APPLYING GEO-DATA TO EVALUATE THE APPROPRIATENESS OF BUS NETWORK

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Abstract

In recent years, a great deal of resources have been invested in public transportation development in Taiwan. Although the Ratio of the Users of Public Transport has increased significantly, the pace of growth has already started to slow down. As a result, all levels of the governments are attempting to boost the ratio of the users of public transport by planning new transit service routes with potential. Due to the limitations of forecasts derived from conventional transportation demand data, some local and foreign scholars and research organizations have employed the service population indicator to plan transit service routes.

In this study, we utilize a variety of geospatial data, such as village and street number diagrams from the Taiwan Geospatial One-Stop Portal, created by the Information Center, Ministry of the Interior; the Household Registration Statistics database; the Bus Dynamic Information System implemented by the Directorate General of Highways, Ministry of Transportation and Communications (MOTC); and other big data sources such as income and land use data. This will enable government transportation agencies to assess the benefits of new transit routes using transportation demand data and the service population indicator.

Based on this analysis, highway authorities can perform objective assessments to quickly determine if the public transit service in a particular area is adequate. This helps remove the administrative blind spots caused by the necessity to employ rules of thumb in the past due to the lack of relevant information, thus making the supply of public transportation services better able to meet the needs of local residents. The analysis will improve the administrative capability of the highway authorities to properly allocate resources for transportation services.

Keywords: the public transportation usage rate, service population coverage, Taiwan Geospatial One-Stop Portal

1. INTRODUCTION

In 2010 the Ministry of Transportation and Communications began to implement the "Highway Public Transportation Development Project (2010-2012)", which resulted in a 9.9% increase in overall public transit ridership in 2011 compared to that of 2009. In 2011 the government introduced a second "Highway Public Transportation Development Project (2013-2016)" to build upon the momentum of its predecessor in order to continue to strengthen the competitiveness of public transportation services, so that the general public will have the incentive to reduce their reliance on private transport vehicles and to adopt public transit systems as their primary mode of transportation. The aims of these projects include achieving an annual increase of 5% in public transport ridership and reaching 18% in the ratio of the users of public transport by 2016. This indicates that the development of public transportation has become one of the most important public policy objectives for many countries. In 2015 the utilization rate of public transport in Taiwan was 16%.

In this study, we utilize a variety of geospatial data, such as village and street number diagrams of the Taiwan Geospatial One-Stop Portal, created by the Information Center, Ministry of the Interior; the Household Registration Statistics database; and the Bus Dynamic Information System implemented by the Directorate General of Highways, Ministry of Transportation and Communications (MOTC); and other big data sources such as income and land use data. This will enable government transportation agencies to assess the benefits of new transit routes using transportation demand data and the service population indicator. In the following sections, we will analyze a study conducted based on data from Chiayi County. The ratio of the users of public transport in Chiayi County is only 5.2%, therefore in this study we will describe how a variety of geospatial data can be used to help the local government rediscover where the maximum transit service gaps are in Alishan Township, as well as to assess business plans for new service routes under such conditions, the purpose of which is to take necessary corrective measures and to provide local residents with a convenient public transit system.

2. LITERATURE REVIEW

2.1 Bus Route Design

Kepaptsoglou and Karlaftis (2009) formulated a version of the transit route network design problem, offering advantages such as mobility enhancement, traffic congestion and air pollution reduction, and energy conservation while still preserving social equity considerations. Nevertheless, in the past decades, factors

such as socioeconomic growth, the need for personalized mobility, the increase in private vehicle ownership and urban sprawl have led to a shift towards private vehicles and a decrease in public transportation's share in daily commuting efforts for encouraging public transportation use focuses on improving provided services such as line capacity, service frequency, coverage, reliability, comfort and service quality which are among the most important parameters for an efficient public transportation system. The problem that formally describes the design of such a public transportation network is referred to as the transit route network design problem (TRNDP); it focuses on the optimization of a number of objectives representing the efficiency of public transportation networks under operational and resource constraints such as the number and length of public transportation routes, allowable service frequencies, and number of available buses

2.2 Operation Cost and User Cost

In many paper present minimum operation cost and user cost but only three people Zhao(2005),Zhao and Zeng (2006) describe the maximum coverage rate

After 2000 many people start use traditional mathematical model and method. Chien et al. (2001) and other researchers using on Genetic algorithm (GA), have been focused on Heuristic mathematical model.

