Travel Demand Forecasting: A Basis for Local Public Transport Route Plan in Apalit, Pampanga

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Abstract- ***The study aims to evaluate the role of travel demand forecasting in establishing local public transport routes in Apalit, Pampanga. The study was conducted using a quantitative approach, a four-step modeling process, in which the researcher's collected data from the PSA and other Local government units and used the 1 percent of the total households in the study, which is 273 households, to analyze the trip distribution and trip generation of Apalit, Pampanga. The results of this study show that every five years from 2023 up to 20 years from now, the year 2043 that the threshold from trip attraction and distribution from every zone is less than 1, which means traffic congestion will not be present. However, nearly all of the participants said that the construction of roads is a major factor in the heavy traffic in Apalit, Pampanga.***

I. INTRODUCTION

Public Transportation is a pivotal part of every growing country worldwide. Enhancement of public transportation in a country provides an easy and effective way for community members to pierce public transportation.

The modeling of trip demand is essential to the planning of transitway investments. It provides ridership estimates and enables design itineraries to detect and examine trip demand requests. For design defense, early planning stage option analysis and selection, latterly planning stage service planning, installation needs evaluation, and unborn income prognostications, ridership estimates are pivotal throughout the transitway development process. Reasonable and at every position of transitways planning and design development, believable trip demand prognostications are needed.

According to Jiangxi Provincial Planning and Design Institute (2011), the factors of the transport-related design were examined using the civic trip demand soothsaying model. The issues of trip soothsaying were used to inform the cost-benefit analysis, feasibility study designs, and cost estimates for the rapid-fire machine conveyance (BRT), civic transport mecca, and road advancements. This allowed for the vaticination of design benefits and the assurance that the scale of investment was commensurate to travel demand. This part outlines the fashion, approach, and results of the trial in trip demand vaticination.

The Public Utility Vehicle Modernization Program (PUVMP), a large-scale transformational action and flagship design of the government, was established by the Department of Transportation Department Order No. 2017- 011, also known as" Omnibus Guidelines on the Planning and Identification of Public Road Transportation Services and Franchise allocation" or the Public Utility Vehicle Modernization Program. It aims for commuters to arrive at their destinations incontinently, safely, and with accessibility while motorists and drivers earn stable, sufficient, and staid livelihoods.

For furnishing land transport services, the Original Public Transportation Route Plan (LPTRP) was a detailed plan route network with designated modes of transportation and the necessary number of units per mode. The minimal conditions set forth for issuing PUV votes are now grounded on this. LPTRP plans to make the route demand-driven, as LGUs can now suggest routes grounded on original demand. Also, it is assumed that applicable vehicle types, roads, scales, and configurations will be assigned as demanded. Original governments also dictate hourly passenger figures and directions for each particular mode of transportation, so they must give substantiation-grounded recommendations and plans.

According to Lipa City's current route plan, tricycles covering the roadways caused four hours of traffic, and some corners needed business signal installation and estimation (Flores, K.B.O., 2019).

Accurate soothsaying of trip demand is essential for effective planning and operating transportation systems. It can help transportation itineraries and policymakers make informed opinions about the allocation of coffers and the development of transportation structure, and it can also support the growth of tourism and hospitality assiduity. In the PUV Modernization Program environment, accurate vaticinations of trip demand can be used to develop original public transport routes that are effective, accessible, and safe for passengers.

- Review of Related Studies

- Travel Demand Forecasting

Analysis and forecasting of travel demand form the foundation of the field of transportation. The subject is still receiving much interest in both academic study and practical transportation planning. Hundreds of travel behavior studies are published annually in journals and conference proceedings, and model application results are frequently utilized to support transportation policy choices (Rasouli & Timmermans, 2012). To evaluate the data gathered, according to Agrawal et al. (2017), the classic four-step travel demand forecasting model has been used for years to assist policymakers in deciding on transportation projects and programs for urban areas. This conventional model makes time-dependent predictions about the traffic volume in each mode of transportation between the traffic analysis zones (TAZs).

Additionally, the four-step paradigm moves forward from trip production to trip distribution to mode selection to route assignment. The number of trips created (produced or attracted) in each traffic analysis Zone is shown by trip generation (TAZ). By considering the geographical distribution of products and attractions and the impedance (time or cost) of connections, trip distribution reveals the destinations of trips by matching trip producers to trip attractions. By factoring trip tables to represent the relative shares of various modes, mode choice reveals the transportation mode utilized for these trips. By allocating travel to networks unique to each mode, route assignment reveals the routes that are followed (Park et al., 2019).

