service trip)Evening(	Total revenue per day)THB(
no.1	20	1	20	35	700.00	2	2	2,800.00
no.2	10	2	20	35	700.00	2	2	2,800.00
no.3	6	2	12	35	420.00	1	1	840.00
no.4	3	1	3	35	105.00	1	1	210.00
Total		**55**			**1,925.00**			**6,650.00**

Remark: Total travel time)Observed(is 75 minutes

5. Discussion of Results

The study derived acceptable travel times from questionnaires to quantify the number of facilities located within the acceptable range of access times. The acceptable range from local piers to transit facilities at the local level (bus stops, MRT stations, motorcycles service spots, and taxi stops) should be reachable within six-to-eight minutes on foot **(Table 5 and Table 6)**. The acceptable time travel from local piers to community attractions is demonstrated in the range of eight-to-ten minutes **(Fig. 9)**. Results from the acceptable travel time analysis was shown that the supportive modes of transportation play a key role for connecting passengers from the Lat Phrao canal to other urban facilities. Motorcycles services become an important feeder system between piers to other facilities which could be used as a local feeder system to support community canal transit system.

6. Conclusions and Recommendation

Waterway transportation is an important mode consideration in regards to supporting city logistics development schemes, urban mobility improvement, urban aesthetics value, especially flooding mitigation which could be an sustainable infrastructure options for Bangkok metropolitan authorities to take into consideration. The Lat Phrao canal is one of the longest canals among all waterway network which is applicable for navigation and has much potential in terms of urban connectivity improvement. With urban mobility choice, it could be lead to promote for community-owned resources to help for improve local economy of communities settled along the current network. However, it needs various improvements such as accessibility, transit services, urban activities spaces, and community activities. All these improvements are necessary to support a community-owned canal transit system for the Lat Phrao canal. Moreover, to expand benefits to other groups in the communities, spatial development based on Transit-Oriented Development (TOD), and value-added transportation services are two keys success to increase local economic competencies. Moreover, there should be connectivity improvement between piers and other different destinations. The implementation of transfer right development (TDR) to revitalize the area must be recommended due to limitations of land development based on Land Use Comprehensive Plan. Finally, this contribution towards smarter and more sustainable mobility on utilization of current water network could then help Bangkok not only towards mobilizing, but also for resilient and sustainable lowland cities.

Consideration of transit operation in local level should be one of crucial issue if local government or local authorities trying to motivate local communities to participate in paratransit services which are communities' members could involve, and it should be integrated in transit planning in city level. These efforts of considerations could also raise level public of public participation, not only during planning process, but also stimulate public involvement in process of urban transit system development

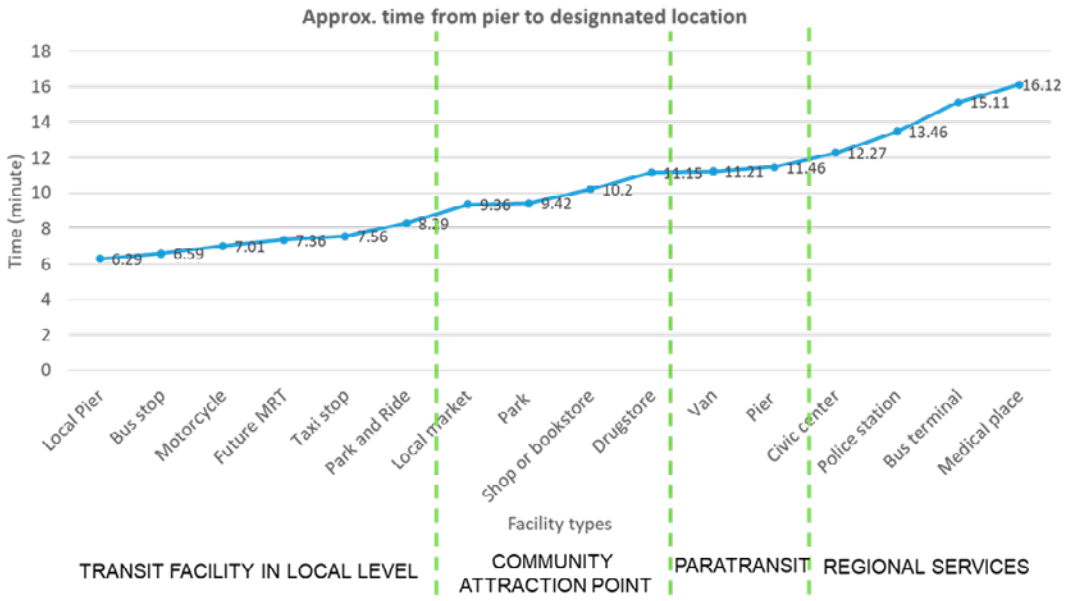

Fig. 9. Approximate time travel from local pier to nearby facilities.

Table 5. Mobility and its connectivity to other modes of transportation.

Facilities type	Average time from location to pier (minute)	Walking distance (meter)	Driving distance (Motorcycle) (meter)
Bus stop	6.59	482.39	3,293.68
Motorcycle	7.01	513.13	3,503.60
Future MRT	7.36	538.75	3,678.53
Taxi stop	7.56	553.39	3,778.49
Local Pier	6.29	460.43	3,143.74
Park and Ride	8.29	606.83	4,143.34
Van	11.21	820.57	5,602.76
Bus terminal	15.11	1,106.05	7,551.98
Local market	9.36	685.15	4,678.13
Park	9.42	689.54	4,708.12
Civic centre	12.27	898.16	6,132.55
Shop or bookstore	10.20	746.64	5,097.96
Drug store	11.15	816.18	5,572.77
Pier	11.46	838.87	5,727.71
Medical places	16.12	1,179.98	8,056.78
Police station	13.46	482.39	6,727.31

Table 6. The number of nearby facilities based on acceptable travel distance.

Facilities type	Average time from location to pier (minute)	Walking distance (Meter)	Driving distance (Motorcycle) (Meter)	Analysis		
				Walking (primary approaching)	Motorcycle (local services)	Difference% (location)
Bus stop	6.59	482.39	3,293.68	44	420	89.52
Future MRT	7.36	538.75	3,678.53	4	54	92.59
Medical service	16.12	1,179.98	8,056.78	13	98	86.73
Police station	13.46	482.39	6,727.31	1	21	95.24

Remarks:
Calculation assumptions and remarks
(1) Average time from location to pier (minute) derived from questionnaire survey
(2) Walking distance (meter) calculated based on normal people walking speed (1.22 m/s)
(3) Driving distance (motorcycle) (meter) calculated based on fixed speed (30 Km/hr. which is equal to 8.33 m/s). Acceleration and deceleration are not in calculation.

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