In Taiwan we use expert's judgment to design bus network. One of the example is by using aces indicator to evaluate performance of the bus line (Mr. Jie 1999). They had three-line route design method but on this study they only choose generate model for bus route. Expert Wang (2013) integrates Geographic information system and genetic aerogram. It is heuristic aerogram. However, he could not use transit demand data in this research. Mr. Su formulated a method that allows design route. They just use household and populations to design bus road. Su Jau Ming (2013), Wang Jan Wei (2013), Zhang Shu Shi (2001), Martinez and Viegas (2011) and Perugia etc. (2011), measured demand of the bus station.

3. CONTENT OF INFORMATION ADOPTED

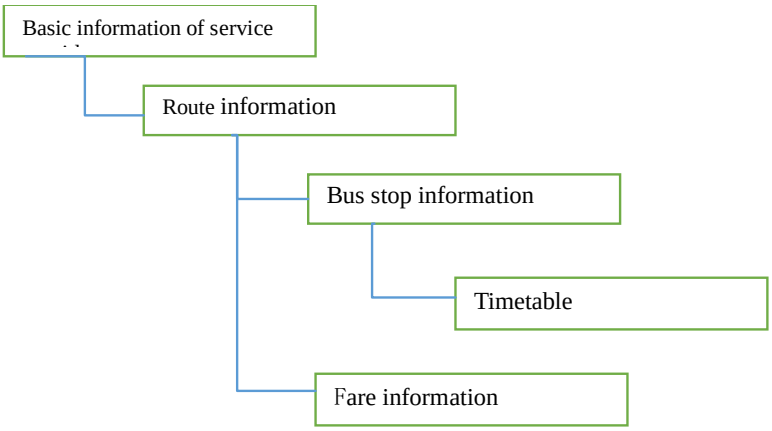
3.1 Data for Analysis

Currently, there are 5 types of relevant public transportation information available in Chiayi County, including basic bus route information; real-time data from the bus dynamic information system, location coordinates of household street numbers, household population attribute data and neighborhood income. The data from these five categories are described as follows:

(1) Basic bus route information: The storage and release of the basic bus route information in Chiayi County is based on the "data exchange, collection, and release mechanism of the Bus Dynamic Information Center V2" defined by the Institute of Transportation, Ministry of Transportation and Communication,

which provides data exchange functions for “operational capital of service providers,” “pre-scheduled timetables,” “real-time bus information,” and “expected time of arrival.” “Operational capital of service providers” and “pre-scheduled timetables” are static data updated once per day through a web service, wherein the operational capital of service providers provides the basic operation information of the bus service provider, including “basic information of the service provider,” “route information,” “bus stop information,” “timetables,” and “fare information.” The XML structure is shown in Figure 1.

Figure 1: XML structure of the basic operation information of bus service providers.



(2) Real-time data of the bus dynamic information system: Based on the “data exchange, collection, and release mechanism of the Bus Dynamic Information Center V2” defined by the Institute of Transportation, Ministry of Transportation and Communication, the bus dynamic information is divided into returning at a fixed time, returning at a fixed location, and expected time of arrival. The content of the information includes route name, bus stop number, coordinates, GPS time, estimated time of arrival, etc. The “Bus Dynamic Information Management System” of the Directorate of Highways issues about 730,000 records of data every day and 260.09 million records every year. With regard to dynamic information, fixed time data has about 730,000 records of data per day calculated based on the service times of each route. The fixed location data are composed of about 600,000 records of data per day and the expected time of arrival contains 600,000 records. In total, there are about 1.93 million records of data per day and 0.7 billion records of data per year.

(3) Location coordinates of household street numbers: The source of location coordinates of street numbers is the static data from the Taiwan Geospatial One-Stop Portal. There are a total of about 180,000 records of household street numbers for Chiayi County in the database. Data fields include

county/city numbers, township/town numbers, village numbers, areas, roads, lanes, alleys, numbers, floors, x coordinates, and coordinates. The existing demographic data fields include county/city numbers, township/town numbers, village numbers, ages, gender, quantities, etc.

(4) Household population attributes data: Personal basic statistics from the Taiwan Geospatial One-Stop Portal, which was implemented by the Information Center, Ministry of the Interior. Data required for this study include date of birth, gender, marital status, address and coordinates, which can be used to analyze the age distribution of the population and to locate potential public transportation demand.

