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Assessment of Trip Behavioral Change and its Application:

A Case Study in Dawei Special Economic Zone, Myanmar

[Satomi Kimijima and Masahiko Nagai]

***Abstract*—Dawei Special Economic Zone (DSEZ) Project is one of the largest petrochemical industrial estates in South East Asia aiming to transform the country into a pivotal hub for regional connectivity and logistics. This project development has directly affected local population's trip behavior. The objectives of this paper are to 1) assess trip behavioral change of local villagers by merging conventional trip behavioral data to GPS data, and 2) assess trip behavioral change associated with land cover change. A total of 345 individual respondents was stratified-randomly selected for evaluating one-day trip behavior. Indexing conventional trip data was conducted using online map service. Land cover changes represented by Normalized Difference Vegetation Index (NDVI) were calculated from satellite imagery. The result shows -1 inverse correlation between trip behavior and NDVI. The study concluded that merging conventional trip behavioral data to GPS data enables to analyze historical trip behavioral change associated with surrounding socio-economic and environmental developments.**

***Keywords*—person trip, behavioral change, rural area, conventional survey, GPS data**

I. Introduction

The economic transition from an isolated country to opening up to the global economy is creating opportunities to develop a high potential for economic growth for Myanmar. Since the establishment of the Dawei Project in 2008, Dawei deep seaport, an industrial estate and highway road and rail links to Thailand have been developed [1]. Particularly, Dawei Special Economic Zones (DSEZ) has been highly expected to be the pivotal hub for better connectivity and logistics among the surrounding regions.

In developing countries, socio-economic factors determine local livelihood, including trip behavior. In this line, tracing past trip behavior of local villagers helps to understand how they have responded to such a massive development. Ways of obtaining trip behavioral data have been shifting from questionnaire survey to Global Positioning System (GPS) survey which has been potential in terms of missing trip reduction, accuracy improvement, route and speed data acquirement and longer travel record [2]. However, merging two trip data set obtained in a different period in various format is critical to trace historical behavioral change associated with socio-economic development. Therefore, the objectives of this study are to 1) assess trip behavioral change of local villagers by merging conventional trip data and GPS trip data, 2) and assess trip behavior associated with land cover change represented by Normalized Difference Vegetation Index (NDVI).

The research is expected to contribute to the conversion and visualization of questionnaire survey trip behavioral data, and merge it with GPS data to identify a long-term trip behavioral change. This enables to conduct further analysis associated with socio-economic parameters in time-series.

Satomi Kimijima
Asian Institute of Technology
Thailand

Masahiko Nagai
Yamaguchi University
Japan

II. Study Area and Dataset

A. Study Area

DSEZ Project is located in Tanuntharyi Region, Southern Myanmar, 132 km from the border of Thailand. This DSEZ with a total area of 204.5 km which was initially developed in 2008 as a joint project between the Thai and Myanmar governments [1]. A total population of the DSEZ is 4,457 households with 26,083 population largely dependent on rural agricultural activities such as paddy cultivation and plantation. The study purposively selected rural villages dependent on lowland agriculture (Figure 1).

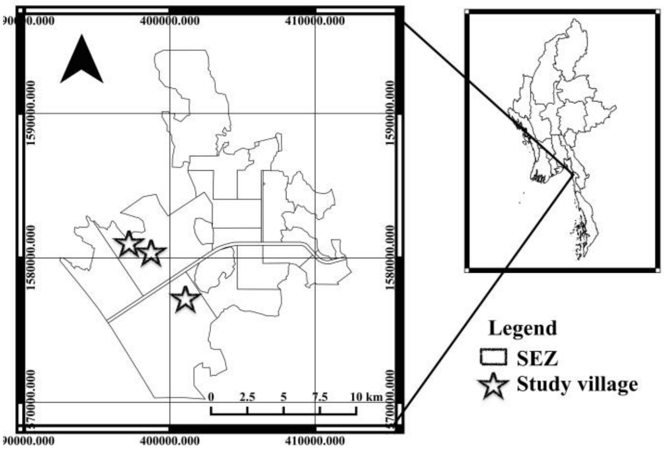

Figure 1. Study area in DSEZ.

