

Exploring Influence Range of Tainan City Using Electronic Toll Collection Big Data

Chen Chou, Feng-Tyan Lin

Abstract—Big Data has been attracted a lot of attentions in many fields for analyzing research issues based on a large number of maternal data. Electronic Toll Collection (ETC) is one of Intelligent Transportation System (ITS) applications in Taiwan, used to record starting point, end point, distance and travel time of vehicle on the national freeway. This study, taking advantage of ETC big data, combined with urban planning theory, attempts to explore various phenomena of inter-city transportation activities. ETC, one of government's open data, is numerous, complete and quick-update. One may recall that living area has been delimited with location, population, area and subjective consciousness. However, these factors cannot appropriately reflect what people's movement path is in daily life. In this study, the concept of "Living Area" is replaced by "Influence Range" to show dynamic and variation with time and purposes of activities. This study uses data mining with Python and Excel, and visualizes the number of trips with GIS to explore influence range of Tainan city and the purpose of trips, and discuss living area delimited in current. It dialogues between the concepts of "Central Place Theory" and "Living Area", presents the new point of view, integrates the application of big data, urban planning and transportation. The finding will be valuable for resource allocation and land apportionment of spatial planning.

Keywords—Big Data, ITS, influence range, living area, central place theory, visualization.

I. INTRODUCTION

THIS study explores intercity interaction by combining Urban planning theories and Big Data, and analyzes original data directly to avoid the error from sampling. Among the currently Taiwan's government open data, ETC is one of the largest, soundest, latest data. ETC is one of ITS applications in Taiwan, used to record origination, destination, distance, travel time and type of vehicle on the national freeway. This study explores the dynamic phenomenon of intercity through analyzing the OD and quantity.

In Taiwan, sedan occupied 79% of intercity transportation [5], suggesting people prefer to use private mode. On the other hand, ETC recorded all the car flow data on the national freeway, representing intercity behavior. The current living area is delimited according to administrative regions, demographic area and socio-economic activities. However, static statistics does not imply the close interactivity inside the living area, nor reflects daily traffics. Under the advancing traffic nowadays, a one-day living area from northernmost to

southernmost of Taiwan is possible, showing the present living area can no longer achieve the need of spatial planning.

This study substitutes "Living Area" with "Influence Range", a certain distance changing through time period and trip objective. Tainan is a county in Taiwan; the study analyzes the interaction between Tainan and other counties by calculating trip volume and visualizing through GIS. The finding not only has a more precise outcome, but also could be applied to land use arrangement.

II. LITERATURE REVIEWS

A. Living Area

In 1995, Council for Economic Planning and Development, Executive Yuan, Taiwan, proposed that the living area should be defined as: The influence scope of socio-economic activities such as work-related activities, housing, schooling, shopping, leisure and medical care [2]. Tseng and Directorate General of Freeways, Ministry of Transportation and Communications R.O.C (hereinafter referred as MOTC) proposed that the living area should be delineated based on the transport facilities, socio-cultural characteristics and other development potentials so as to meet the economic benefits and promote the reasonable distribution and development of population and industry [4], [7]. It can be used to allocate appropriate land use, provide necessary public facilities, and develop different industries according to regional characteristics and geographical environment, and create local competitive advantage to promote economic and social development.

Strategic Plan for National Spatial Development, a spatial planning strategic proposal from the perspective of Taiwan, considers that both Hong Kong and Singapore are economies of "small is beautiful" that have the potential to create GDP growth by supporting the size of the market or population [5]. Therefore, Strategic Plan for National Spatial Development references the population or acreage of Hong Kong and Singapore to delimit Living area, divided Taiwan into seven living areas, namely, Taipei- New Taipei- Keelung- Yilan, Taoyuan- Hsinchu- Miaoli, Taichung- Changhua- Nantou, Yunlin- Chiayi- Tainan, Kaohsiung- Pingtung, Hualien- Taitung, Penghu- Kinmen- Matsu, as shown in Fig. 1. These living areas contain considerable population and hinterland to support the market and regional development.

The current delineation method deviates from the definition of the Executive Yuan. The study proposes the new point of view about living area, and compares and explores the current living area in order to be closer to the actual situation.

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Fig. 1 Seven Living Areas in Taiwan

B. Central Place Theory

In 1933, German geographer Walther Christaller published "The Central Place Theory", explaining the number, scale, and pattern of "Central Place". "Central Place" provides a variety of goods and services to the surrounding residents. The meaning of the word "Central Place" is the most accessible in a hierarchical service area [9].

According to "Transportation system Plan for Living Areas (2015-2018)", proposed by MOTC, activities in living areas were classified into the following three kinds [4]:

- (1) Daily activities: such as going to school, employment, purchase of daily necessities, from local to local center.
- (2) Weekly activities: such as entertainment, recreation, social, purchase of optional supplies, from local center to the regional center.
- (3) Seasonal activities: such as sightseeing, the purchase of special supplies, for private special affairs, from the regional center to national central city.

The government plans the "local living area" based on Central Place Theory, and references the local history, industry,

population, geographical environment and urban functions as regional planning and promotes the effective use of land.

C. Interchange Service Area

In Taiwan, most of the studies 15 to 20 km buffer from the interchange to be the service area [1], [3], [4], [6]. In this study, 15 km buffer from the interchange is adopted as an interchange service area.

