The Concept of Quality of Life in Daily Travelling and Its Optimisation by MaaS

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***Abstract*— During the stage of rapid economic growth, the demand for cars increases dramatically, especially in car-dependent cities. When the road infrastructure is unable to meet demand, this causes traffic congestion and subsequently undermines citizen's life. Mobility as a Service (MaaS) can be one of the solutions for traffic congestion that many countries are suffering from. It attempts to provide comfort, seamless, and reliable transportation for people to enhance their life by utilizing ICT. However, it is only an improvement of urban life limited to the transportation system. The daily routine of people also affects the quality of life. Proper activity planning, such as choosing a suitable place and time for activities, can also improve the quality of life. Therefore, MaaS should provide not only solutions for transportation but also a daily activity plan for people to get the maximum quality of life. In this paper, we propose the concept and measurement of quality of life in daily travelling, which can be applied in the trip planning system of the MaaS services. To demonstrate the benefits and applications, we analyze the impact of the departure time based on the proposed quality of life indicator by using a hypothetical scenario.**

***Keywords*— quality of life, travel planning, Mobility as a Service, smart transport, choices of travel time**

I. INTRODUCTION

Traffic congestion is a severe problem that undermines people's quality of life. Many mega-cities have been facing terrible traffic congestion for many years. People have suffered from long journeys every day. For a long time, public transport has been overlooked, resulting in not being able to attract customers. Using a private car is preferred, and public transportation is avoided because of poor service, inconvenient, and time-consuming. Recently, Mobility as a Services (MaaS) has been widely mentioned among urban planners and researchers. MaaS is described as an emerging concept of transportation service, which can change people's lifestyles in transportation. MaaS aims to shift from personally owned modes of transport towards public modes of transport, which can be a solution to relieve traffic congestion. To satisfy people, MaaS needs to provide a mobility solution suitable for a variety of activities in a day for the maximum satisfaction of users.

To enhance the quality of life of people, MaaS (In the level of information service) should provide a comprehensive solution for daily activities. In the near future, working and living lifestyle will change due to the development of technology and innovation. Companies will allow their employees to design work hours that differ from normal company start and stop time. Moreover, the workplace can also be flexible that employees don't need to stay at the office all the time because they can work through the internet. To support the future lifestyles, MaaS should provide not only choices for transportation but also choices of place and time for daily activities to gain QOL as shown in Fig. 1.

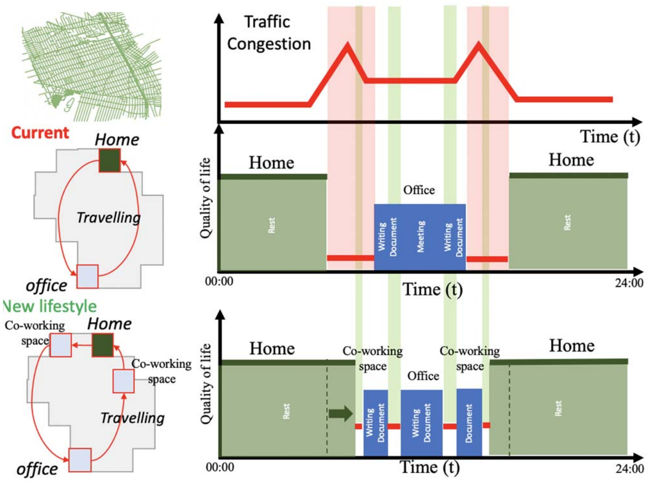

Fig. 1. Quality of life in daily travelling improvement by activities planning

By applying the quality of life (QOL) concept, developers will be able to understand the needs and satisfaction of users and can provide a suitable travelling plan for them. In this paper, we propose the conceptual framework to measure people's satisfaction toward environment factors while doing various activities in any places (place's QOL) and satisfaction toward travelling environment factors during travel (travelling QOL). In daily activities, people travel to various locations to carry out activities receiving both types of QOL. The total QOL that a person achieves in one day will be defined as a daily quality of life (DQOL).