B. Questionnaire Survey Data

A field survey was conducted with a questionnaire in 2015 to collect information for trip behavior and personal profiles. Stratified-random sampling by sex and age was used to understand behavioral characteristics and 345 individual data were collected. Non-spatial personal attributes such as age, sex, marital status, education level, household status, occupation, trip mode and monthly household income in 2005, 2010 and 2015 were collected through a pre-tested questionnaire conducted earlier in 2014. Spatial information such as trip origin, destination, direction,

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distance, and duration in 2005, 2010 and 2015 was also collected. The study also employed formal and informal interviews with key informants such as village heads, using checklists. The data collection also involved direct field observation.

C. GPS Log Data

Wearable GPS devices such as "i-gotU USB Travel & Sports Logger – GT-600" were used to log trips and validate the behavioral data obtained from the questionnaire survey. This device is lightweight (37g) and small (44 x 41.5 x 14 mm) with an automatic motion detector [3] which can be worn on the waist or clipped to clothes. The device recorded 24-hour trips with a 5-second interval using the motion detection mode. A maximum of 38 devices was distributed at one time to a total of 345 respondents aged 16 years plus. Both questionnaire and GPS log trip behavioral data are available from the 345 samples.

D. Satellite Imagery

Cloud-free Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) Satellite imagery from United States Geographic Survey (USGS) were used for detecting the level of NDVI in the study area. NDVI is an indicator correlating to leaf density or coverage, or total biomass [4]. The satellite imagery was taken in December 2000, 2002, 2005, 2008 and 2013 with a resolution of 30m x 30m in the World Geodetic System 84 (WGS84) geographic coordinate reference system covering the study area.

III. Methodology

The following Figure 2 is the overall methodology used in this study. The methodology focused on five major steps. First, non-spatial one-day trip data from the questionnaire survey was converted to spatiotemporal data. Second, trip parameters such as stay points, moving segments, the number of trips, trip distance, and trip duration were extracted both from the questionnaire survey and the GPS data. Third, the questionnaire trip behavioral data in 2015 was validated using the GPS log data. Fourth, the behavioral change in 2005, 2010 and 2015 was analyzed. Fifth, the correlation between trip behavior and land cover changes were assessed.

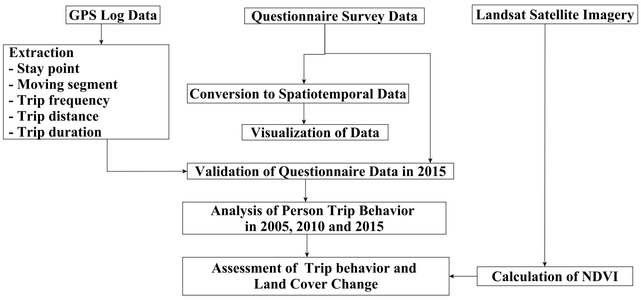

Figure 2. Overall methodology.

A. Conversion of Trip Behavioral Data

In rural areas in developing country like Myanmar, there are no significant landmarks such as prominent shopping centers and buildings as in the major cities. Furthermore, as local address and Geographic Information System (GIS) data are not well developed, topological approach represented by connectivity, adjacency, and enclosure with questionnaire survey can be more appropriate for the local villagers. To obtain a clearer picture of local villagers' trip behavior, trip information such as trip origin, destination, direction, distance, and duration in 2005, 2010 and 2015 was collected. This information was indexed and converted to spatiotemporal information by utilizing online mapping service and visualized in an animation format. All indexed spatiotemporal data are listed in a timeline and saved in a comma-separated values (csv) format. Simultaneously, non-spatial attributes such as age, sex, marital status, education level, household status, occupation and household income, were also integrated with the file.

Details of the moving segment such as the total number of trip, trip distance, and trip duration were manually extracted from the questionnaire survey and listed in excel format. In this study, a single trip is defined from a starting from a location to a destination, such as from home to a workplace.

B. Stay Point and Moving Segment Extraction from GPS Data

After the behavioral data had been obtained with GPS loggers, spatiotemporal data such as time, latitude and longitude were extracted from the devices. The break up of the trip segment was performed to find the stay points. In this study, stay point extraction with outlier detection and removal technique [5] were employed by using the following Eq. (1):

$$Distance\ (p_{start}, p_{end}) < D_{threh}\ and\ TimeDiff\ (p_{start}, p_{end}) > T_{threh} \quad (1)$$

Where the parameters D_{threh}, considerable maximum distance as a stay point, and T_{threh}, minimum time spending at the same place, are adjustable. In this study, a stay point is detected if T_{threh} > 20 minutes and D_{threh} <= 300 meters. Based on the calculation, stay points are extracted and are listed by start-time, end-time, duration, distance in meters, average speed in km/h. and the total number of stay points. Additionally, outlier detection and noise removal technique were applied by using standard deviation (σ).