D. Intercity Travel Propose Investigation

MOTC conducted the intercity travel behavior questionnaire of Taiwan area in 2013. In July 2015, it published the "The 5th Taiwan Area Comprehensive Transportation Planning Research Series - Intercity Travel Survey and Preliminary Analysis" [8]. It investigated OD, purpose, preference of the transportation, occupancy rate and passengers' basic Information. The study directed intercity trips and was conducted in the past month. It divided the date into three types: Tuesday to Thursday, Monday and Friday, Saturday and Sunday, respectively. Furthermore, festival and continuous holiday was excluded from the investigation.

The study discovered the intercity transportation, which are allowed being driving on the freeway, has the following characteristics:

- (1) Bus: In Taiwan, although the high speed railway was opening to traffic, the bus still has a role to play in the medium and long-distance travel.
- (2) Sedan: Sedan has good accessibility and mobility, and account a large number of intercity transportation.
- (3) Truck: The traffic volume of truck on weekday is twice as much as it on weekend. It is contrary to other transportation.

The study divided the main purpose of the trip into seven categories: "leisure and entertainment", "tourism and business trip", "commercial affairs", "visiting relatives and friends", "commuting to work", "commuting to school" and "other activities". And it also discovered that people almost have only one travel purpose and choose one transportation in an intercity travel. The study also classified and analyzed the travels:

- (1) Purpose: The main purpose of intercity travel is "visiting relatives and friends"; "Commercial affairs" is significantly higher than other purposes in Tuesday to Thursday; "commuting" on Monday and Friday is higher than other days.
- (2) Length: The length of travel is mainly 20-50 km on weekdays, mostly 50-100 km on weekends.
- (3) Frequency: Trips on weekdays are more than weekends'.

The study found that the combination of different types of cars, dates, length and other characteristics of the trip have a specific significance. This study can be based on travel characteristics to speculate the purpose of travel.

III. DATA COLLECTION

The study selected October 20, 2015 (Tuesday) to October 22, 2015 (Thursday) and October 17, 2015 (Saturday) to October 18, 2015 (Sunday) of the original route data of ETC. The data includes the following items:

- (1) VehicleType: 31 (Sedan), 32 (Pick-up), 41 (Bus), 42 (Truck), 5 (Trailer).
- (2) DetectionTime_O: The time point of the first detection station which vehicle passes at one trip.
- (3) GantryID_O: The numbering of the first detection station which vehicle passes at one trip.
- (4) DetectionTime_D: The time point of the last detection station which vehicle passes at one trip.
- (5) GantryID_D: The numbering of the numbering detection station which vehicle passes at one trip.
- (6) TripLength: The length of one trip.
- (7) TripInformation: Each time point and numbering of the detections which vehicle passes at one trip.

IV. METHOD

The original route data of ETC are recorded independently. The data in the same hour will be classified in the same form, while the others remained unprocessed. This study analyzed data by Python and Excel to become ordered and meaningful information, and to build an intercity trip model. Meanwhile,

the study circumscribes the interchange service areas and calculates land use coverage status to establish living area data base.

A. The Principle of Selecting the Interchange for Analysis

A living sub-area may cover several administrative districts and freeway interchanges. This study selected interchanges covered by a living sub-area if they are within "Special municipality or provincial city and its neighboring administrative regions" or "county-level city". Therefore, the Tainan living sub-area (hereinafter referred as Tainan City) included old Tainan city, Jen-Te Dist., Yong-Kang Dist., Hsin-Shih Dist. and An-Ding Dist., and covered An-Ding interchange, Yong-Kang interchange, Da-Wan interchange and Tainan interchange.

B. Establishing Intercity Trip Model

Python is a programming language that can be used to process files, text, and so on. In this study, the same OD of each trip are merged and calculated. After processing the data, the interchanges are selected by Excel, and the number of transportation is sorted. Finally, the data are visualized by GIS.

C. Build a Database of Service Area

After selecting the interchanges to be analyzed, the area of analysis (15 km buffer from the interchanges) is delineated. Fig. 2 is an example of Tainan City. The residential, commercial and industrial land uses are calculated by GIS, and a database is built to support the research.

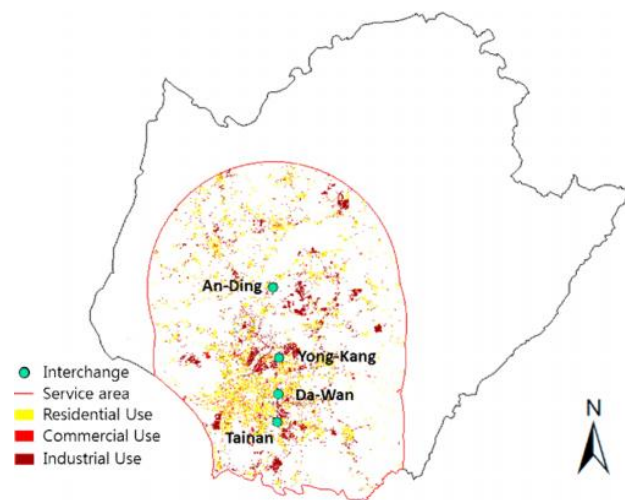


Fig. 2 Land Use in the service area of Tainan

V.RESULT

A. Sedan

Most sedans are traveling short-distance. From Fig. 3, the trips from Tainan arrive at Tainan local centers such as Madou, Xinying, Kaohsiung and Chiayi. The trips to Tainan from Tuesday to Thursday start from Kaohsiung, Madou, Xinying, Chiayi and other places.