To gain QOL, scheduling of daily activities is very important, and one of the significant factors is the choice of departure time of travel. Choosing the right departure time will result in higher transport QOL due to more satisfying traffic conditions. Therefore, we also propose the method to obtain the best choice for departure time to get the maximum DQOL, which can be one of the recommendation services for the MaaS system.

II. Related Research

A. Mobility as a Service (MaaS)

MaaS is a concept that researchers in transport planning are paying attention to. Currently, it is the early phase of MaaS development, so its definition has not yet been clarified. [1] proposes a method to classify MaaS into five levels based on integration characteristics. The concept , definition, and function of the existing MaaS schemes are examined [2], and payment integration is evaluated [3]. Researches related to MaaS are conducted widely throughout many countries. In London, a survey is conducted to examine the potential of using subscription bundle payment to promote MaaS and to understand the decision-making of people in purchasing the MaaS package. MaaS for community transport is studied in Sydney [4].

TABLE I. represents the selected existing MaaS schemes extracted from literature [1] [2] [3]. In this table, the five columns characterize each scheme of MaaS in terms of service functions. Integrated transport modes initially, public transport and taxi are available for most MaaS schemes. A sharing system, such as bike and car sharing, usually emerge later. The third column (1.3 information) shows the availability of information service function, and the fourth column (1.4 Customization) shows the options that users can customize for their trip. The transport modes and payment choices are the basic options that are enabled in many schemes. Some of MaaS schemes allow the users to custom the factor (e.g., shortest path, shortest travel time) for route selection. Whim and SMILE provide the option for minimization of CO2 emission. Finally, the last column (1.5 Recommendation) shows the available recommendation for transport solutions for users. The route and transport modes scheduled are the generally provided information. Transport network and traffic condition data are combined for routing. For the solutions of departing time and arrival time, though most of the MaaS schemes have this function, they still require the users to specify one departing time or arrival time of travel.

TABLE I. SUMMARY OF MOBILITY AS A SERVICE CHARACTERISTICS AND FUNCTION

1.1) Name	Service Functions											
	1.2) Transport modes				1.3) Information			1.4) Customization		1.5) Recommendation		
	Public Transport	Bike or Car Sharing	Car rental	Taxi	Trip planning	Real time info.	Notifications	Services options	Route optimisation factors	Route	Transport modes schedule	departure-arrival time
UBIGO	✓	✓	✓	✓	✓			Transport modes selection, Mobility Budget, Subscription top-up, Depart/ arrival time		✓	✓	*
Whim	✓	✓	✓	✓	✓	✓		Mobility budget, Subscription top-up, Depart/ arrival time	Travel Time, Green trip	✓	✓	*
SHIFT		✓		✓	✓			Mobility budget, Subscription top-up		✓	✓	
SMILE	✓	✓		✓	✓	✓	✓	Transport mode filtering	Cost, Travel Time, CO2 footprint	✓	✓	
Moovel	✓	✓		✓	✓	✓	✓	Transport mode, Depart/arrival time		✓	✓	*
Optymod Lyon	✓	✓			✓	✓	✓	transport mode, Depart/arrival time, Personal capability (Driving, riding, walking)		✓	✓	*

* mean users need to specify one departing time or arrival time

B. Quality of life

For many years, researchers and experts in many fields have tried to describe the meaning of quality of life. Many definitions have been defined. According to the literature, most researchers agree that quality of life should be formulated with two components, which is a subjective component and an objective component [5]. The subjective (endogenous) component is described as a people's perception toward the objective component, and the objective (exogenous) component is defined as an existing object in reality. The original quality of life concept has been integrated from multiple domains. WHO [6] proposed six domains ,which are physical, psychological, social relationship, level of independence, personal beliefs, and environment. [7] categorized QOL factors into five domains: physical well-being, material well-being, social well-being, development and activity, and emotional well-being. To apply the quality of life concept for a specific purpose, many researchers have uniquely defined the quality of life factors based on their study area, for example, health-related QOL, work-related QOL, transport-related QOL, etc.