(5) Neighborhood income: The latest consolidated income tax declaration of each year compiled by the Fiscal Information Agency, Ministry of Finance, excluding separate taxation, tax exemption, and non-taxed consolidated income tax declaration in the primary approval statistics book. The information includes taxable unit, average, first quantile, third quantile, standard deviation, and coefficient of variation which can be viewed as the basis of income within the administrative regions.

3.2 Analysis Indicators

Spatial transit service gap scanning analysis: The purpose of spatial transit service gap scanning analysis is to determine whether the regional public transit system is capable of providing the most basic level of services. In other words, the analysis evaluates the proportion of residents who are able to arrive at a public transit stop within a reasonable walking distance. This indicates whether basic public transportation services are available to local residents. Spatial transit service gap analysis provides very important reference information to any subsequent plans to improve public transportation services. If a spatial transit service gap has been identified in a particular area, it indicates that residents living in that area have no access to any public transportation services at all. When a spatial transit service gap has been pinpointed, subsequent analysis will determine if the area identified with the gap is a potentially feasible candidate for new transit services and also whether a potential population requiring public transportation services exists. Relevant definitions are described as follows:

(1) Locations potentially viable for new public transit services: The U.S. Transit Capacity and Quality of Service Manual (TCRP), 3rd Edition states that it is feasible to provide public transportation services in an area if the number of households per acre (4046.87 square meters) in that area is above 4. Based on this principle, this system divides the area identified with a service gap into two categories: potentially feasible (above 4 households per acre) and non-potentially feasible (below 3 households per acre).

(2) Potential population for public transportation services: The makeup of each age group in the households can be determined based on the population attributes data provided by the Information Center, Ministry of the Interior.

Treating the 6-11, 12-18 and above-65 age groups as the population segments that potentially need public transportation the most, in Chapter 6 we will analyze the size of the potential population in each administrative division. If a large number of potential public transit users exist in a particular administrative division, careful consideration can be made to decide whether public transit services should be made available to its residents.

4. CASE STUDY

Chiayi County, comprising 16 townships, has a total area of 1,903.64 square kilometers and a population of 524,783. Population statistics for the county's administrative divisions are listed in Table 1 below.

Table 1: Population statistics for the administrative divisions of Chiayi County

Administrative division	Area(sq. km)	Population	Population density (No. of persons/sq. km)
Dalin Township	64.17	32,159	501.18
Dapu Township	173.25	4,658	26.89
Zhongpu Township	129.50	46,156	356.41
Liujiao Township	62.26	24,613	395.31
Taibao City	66.90	37,038	553.66
Shuishang Township	69.12	50,726	733.89
Budai Township	61.73	28,423	460.44
Minxiong Township	85.50	71,903	841
Puzi City	49.57	43,250	872.44
Zhuqi Township	162.23	36,924	227.61
Dongshi Township	81.58	26,235	321.58
Alishan Township	427.85	5,764	13.47
Meishan Township	119.76	20,304	169.54
Lucao Township	54.32	16,384	301.65
Fanlu Township	117.53	12,089	102.86
Xingang Township	66.05	33,186	502.44

Xikou Township	33.05	15,393	465.8
Yizhu Township	79.29	19,578	246.91
Total	1903.64	524,783	275.67

4.1 Results of Spatial Transit Service Gap Scan

The service coverage distance for public transportation in Chiayi County is established to be 500 meters. Using the public transportation service gap scanning decision support system, the results of spatial gap scanning in Chiayi are shown in Figure 2 and Table 2. From the data presented in the table, it can be seen that Alishan Township is an administrative area with unsatisfactory spatial transit service coverage.

Figure 2: Chiayi County public transportation service spatial gap scanning diagram