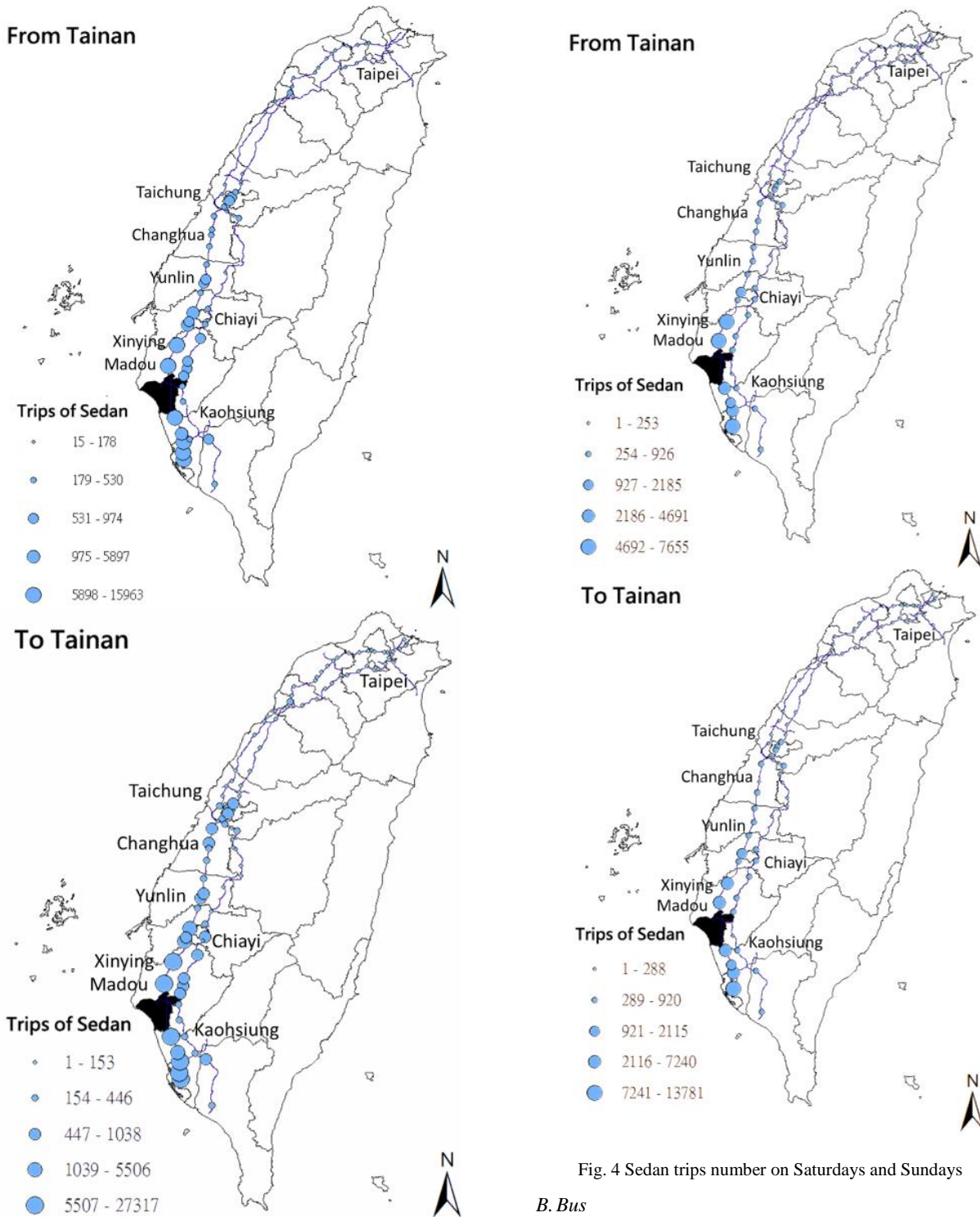


Fig. 3 Sedan trips number on weekdays

From Fig. 4, we can see that the primary arrival locations from Tainan are Tainan local centers such as Madou, Xinying and Kaohsiung. The trips to Tainan on Saturdays and Sundays start from Kaohsiung, Madou, Xinying, Chiayi and Taichung.

Fig. 4 Sedan trips number on Saturdays and Sundays

B. Bus

From Fig. 5, we can see that the buses can reach middle to long distance from Tuesday to Thursday, and the metropolitan areas are significant. The primary arrival locations from Tainan are Kaohsiung, Taichung, Taipei and so on. The trips to Tainan from Tuesday to Thursday start from Taichung, Kaohsiung, Taipei, Madou, Xinying and other places.