Urban quality of life interests many researchers in transportation and urban planning. Some urban research projects used quality of life as an indicator to measure social progress, as shown in TABLE II. The factors used to evaluate urban quality of life can be divided into 2 groups, 1) Service opportunity factors containing 5 subcategories which definition is described in [8][9], and 2) Transport factors considering route conditions (e.g. travel time, distance, etc.) and transport modes characteristics (services and facility while travelling). There are many urban studies concerning QOL around the world. [10] applied QOL to evaluate Mexico City. In Bangkok, [11] evaluated the long-term effect of rail-oriented development associated with quality of life improvement. And the relationship between quality of life and transit-oriented development was examined [12]. the spatial distribution of quality of life in Nanjing was illustrated [13]. An international comparative study of residential quality of life was conducted [14]. In the second column (2.2 domain-specific QOL), We can classify characteristics of the quality of life analysis into two types 1) Place related QOL which analyze surrounding conditions in specific places, and 2) Transport related QOL which considers transport modes and route conditions.

TABLE II. SUMMARY OF URBAN QUALITY OF LIFE FACTORS

2.1) Authors	**2.2) domain-specific QOL**	**2.3) Services Opportunity Factors**					**2.4) Transport Factors**		**2.5) Study area**
		Economic	**Living**	**Amenity**	**Safety**	**Environment**	**Route condition**	**Transport mode Characteristics**	
(Kim & Cocks, 2017)[15]	Place	✓	✓	✓	✓	✓			Suzhou
(Nakamura et al., 2017)[14]	Place	✓	✓	✓	✓	✓	✓		Bangkok, Nagoya
(Berežný & Konečný, 2017)[16]	Transport						✓	✓	Žilina
(Nakamura et al., 2016)[12]	Place	✓	✓	✓	✓	✓	✓		Bangkok
(Gu et al., 2016)[13]	Place	✓	✓				✓		Nanjing
(von Wirth, Grêt-Regamey, & Stauffacher, 2015)[17]	Place	✓	✓		✓		✓		Limmattal region
(Nakamura et al., 2015)[11]	Place	✓	✓	✓	✓	✓	✓		Bangkok
(Lotfi & Koohsari, 2009)[18]	Place	✓	✓	✓			✓		Tehran City
(Doi et al., 2008)[9]	Place	✓	✓	✓	✓	✓	✓		Takamatsu
(KACHI, KATO, and HAYASHI 2007)[19]	Place	✓	✓	✓	✓	✓	✓		Iida City
(Talen, 2003)[20]	Transport						✓	✓	Portland
(Lever, 2000)[10]	Place	✓	✓	✓	✓	✓			Mexico City

III. METHODOLOGY

In this section, we will focus on the daily quality of life (DQOL) concept and its optimisation by the choices of departure time of travel. The following section will explain by using equations and illustrations.

A. Concept of daily quality of life (DQOL)

In the past researches, urban quality of life is often analyzed from the viewpoint of people's satisfaction in the residential area towards a level of environment and accessibility to services (e.g., shopping center, workplace, hospital, etc.). In real life, people do not always stay in one place all the time each day. But they travel to different places to carry out various activities. Therefore, we analyse at the individual level to evaluated QOL closer to reality. In the proposed concept, daily quality of life (DQOL) consists of 2 components: 1) place's QOL and 2) travelling QOL. QOL is referred to the total satisfaction of people with surrounding factors during place activities (place's QOL) and during transportation (Travelling QOL). By analyzing individual activity schedule, the QOL that people achieve each day can be represented as a daily profile shown in Fig. 2. The daily quality of life is defined as a total QOL achieved in one day, which can be calculated by integration of the area under the graph.