Once the stay points are extracted from the GPS data, the moving segments can be extracted. The extracted parameters in this study are total trip distance per trip in meter, duration per trip in minutes, starting time, ending time, average speed km/h. and total points. These parameters are calculated for a single trip by utilizing Java language. The selected parameters from the GPS data were summarized by utilizing the PostgreSQL.

C. Comparison of Two Data Sets

After processing the data, the following Eq. (2) was used to calculate differences in the number of one-day trips, trip distance and trip duration between the two data sets.

$$Relative\ Change\ (x, y) = |\triangle| / Max\ (x, y) * 100 \quad (2)$$

Where x is the trip behavioral data from the questionnaire survey and y is the GPS log data. Based on the result, changes in the trip parameters obtained from the questionnaire survey in 2005, 2010 and 2015 were calculated. In this process, trips made out of villages such as in Yangon and Thailand, and unfixed trips such as daily employment at various places within or outside the villages, were excluded.

D. Calculation of NDVI

DSEZ map was geo-referenced, and the area was digitized in a vector format. The same area was extracted from the satellite imagery for examining NDVI level representing leaf density or coverage, or total biomass. This NDVI values range from -1.0 to 1.0 and is calculated by the following algorithm. Increasing positive NDVI values indicates denser the vegetation and values near zero and decreasing negative values indicate non-vegetated features such as barren surface (rock and soil) and water, snow, ice, and clouds [6].

$$NDVI= (NIR\ Band- Red\ Band)/(NIR\ Band+ Red\ Band) \quad (3)$$

IV. Results and Discussion

A. Indexing and Visualizing Questionnaire Trip Behavioral Data

Trip behavioral data obtained from the questionnaire survey was indexed and converted to the spatiotemporal data. Those converted trip behavioral data was visualized together with GPS log data (Figure 3). Trips can also be displayed according to the attributes obtained from the questionnaire survey. This visualization of trip behavioral data provides more useful behavioral characteristics such as trip distance, the number of trips, and trip duration by parameters than paper-based information. Illustrative visualization is easy to understand, and more information can be obtained for a better understanding of the underlying tendency behind the data [7].

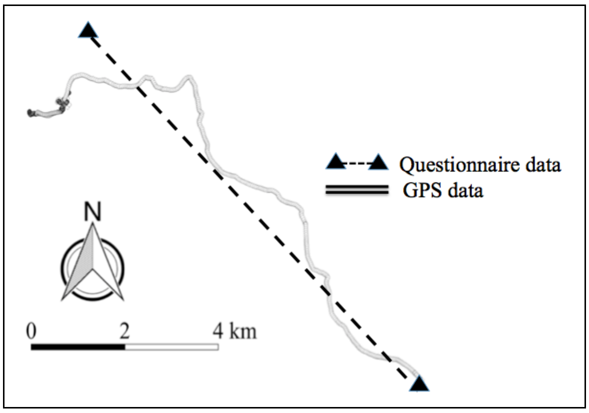

Figure 3. Conversion of the questionnaire trip data and its comparison to the GPS data.

B. Comparison of Two Datasets

To validate the trip behavioral data from the questionnaire survey, the average differences between two data sets were calculated. This reveals a total of 543 trips, with a total 1,936.3 km trip distance and 7,457.0 minutes of trip duration from the questionnaire while data from the GPS loggers shows a total of 403 trips, 2,302.0 km trip distance and 7,403.6 minutes of trip duration. The result shows the average differences between the two data sets as 25.1%, 34.9% and 38.0% in the number of trips, trip distance, and trip duration, respectively (Table I). Those differences between the two data sets can be caused by gaps between definition given to the parameters during the GPS log data processing and understanding of single trip among local villagers. Several studies conducted in Australia, United States of America and United Kingman show much larger differences in trip duration between GPS and self-reported, 75.4%, 62.4%, 46.7%, respectively [8]. In this line, the level of difference allows utilizing the trip behavioral data in 2015, 2010 and 2005 obtained from the questionnaire survey.