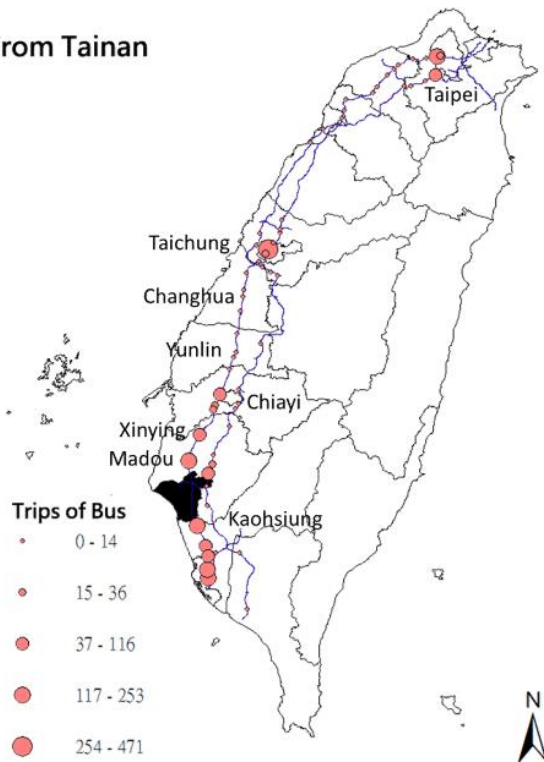
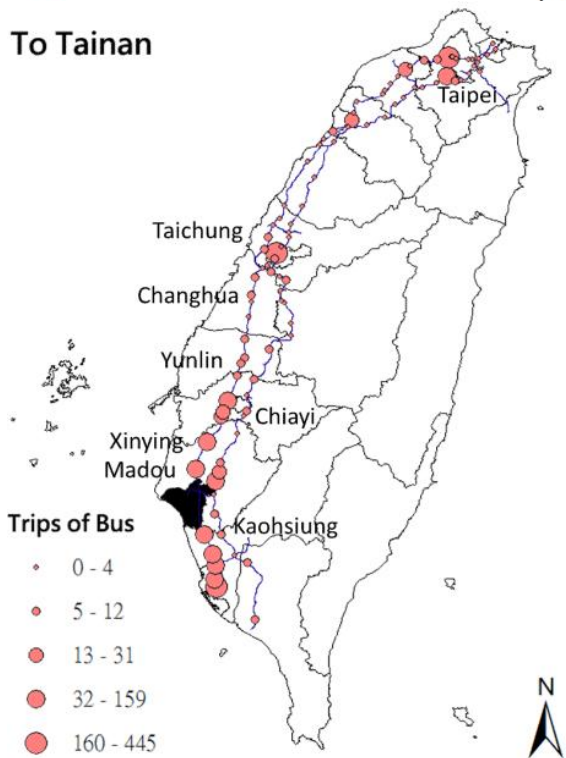
From Tainan**To Tainan**

Fig. 5 Bus trips number on weekdays

Xinying. The trips to Tainan on Saturdays and Sundays start from Taipei, Taichung, Kaohsiung, Chiayi, Madou and Xinying.

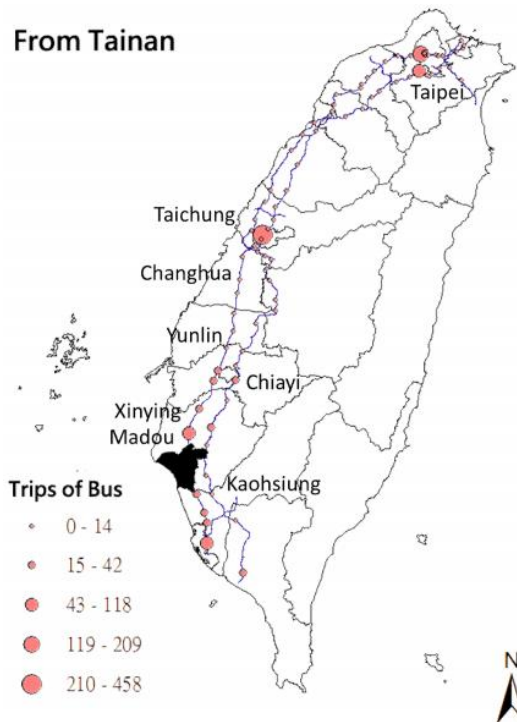
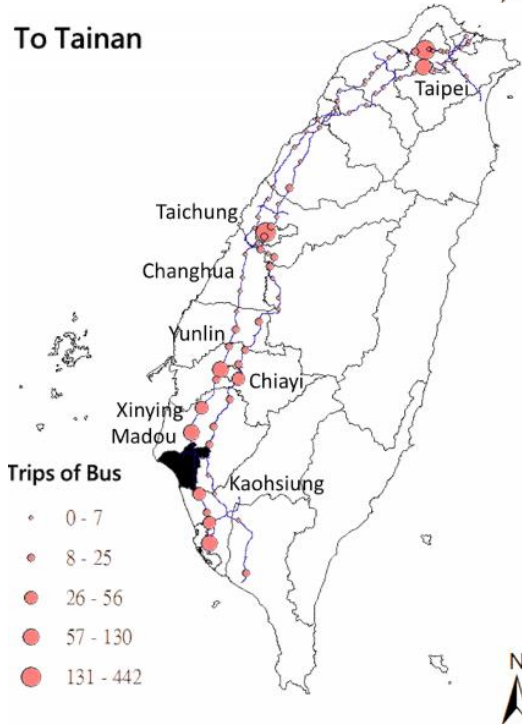
From Tainan**To Tainan**

Fig. 6 Bus trips number on Saturdays and Sundays

As shown in Fig. 6, buses travel on Saturdays and Sundays with medium to long distance distances, which are more significant than usual. The primary arrival locations from Tainan are Taipei, Taichung, Kaohsiung, Chiayi, Madou and