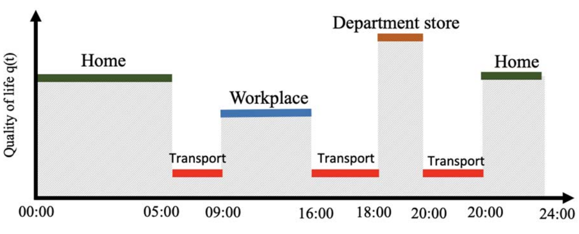

Fig. 2. The example of daily quality of life profile in one day

1) Place's QOL ($q_{P,A}$)

In our proposed method, place's QOL is constructed by weight summation of the site-specific factors which people satisfy while carrying out activities. For example, while working, people may prefer to have a co-working space, coffee shop, or convenience store in the surrounding area. On the other hand, people may need green space while relaxing. Therefore, the QOL function of place *P* for activity *A* is defined as $q_{P,A}$ expressed in (1) where $W_{A,M}$ is weight of satisfaction toward surrounding factors *M*, where *K* is the number of factors, while carrying out the activity *A*, and $X_{P,M}$ is the objective value or indicator representing the quantity of surrounding factors *M* in place *P*.

$$q_{P,A}(t) = \sum_{M=1}^{K} W_{A,M} \cdot X_{P,M}(t) \tag{1}$$

2) Travelling QOL (q_R)

Previously the place's QOL was introduced, which represented the benefits of each place that people visit each day. In order to access each place, transportation is an indispensable part of daily activities. Therefore, travelling QOL is defined. The travel route can be divided into small segments. Each segment has a specific QOL function with time defined as $q_{S_{R,n}}(t)$ where *n* is the sequence of segment in the route *R* which the calculation concept of segment QOL is similar to place's QOL which is constructed by weight summation of the surrounding factors but limits itself to transport conditions such as scenery, road segment quality, transport mode characteristic, and etc. While moving along the route, the segment QOL functions will shift the sequence *n* according to the location changed by the time as shown in Fig. 3. Therefore, travelling QOL function (q_{R,T_0}) for route *R* can be expressed as (2) where T_0, T_n, and T_N represent departure time of journey, the time at the end of segment *n*, and arrival time respectively. And *u*(*t*) is the unit step function.

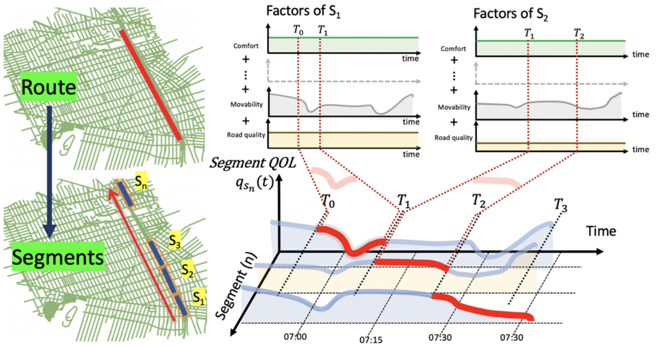

Fig. 3. The example of segment QOL functions (blue line) and travelling QOL function (red line).

$$q_{R,T_0}(t) = \sum_{n=1}^{N} q_{S_{R,n}}(t) \cdot [u(t - T_{n-1}) - u(t - T_n)] \quad (2)$$

T_n can be calculated by (3) and (4) where D_{S_n} and $V_{S_n}(t)$ represent distance and moving speed function of segment n.

$$T_n = T_0 + \Delta T_{R,n,T_0} \quad (3)$$

When ΔT_n is the travel time from T_0 to T_n.

$$\Delta T_{R,n,T_0} = \sum_{x=1}^{x=n} \frac{D_{S_{R,x}}}{V_{S_{R,x}}(T_{x-1})} \quad (4)$$

B. *Quality of life optimisation by choices of departure time*

In this section, the formula to estimate the impact of departure time on daily quality of life is derived. To simplify (1) and (2), place's QOL and travelling QOL are assumed to be a constant for the following example.