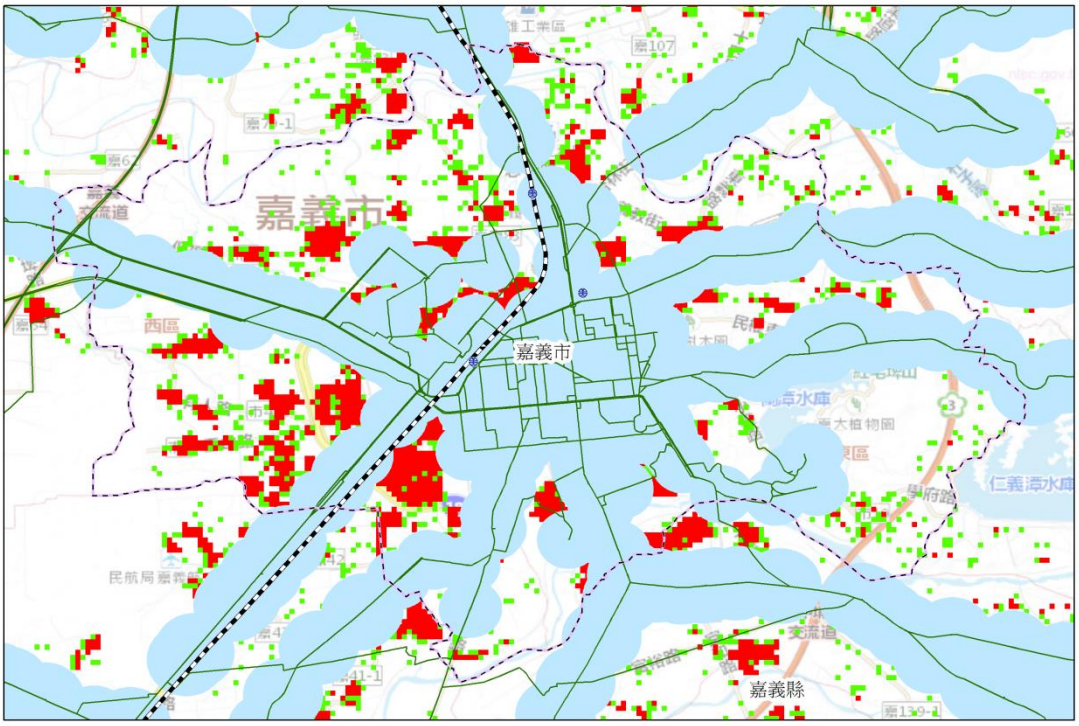


Table 2: Summary of the results of Chiayi County public transportation service spatial gap scanning

Administrative division	Total population	Population coverage	Spatial transit service coverage (%)	Ages 6-11 potential population service ratio (%)	Ages 12-18 potential population service ratio (%)	Age 65 and above potential population service ratio (%)
Dalin Township	32257	26806	83.1	83.65	83.87	80.52
Dapu Township	4636	2944	63.5	63.08	62.14	63.51
Zhongpu Township	45966	27978	60.87	65.61	61.37	57.35
Liujiao Township	24746	15516	62.7	63.06	62.14	59.95
Taibao City	37031	27720	74.86	80.89	80.31	67.54
Shuishang Township	50826	32666	64.27	68.22	65.36	61.48
Budai Township	28520	22415	78.59	80.62	76.74	76.61
Minxiong Township	71965	51555	71.64	74.72	73.5	68.33
Puzi City	42238	31518	74.62	78.78	76.08	73.31
Zhuqi Township	36955	28053	75.91	79.93	79.4	72.5
Dongshi Township	26347	19131	72.61	72.34	73.19	71.03
Alishan Township	5740	2396	41.74	34.62	39.05	44.84
Meishan Township	20365	15364	75.44	76.48	76.79	72.87

Lucao Township	16481	12783	77.56	74.86	76.82	81.41
Fanlu Township	11168	8424	75.43	79.9	78.86	72.54
Xingang Township	33340	25839	77.5	76.31	76.99	77.94
Xikou Township	15535	12239	78.78	85.74	82.59	77.34
Yizhu Township	19642	13858	70.55	75.3	69.94	69.99

The proportions of potential and non-potential areas for public transportation services among households in townships identified with service gap are shown in Table 3. From the figures, we can see that Minxiong Township has the largest population (3,222) in the potential area, followed by Shuishang Township (3,052). This indicates that the two communities are still in need of public transit service, but whether there is actual demand is unknown until surveys and interviews are conducted in these townships.