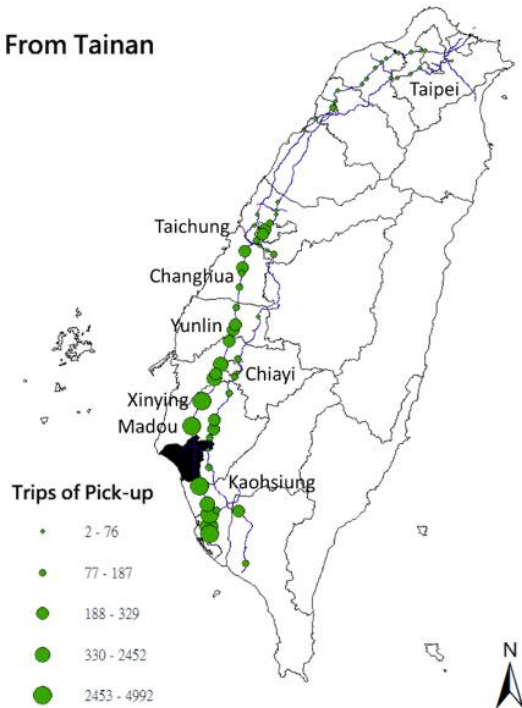
C. Pick-up

From Fig. 7, it can be seen that pick-up is mainly short to

medium distance from Tuesday to Thursday. The primary arrival locations from Tainan are Madou, Xinying, Kaohsiung, Chiayi and so on. The trips to Tainan from Tuesday to Thursday start from Madou, Xinying, Kaohsiung, Chiayi and other places.

distance on Saturday and Sunday. The primary arrival locations from Tainan are Madou, Xinying, Kaohsiung, Chiayi, Taichung and so on. The trips to Tainan on Saturdays and Sundays start from Madou, Xinying, Kaohsiung and Chiayi.

From Tainan



To Tainan

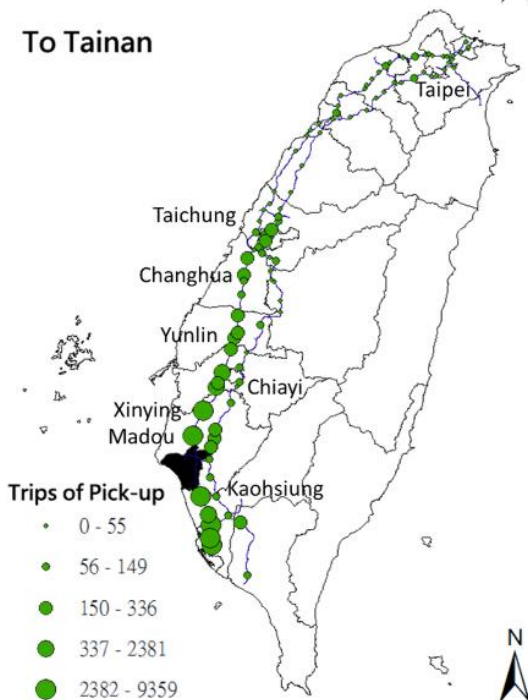
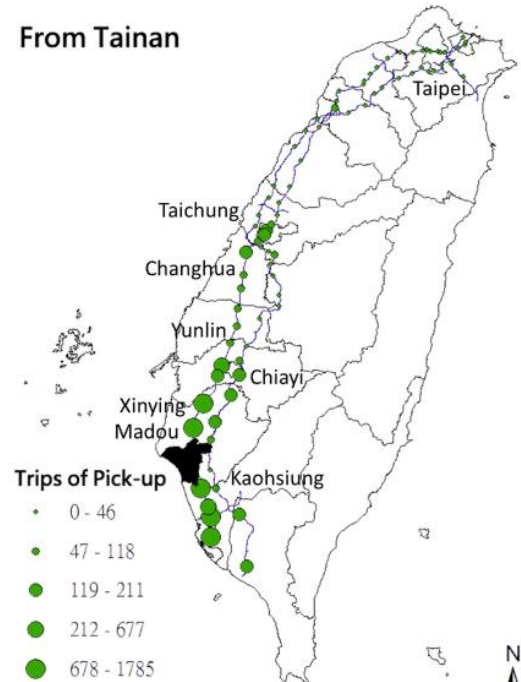