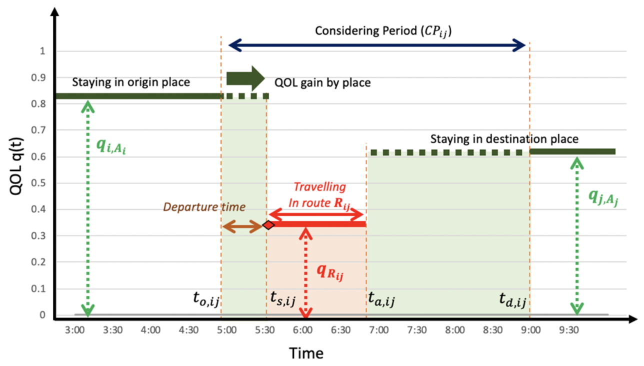

Fig. 4. Daily quality of life optimisation by departure time of travel

Fig. 4. shows the QOL profile of a person while travelling from origin (i) to the destination (j). From the schedule, this person ready to leave from the origin at 5:00 (earliest departure time at the origin: $t_{o,ij}$) and need to arrive at destination by 9:00 (a critical time of arrival at destination: $t_{d,ij}$) which this given duration is defined as considering period for optimisation (CP_{ij}). The DQOL during CP_{ij} ($Q_{CP_{ij}}$) can be determined by the area under the QOL profile graph shown as (5) .

$$Q_{CP_{ij}} = q_{i,A_i} \cdot [t_{s,ij} - t_{o,ij}] + q_{R_{ij}} \cdot [t_{a,ij} - t_{s,ij}] + q_{j,A_j} \cdot [t_{d,ij} - t_{a,ij}] \quad (5)$$

Also, can be written as

$$Q_{CP_{ij}} = [q_{i,A_i} - q_{R_{ij}}] \cdot t_{s,ij} + [q_{R_{ij}} - q_{j,A_j}] \cdot t_{a,ij} - q_{i,A_i} \cdot t_{o,ij} + q_{j,A_j} \cdot t_{d,ij} \quad (6)$$

According to the (3), arrival time ($t_{a,ij}$) is depend on the departure time of travel for route (R_{ij}), can be rewritten as (7)

$$t_{a,ij} = t_{s,ij} + \Delta T_{Rij}(t_{s,ij}) \quad (7)$$

From (6), substitute $t_{a,ij}$ with (7). We will obtain (8).

$$Q_{CP_{ij}} = [q_{i,A_i} - q_{R_{ij}}] \cdot t_{s,ij} + [q_{R_{ij}} - q_{j,A_j}] \cdot [t_{s,ij} + \Delta T_{Rij}(t_{s,ij})] - q_{i,A_i} \cdot t_{o,ij} + q_{j,A_j} \cdot t_{d,ij} \quad (8)$$

By using (8), $Q_{CP_{ij}}$ can be optimized by finding the critical point of departure time of travel ($t_{s,ij}$) where $Q_{CP_{ij}}$ is maximum.

C. *Hypothetical scenarios*

For illustration, the necessary parameters for equation (8) were assumed, and the example of the daily life of a hypothetical schedule is given. In the following parts, the assumption of input data and the potential to obtain will be described.

TABLE III. shows a given activity schedule consisting of 4 columns which are 1) activities 2) places 3) schedule and 4) $q_{P,A}$ value. The first three columns are required information of input data from users. But for the last column, $q_{P,A}$ values are arbitrary set to 0.90, 0.80, and 0.85 for home (A), workplace (B), and department store (C) respectively.

TABLE IV. shows information on transportation plan consisting of 4 columns, which are 1) origin-destination, 2) transport modes available, 3) travelling QOL value (q_R), and 4) considering period (CP) for optimization. The travelling QOL values are set to 0.3 and 0.20 for travelling by car and Skytrain respectively.

TABLE III. ACTIVITY SCHEDULE AND PLACE'S QOL

Activities Schedule			
Activities	**Places**	**Schedule**	**$q_{P,A}$**
Rest	House (A)	00:00 – 05:00	0.90
Working	Workplace (B)	09:00 – 16:00	0.80
Recreation	Department store (C)	18:00 – 20:00	0.85
Rest	House (A)	23:00 – 00:00	0.90