Table 3: Summary of results of analysis of potential areas for public transit services in Chiayi County

Township/City	Non-potential area				Potential area			
	No. of households	Potential population for public transit service	Non-potential population for public transit service	Ratio of potential population for public transit service (%)	No. of households	Potential population for public transit service	Non-potential population for public transit service	Ratio of potential population for public transit service (%)
Dalin Township	676	1017	2358	30	505	658	1418	32
Dapu Township	233	309	1099	22	80	75	306	20
Zhongpu Township	1498	2592	7559	26	1961	1652	6130	21
Liujiao Township	849	1577	3397	32	844	1433	2823	34
Taibao Township	678	866	2705	24	1352	1409	4330	25
Shuishang Township	890	1277	3242	28	3755	3052	10589	22
Budai Township	488	605	1573	28	896	1129	2848	28
Minxiong Township	1295	1687	4976	25	3417	3222	10531	23
Puzi Township	592	903	2207	29	1598	2090	5519	27
Zhuqi Township	1077	1607	4419	27	555	773	2143	27
Dongshi Township	464	673	1687	29	942	1460	3404	30

Alishan Township	474	464	1683	22	243	260	917	22
Meishan Township	805	1308	3009	30	130	182	511	26
Lucao Township	339	445	1448	24	351	540	1259	30
Fanlu Township	458	546	1509	27	181	161	478	25
Xingang Township	672	1063	2598	29	788	1112	2762	29
Xikou Township	369	619	1450	30	216	365	862	30
Yizhu Township	465	734	1647	31	708	1041	2362	31

4.2 Analysis of Program

The Chiayi County Government has identified Alishan Township as the administrative division in the entire county with the largest service gap in public transportation. In order to improve the quality of transit connection services in Alishan Township, a new service route is planned to serve Shanmei, Xinmei, Chashan and other villages. Local residents are encouraged to use these shuttle services, which will connect them to Provincial Highway 18 for additional transport services such as intercity bus stations, the Chiayi Railway Station and the High-Speed Rail Station (refer to Figure 3). The report of the program is shown in Table 4. The route passes through the following villages in Alishan Township (except where indicated): Chashan, Gongxing (in Fanlu Township), Xinmei and Shanmei. The average income (for taxation purposes) of each village is shown in Table 5. The figures show that the average household income is less than NT$600,000, indicating that these areas are among the low-income communities. As a result, this new route is expected to effectively fill the existing public transportation service gap and improve the accessibility of public transit services.

Figure 3: Chashan Route, Alishan Township

Table 4: Transit service indicator analysis for Chashan Route, Alishan Township

Indicator attribute	Indicator name	Current measure	Value from reviewed proposal
Route attribute	Route travel time indicator (min.)	-	53
	Circuity	-	1
Potential demand for route	Change in no. of street numbers serviced by route	-	106
	Change in population serviced by route	-	-
	Service coverage rate of transit stations (%)	-	0

Status of overlapping routes	Overlapping rate of population serviced by route (%)	-	16.04
	Overall road network duplication ratio indicator (%)	-	-
	Individual repetition rate based on reviewed routes (%)	-	-
	Individual repetition rate based on existing routes (%)	-	-
Demand fulfillment rate	Administrative division-based public transportation demand fulfillment rate (%)	16.67	100
	Transit stop-based public transportation demand fulfillment rate (%)	100	100
Time accessibility	End-to-end public transit travel time (min.)	No bus services currently available	53.85

Table 5: Average household income statistics of communities along the Chashan Route, Alishan Township

Village / Item	Alishan Township Chashan Village	Fanlu Township Gongxing Village	Alishan Township Xinmei Village	Alishan Township Shanmei Village
Average income (unit: NT$10,000)	49.3	57.5	55.7	55.5
Median	35.3	50.3	51.4	51.6
1st quartile	22.7	33.8	33.0	33.3
3rd quartile	79.0	68.7	70.7	76.8

5. CONCLUSIONS

In this study, we utilize a variety of geospatial data, such as village and street number diagrams of the Taiwan Geospatial One-Stop Portal, created by the

Information Center, Ministry of the Interior; the Household Registration Statistics database; the Bus Dynamic Information System implemented by the Directorate General of Highways, Ministry of Transportation and Communications (MOTC); and other big data sources such as income and land use data. This will enable government transportation agencies to assess the benefits of new transit routes using transportation demand data and the service population indicator.

The assessment results of the new transit route in Alishan Township, Chiayi County showed that diverse information can help improve the decision making of route planning and assessment in terms of the continuation/termination of existing routes or creating new routes. The relevant analysis has been forwarded to the Chiayi County Government as a reference for decision-making purposes. In the future, if mobile phone information can be incorporated into the study, we can further understand the public's demand pattern and plan bus routes that are more in line with public demand.

6. ACKNOWLEDGMENT

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