Fig. 7 Pick-up trips number on weekdays

From Fig. 8, it can be seen that the pick-up is mainly short

From Tainan



To Tainan

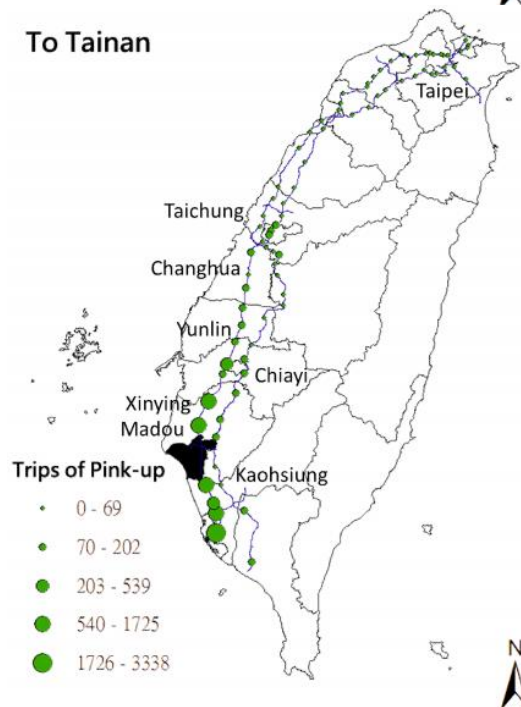


Fig. 8 Pick-up trips number on Saturdays and Sundays

D.Truck

As shown in Fig. 9, trucks travel mainly from short distance

on Tuesdays to Thursdays. The primary arrival locations from Tainan are Madou, Xinying, Kaohsiung, Chiayi, Yunlin and Changhua and so on. The trips to Tainan from Tuesday to Thursday start from Madou, Xinying, Kaohsiung, Chiayi, Yunlin, Changhua and other places.

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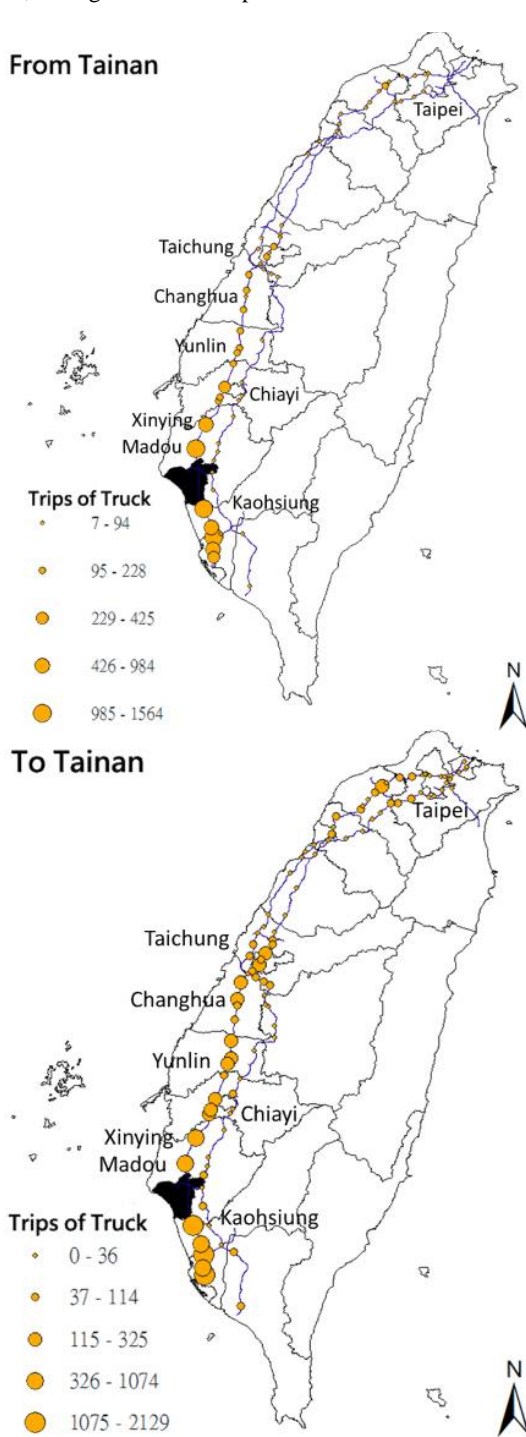