- Traffic Analysis Zones

Traffic Analysis Zones (TAZ) are geographic units used in transportation planning to divide an area into smaller segments to analyze transportation patterns, forecast traffic demand, and assess the impact of new developments on traffic flow.

In "A Framework for Traffic Analysis Zone Design" (Hernandez & Horner, 2007), the authors present a framework for designing TAZs considering land use, road network, and population density. The framework was tested in a case study in Austin, Texas, and the results showed that the proposed TAZs effectively predicted traffic patterns. The study of Rios and Knaap (2012) found that using block groups was an effective way to capture local variations in land use and demographics and that the resulting TAZs were useful for transportation planning. A comparative study by Golias and Karlaftis (2002) suggests that the most effective method depends on the specific characteristics of the study area. The study also suggests that combining different methods may be the best approach.

Traffic Analysis Zones are an essential tool in transportation planning, allowing planners to analyze traffic patterns, forecast demand, and assess the impact of new developments on traffic flow. The research reviewed here suggests that TAZ design should

consider factors such as land use, road network, and population density and that different delineation methods may be most effective depending on the characteristics of the study area. Additionally, incorporating spatial dependencies between adjacent zones may improve the accuracy of traffic flow predictions.

- Trip Generation

As per the paper of Chang et al., 2014, the trip generation estimation technique uses mathematical models that link each purpose to TAZ demographics such as population, households, employment, car ownership, and income. Household surveys or census reports can provide up-to-date information on these factors. Projections, on the other hand, provide future knowledge. Also, according to the review of Weinberger et al., 2015, Several studies have been conducted to investigate the influence of the built environment on trip creation and other travel behavior. This analysis's primary indicators for travel behavior are density, land use, and population. The use mix, the cost and availability of parking, and the quality of non-automobile modes are all factors to consider. Researchers find Correlations in consistent directions, although to varying degrees for various variables. Travel

Vehicle miles traveled (VMT) or vehicle miles traveled (VMT) are used to quantify behavior. The ARIMA approach is used to predict trip creation, whereas the Fratar method is used to assess trip distribution.

When predicting future trip distribution based on the current Detroit technique, the average factor method, and both the Fratar technique are equally precise carries out an adequate number of subsequent iterations. In every case evaluated, the Fratar technique's second approximation had the highest accuracy, while the other two approaches frequently required two or more guesses. The test's outcomes highlighted that the vast majority of journeys within a city comprise a very large number of Zone-to-Zone, low-volume transmissions where the zones are sized normally motions. In converting small-volume movements into associated volumes with ramps, streets, and expressways, statistical models should produce results with adequate accuracy, but this will need to be proven by additional research.

Each technique, except for the Fratar method, obtains the same minimum error in the second approximation, although the other ways typically need more iterations.

- Trip Distribution

Trip distribution is the first step in the 4-step classic travel demand forecasting. This is a critical step in transportation planning to allocate trips generated in one location to their respective destinations. A review by Kiarash Motamedi and Abdullah Al-Ghamdi (2015) about the trip distribution models in urban transportation planning provided an overview of the different types of trip distribution models, including gravity models, entropy maximization models, and spatial interaction models. A paper by Qing He et al. (2019) presented a Bayesian approach to jointly modeling trip generation and distribution. The Bayesian method implies that probability can be ascribed to neither repeatable nor random phenomena. The model is applied to a case study in Beijing, China, and results show that the Bayesian model outperforms traditional models in terms of accuracy and prediction.

To summarize, trip distribution has been an area of research in transportation planning for several decades, and many different modeling methodologies have been developed. The literature suggests that models that account for socioeconomic characteristics, land use, and spatial interaction perform better than traditional gravity models. Additionally, recent research has explored using Bayesian methods for trip distribution modeling.

- Modal Split

According to Loganayagan and Umadevi (2014), Modal split is used to describe the proportionate allocation of the total number of passenger trips among different modes of transportation. Separating trips by mode of transport is what it is all about.

Based on the paper of Sierpiński (2013) presented that the modal split is the outcome of the decisions made by travelers. As a result, the subjective preferences of individuals provide a picture of how traffic is divided into modes of transportation for a certain location. According to this strategy, the modal divide can be seen as an evaluation of national, regional, or local

efforts that alter transportation policy in favor of pro-ecological mobility options. Some communities use innovative approaches to reduce the number of passenger cars in their downtown areas. Still, too many cities exclusively choose certain locations to implement such solutions. Lack of a thorough strategy leads to poor or nonexistent improvement in the situation.