TABLE I
AVERAGE DIFFERENCE OF TWO DATASETS

Trip Parameters	Average Differences (%)
(A) Number of Trips	25.1
(B) Trip Distance	34.9
(C) Trip Duration	38.0

C. Trip Behavioral Changes by Year

Trends of parameters in 2005, 2010 and 2015 were compared, and the results of yearly change are described in Table II. The results show that the number of trip does not show much difference over a period of 10 years. Trip distance increases yearly, and the changes are 1.9 (2005-2010), 2.1 (2010-2015) and 4.1 (2005-2015) times. Trip duration also increased in 2010; however, in 2015, it again decreased to a duration similar to 2005. Based on these trends, it can be said that the main change in trip behavior is the increase of the trip distance and this can result from the change in the trip modes such as walking, traveling by motorbike, car or other modes. It can be confirmed that as the trip distance increases, the trip mode also changes. Indeed, the motorbike mode increased 5.9 times from 2005 (9.2%) to 2015 (54.0%). Furthermore, project-induced employment opportunities as local project staff, surveyors, and road construction workers have largely impacted on this trip increase.

TABLE II
AVERAGE NUMBER OF PERSON TRIP, TRIP DISTANCE AND TRIP DURATION BY YEAR

Trip Parameters	Year		
	2005	2010	2015
Number of Trips (Time)	2.3	2.1	3.0
Trip Distance (Km)	2.3	4.1	9.2
Trip Duration (Minutes)	40.6	58.4	46.0

D. Application of Behavioral Change to Land Cover Changes

Identifying a long-term trip behavior change by merging both questionnaire survey and GPS data set enables to conduct a further assessment with related parameters. As one of the applications, trip distance was further assessed with land cover changes represented by NDVI calculated by the Landsat satellite imagery. As both trip behavior data are obtained in the different period, the study interpolated missing values by use of regression analysis for further correlation analysis. The result of the regression analysis indicates that the two values are both strongly related to a correlation coefficient of R^2=1.0 (Figure 4). Furthermore, the correlation level between two parameters was identified as -1 negative correlation. This result can be explained that development of each sector including industrial estate and roads has required a massive area of land. Along with infrastructure construction, the project has mobilized local workforce as road construction work, field survey, and project office staff. Indeed, both the 18.5 km road infrastructure within the DSEZ and the approximately 132 km main road infrastructure from Dawei to the Myanmar-Thai border, have been constructed [9] with the large involvement of local employee. Furthermore, improved road condition and increased level of motorbike use have increased accessibility and expanded trip distance among local villagers. As trip behavior can be sensitive to surrounding socio-economic and environmental factors, trip behavior can be a critical indicator to evaluate dynamic socio-economic changes.

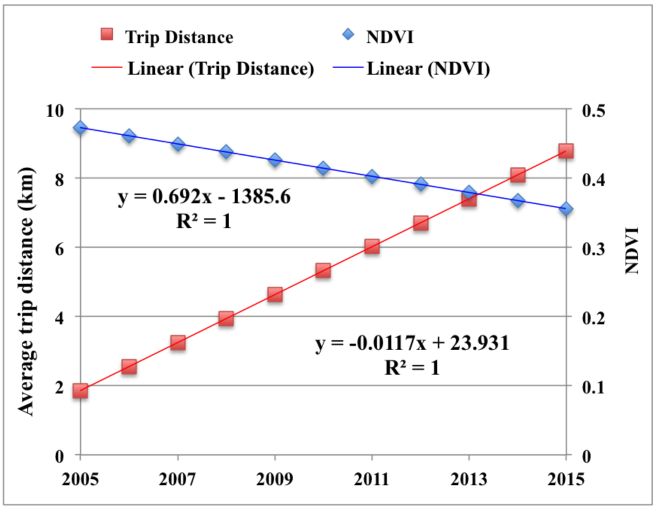

Figure 4. The relationship between trip behavior and NDVI by year.

V. Conclusion

The establishment of Dawei project is the significant key factor which reconstructs trip patterns of local villagers. To trace long-term impacts from the trip behavior perspective, this study indexed and converted conventional questionnaire trip behavioral data and merged it with GPS data. The average difference between the two data sets in the average number of trips, trip distance, and trip duration was found as 25.1%, 34.9%, and 38.0%, respectively. Converted questionnaire trip behavioral data can be merged with the GPS data, and its visualization help easily tracing past trip behavior. As trip behavior can be sensitive to surrounding socio-economic and environmental environment, associating it with related socio-economic parameters will provide further useful information regarding the ways of their reaction along with future accelerated massive socio-economic transformation.

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