Fig. 9 Truck trips number on weekdays

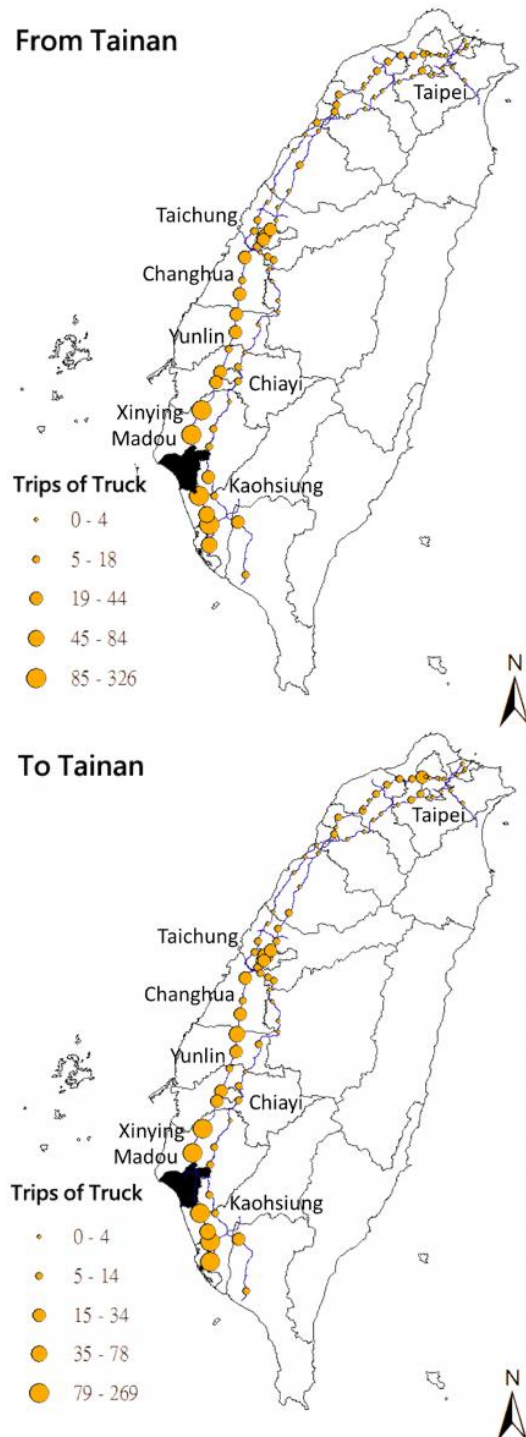


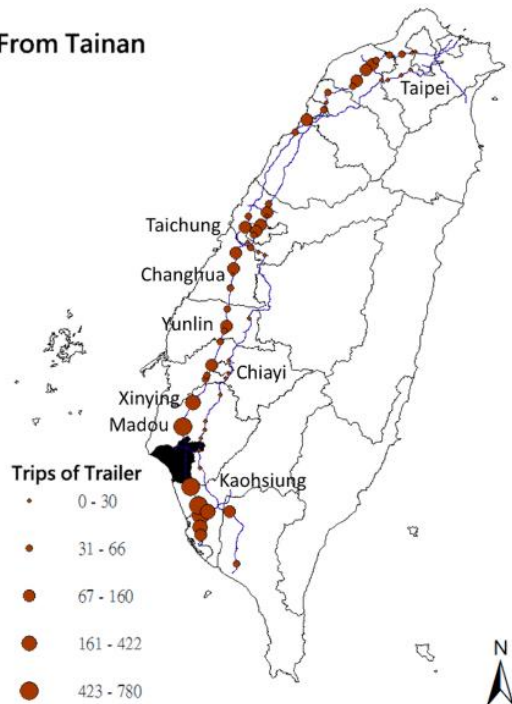
Fig. 10 Truck trips number on Saturdays and Sundays

As shown in Fig. 10, trucks travel mainly on medium and

E. Trailer

Trips to the vicinity of the industrial area are significant. As shown in Fig. 11, the primary arrival locations from Tainan are Madou, Xinying, Kaohsiung, Taichung and so on. The trips to Tainan from Tuesday to Thursday start from Madou, Xinying, Kaohsiung, Changhua, Taichung and other places.

From Tainan



To Tainan

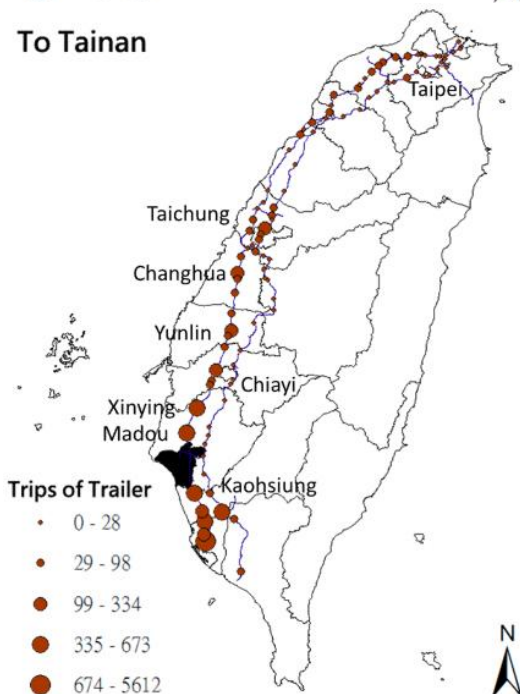
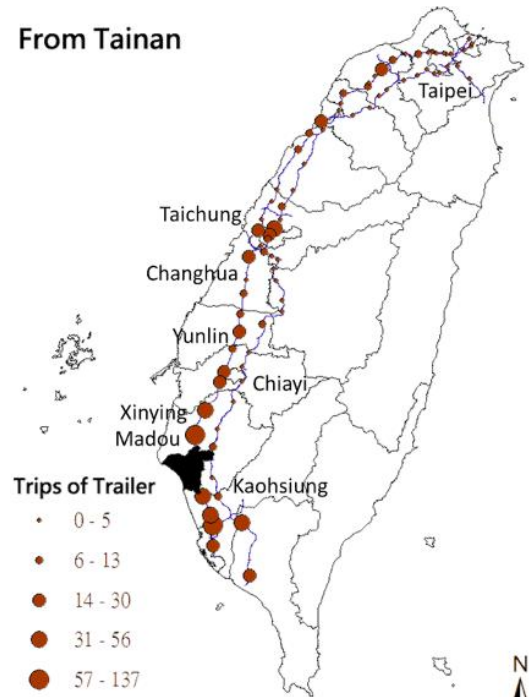


Fig. 11 Trailer trips number on weekdays

As shown in Fig. 12, the primary arrival locations from Tainan are Madou, Xinying, Kaohsiung and Taichung. The trips to Tainan on Saturdays and Sundays start from Madou, Xinying, Kaohsiung and Taichung.