TABLE IV. TRANSPORT SCHEDULE AND TRAVELLING QOL

Transport Schedule			
Origin-destination	**Modes**	**$q_{R,T0}$**	**Considering Period (CP)**
A-B	Car	0.30	05:00 – 09:00
	Walk and Skytrain	0.20	
B-C	Car	0.30	16:00 – 18:00
	Walk and Skytrain	0.20	
C-A	Car	0.30	20:00 – 23:00
	Walk and Skytrain	0.20	

For calculating (8), Another essential component is the travel time function, which depends on transport mode, route, and departure time. The main factor involved with travel time is traffic congestion affecting the speed of movement, as shown in (4). In case of Skytrain, travel time is assumed constant. the relationship between travel time and the departing time of travel for trip A-B, B-C, and C-A (from TABLE IV.) is shown as a graph in Fig. 5.

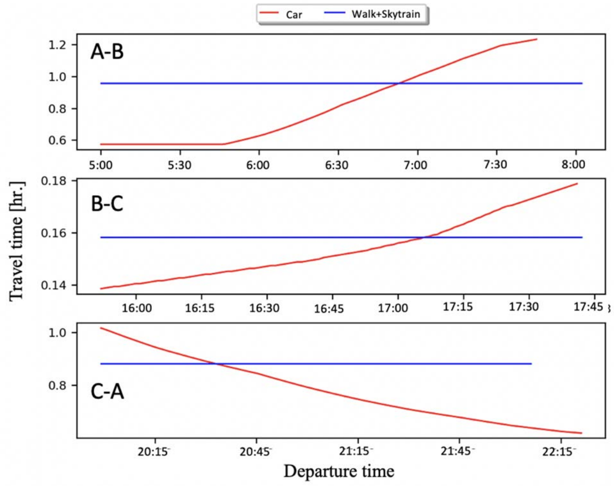

Fig. 5. The relationship between the departure time of the journey (horizontal axis) and travel time (hours) from origin to destination of 3 trips 1) from A to B (top), 2) form B to C (middle), and 3) from C to A (bottom). the red line and blue line represent road-based transport and rail-based transport respectively.

IV. Results and Discussion

A. *Effect of departure time on quality of life*

From the calculation by (8) based on previously assigned parameters, the graphs relationship between the departure time and the Q_{CP} are shown in Fig.6. Obviously, each departure time affects the quality of life. In the case of the trip from home to the workplace (the top graph in Fig. 6.), we can see that the best departure time is 5:47 and 8:02 for travel by car and Skytrain, respectively. Leaving too early will result in losing the opportunity to rest at home, where people gain QOL, despite less travel time. On the other hand, late departure may stick in traffic congestion and take a long journey. Therefore, choosing the appropriate choice of departure time of travel is important, which should not be overlooked.

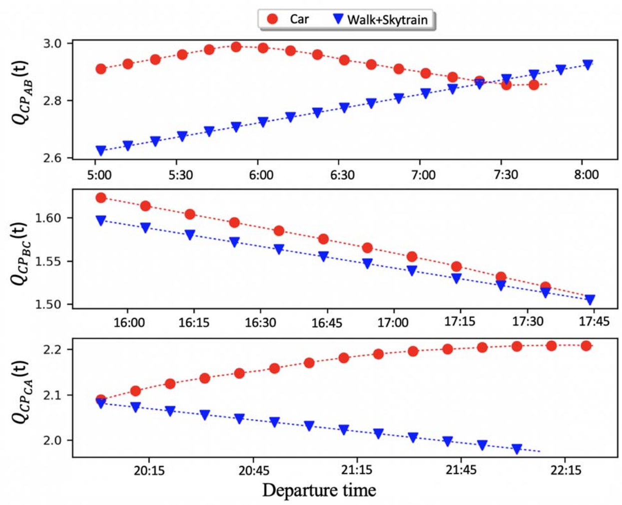

Fig. 6. The relationship between the departure time of the journey (horizontal axis) and quality of life value of 3 trips 1) from A to B (top), 2) form B to C (middle), and 3) from C to A (bottom). the red line and blue line represent road-based transport and rail-based transport respectively