From Tainan



To Tainan

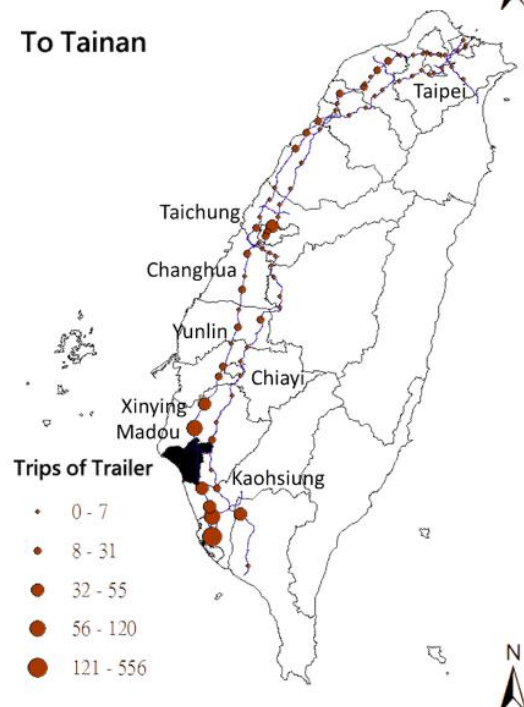


Fig. 12 Trailer trips number on Saturdays and Sundays

VI. DISCUSSION

On the same date type, each type of transportation of Tainan

is very similar to the OD and the number of trips, indicating that there is round-trip relationship on the same date type. Overall, Tainan has a significant influence on the neighboring administrative regions, including Kaohsiung, Chiayi, Yunlin, Changhua and Taichung. According to the results, sedans are more likely to travel to Kaohsiung downtown area and its industrial areas, Madou, Xinying, and Chiayi. According to the questionnaire data of MOTC, the characteristics can be used to speculate that above regions have relationship of "commuting to work", "commercial affairs" or "visiting relatives and friends" between Tainan. Bus connects three major metropolitan areas in Taiwan: Taipei, Taichung and Kaohsiung. Travel purposes are speculated "commuting to work", "commercial affairs" or "visiting relatives and friends". On the other hand, Buses often pick up the passengers in Madou and Xinying on the way to Taichung or Taipei. The actual situation is also similar with the study results.

In the sector of cargo transportation, pick-ups and trucks ply between Kaohsiung city and its industrial areas, Madou, Xinying, and Chiayi on weekdays. In addition, the purpose of the trip may be industrial freight, commercial freight or home delivery according to the land use. Compared with the truck, the trailer has more trips for the long distance, with the cargo type and volume.

On Saturday and Sunday, the vehicles except the bus are less than weekdays, but the trips of sedan to tourist areas increase. The purposes of trips are more "leisure and entertainment" and "tourism and business trip". Cargo transportation is less than twice as weekdays.

Comparing the results of the study with the seven regional living areas defined in 2010, it can be found that Tainan influence area reaches to Kaohsiung, which includes Kaohsiung downtown area and industrial area. Currently, Yunlin, Chiayi and Tainan are the same living area, and Kaohsiung is another's. However, the trips between Tainan and Kaohsiung are even more than Tainan local centers such as Madou and Xinying, and trips between Tainan and Yunlin are rare. The study indicates that the range of the current living area is arguable.

VII. CONCLUSION AND SUGGESTION

Since Taiwan ETC is currently only located on north-south freeway, the scope of this study is limited to districts where ETC is located. And it is unable to analyze the district which is not located within any interchange service area, so the study may not be able to include them in influence area. Through the ETC, we can grasp which district Tainan City influence, but cannot judge which district is not affected.

In this study, the living area should not be divided completely according to the boundary of the administrative area, and the range should be different with the purpose, date type and time. The influence area can be designated into commuter, freight, tourism etc., and different influence area may overlap. It is also prone to reshape the influence range when data updating.

REFERENCES

- [1] Pai, J. T., Yuch, Y. C., LIN C. Y., (2000), Spatial Impacts of Chung-Sun Freeway on the Industrial Development in Taiwan's West Corridor, "Journal of city and Planning", Vol.27, No.2, 211-232.
- [2] Council for Economic Planning and Development of Taiwan, Executive Yuan (1996), Territorial Comprehensive Development Plan.
- [3] Ministry of Transportation and Communications R.O.C, (2016), Principles for the addition and improvement of expressway interchanges.
- [4] Directorate General of Freeways MOTC R.O.C, (2014), Living Road Nets Transportation Construction 'Freeway system' Four-Year Plan '2015-2018'.
- [5] National Development Council, (2010), Strategic Plan for National Spatial Development.
- [6] Chen, S. S., (2012), The impact of freeway construction on the spatial distribution of population and economic activities- the case study in Taiwan, Master Thesis of Department of Land and Economics, National Chengchi University Institute of Urban Planning Master's thesis.
- [7] Tseng, H. P., (2009), Local Living Circle, Encyclopedia of Taiwan, Ministry of Culture, URL: <http://nrch.culture.tw/twpedia.aspx?id=1670>, (Accessed on: August 15, 2016 web information).
- [8] Yang, Y. W., Lu, Y. C., Chang, Y. C., Jenq, J. Y., Lee, S. W., Chuang, Y. J., Li, D. C., Yeh, W. Y., Shen, P. W., The 5th Taiwan Area Comprehensive Transportation Planning Research Series - Intercity Travel Survey and Preliminary Analysis, Institute of Transportation MOTC R.O.C.
- [9] Chrstraller, W., (1933), Die zentralen Orte in Süddeutschland, Jena: Gustav Fischer Verlag.