TABLE V. Reccomended Choices For Departure Time

Modes	Trip A-B		Trip B-C		Trip C-A	
	departure time	$Q_{CP_{AB}}$	*departure time*	$Q_{CP_{BC}}$	*departure time*	$Q_{CP_{CA}}$
Car	05:47	2.99	16:00	1.62	22:15	2.21
Walk and Skytrain	8:02	2.93	16:00	1.59	20:00	2.08

TABLE V. shows the results of 2 cases of transport modes. The result implies that the system can provide a better solution for departure time for people's satisfaction by analyzing more comprehensive factors and more complex information than human capability. The use of DQOL concept in the recommendation system can also be extended to provide services other than departure times, such as recommending the flexible working place (e.g., coffee shop, co-working space, and etc.) to avoid lowering QOL being involved in a traffic jam.

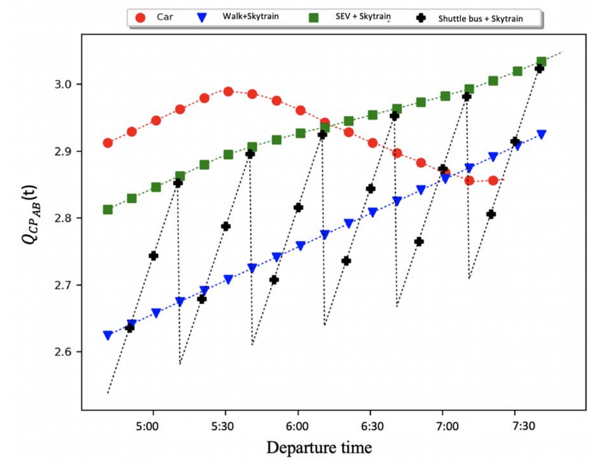

Fig. 7. The relationship between the departing time of the journey (horizontal axis) and quality of life value of trip A-B with 2 additional connected transport to skytrain: on-demand small electric vehicle (SEV) and timetable based shuttle bus.

B. *Role of connected mobility to enhance quality of life*

In the perspective of MaaS operators, DQOL also can be utilized as an evaluation measure to understand the implication of MaaS scheme development toward users' perception. For example, before the new mobility services are proposed such as community sharing bike, scooter, small electric vehicle (SEV), or shuttle vehicle to improve the accessibility to public transport, by analyzing QOL, the potential that the target people will shift from the current transport mode (car) to the new services with public transport can be examined by considering the gains of target people's DQOL based on their activities.

Now we consider the choices of departure time of 2 transport modes in Fig. 7., which are 1) car (red line) and 2) combination of walk and Skytrain (blue line), obviously that traveling by "mode 1)" provide a higher quality of life than "mode 2)" during 5:00 to 6:20 and lower during 6:20 to 8:00. In the case that the user wishes to depart between 5:00 and 8:00, There is a high possibility that the user might choose to travel by mode 1) more than mode 2) due to the higher quality of life in many choices of the departure time. The travelling quality of life can be applied to study the impact of proposed new mobility services, for example, on-demand small electric vehicle (green line in Fig. 7.) and shuttle bus (black line in Fig. 7.) connected to the Skytrain which shown the potential to attract people to shift to public transport.

V. Conclusion

In this paper, we propose the concept and measurement method of daily quality of life, which is an evaluation of the quality of life from the viewpoint of people's satisfaction towards transportation and places to carry out daily activities. The quality of life can improve by effective activities planning. We propose the method for maximizing the quality of life by analyzing the choices of departure time in daily travel. To prove the concept and illustrated more clearly image, the hypothetical scenario was set up, and the necessary parameters for calculation were assumed. The result from the hypothetical scenario showed that choices of departure time have a significant effect on the daily quality of life, and the optimisation method is beneficial for further developed of the recommendation system of the MaaS application.

Acknowledgment

This research is a part of the SATREPS program of "Smart Transport Strategy for Thailand 4.0" (co-leaders: Prof. Yoshitsugu Hayashi, Chubu University and Prof. Thanaruk Theeramunkong, Thammasat University) supported by the Japan Science and Technology Agency (JST) and the Japan International Cooperation Agency (JICA).

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