According to Rambonilaza, and Elodie Brahic (2016), in multinomial logit models applied to the results of the choice experiment; all participants should apply the same heuristics based on readily discernible characteristics of the forest landscape to indicate their use and nonuse values of the environment. A set of entirely unimodular constraints must be met while discovering an assortment that maximizes predicted income per customer.

- Traffic Assignment

A review of Andrea Raith et. Al, 2014, An essential element of transport planning models is traffic assignment. In terms of route selection, it simulates travel behavior. This is necessary to effectively predict travel demand and, more crucially, to make it possible to accurately estimate the advantages of alterations to transportation policy and infrastructure improvements. Additionally, a paper of Bliemer et al., 2017, the primary goal of a traffic assignment process is to simulate the movement patterns of vehicles using predetermined behavioral rules. The process's outputs are then fed into emission model inputs. Traffic assignment models are divided into three groups based on the consideration of the temporal dimension: dynamic traffic assignment (DTA), semi-dynamic traffic assignment, and static traffic assignment (STA) models.

- Person Trip Surveys

A person trip survey is a widely used technique to collect data on individuals' travel behavior. Ram M. Pendyala and Konstadinos G. Goulias (2011) reviewed the role of travel surveys in transportation planning, including person trip surveys. The authors discussed the importance of data quality, survey design, and data analysis in the success of travel surveys. Jonathan Levine et al. (2007) compared in-person, telephone, and web-based survey methods for urban public transit planning. The authors found that web-based surveys are more cost-effective and reach a broader audience but may suffer from self-selection bias.

In summary, survey design, data quality, and data analysis are critical to the success of person trip surveys. New technologies, such as smartphones and GPS devices, offer opportunities for innovative data collection methods. Additionally, response rates can be improved through incentives, follow-up with non-participants, and minimizing survey length.

- Public Utility Vehicle Modernization Program (PUVMP)

Poor maintenance procedures, tampering with engine systems, subpar vehicle design and manufacturing techniques, and negligent driving habits are other causes of the air pollution brought on by PUJs. (Blacksmith Institute and Clean Air Asia, 2016). Therefore, Public Utility Vehicle Modernization Program was introduced. As stated in the study of Pontawe and Napalang (2018), the significant amount of air pollution, particularly that from mobile sources, is intended to be eliminated with the recent launch of the DOTr PUV Modernization Program through Department Order 2017- 011 or the Omnibus Franchising Guidelines and the impending release of several Memorandum Circulars by the LTFRB. In order to increase service levels, PUVMP strives to modernize public fleets, strengthen franchise issuing processes, reform the planning and rationalization of public transportation routes, and encourage industry consolidation and professionalization. In order to bring about a significant shift in the nation, the Department of Transportation intends to maintain the high standards and environmental viability of public vehicles and their operations. With that stated, all public utility operators are obligated to use their new cars in line with the Euro I emissions requirements and Philippine National Standards, and public vehicles older than fifteen years of age will be phased out (Malasique et al., 2022). The PUV Modernization Program, which the government unveiled in June 2017, is a very ambitious initiative that aims to transform the transportation industry into one that is contemporary, well-managed, and ecologically friendly. It has ten parts: regulatory reform, local public transport route planning, route rationalization, fleet modernization,

industry consolidation, financing, pilot implementation, stakeholder support mechanism, and communication (Sunio et al., 2019). PUV Modernization program intends to enhance the public transportation network by substituting modernized, eco- friendly PUVs for older, potentially dangerous ones. Although the program has many advantages, including increased safety, decreased pollution, and increased effectiveness, it also needs help with affordability, displacement, and operation. Efforts are being undertaken to overcome these issues and guarantee the program's successful implementation to benefit commuters, operators, and the environment.

- Background of the Study

In the PUV Modernization Program context, travel demand forecasting may also highlight the role of forecasting in developing local public transport routes. The PUV Modernization Program aims to improve the quality and efficiency of public transport in the Philippines, and accurate forecasts of travel demand can help transportation planners identify areas where new routes may be needed or where existing routes can be improved.

Additionally, travel demand forecasting under the PUV Modernization Program may include information about the area's unique characteristics that may impact travel demand. For example, Apalit may be a popular destination for tourists due to its proximity to the capital city of Manila or its rich cultural heritage. Understanding these factors can help researchers develop more accurate forecasts of travel demand in the area.

Furthermore, travel demand forecasting may include information about previous research on the topic. This can help researchers build on the work of others and gain a better understanding of the challenges and opportunities associated with forecasting travel demand in the area. By considering the existing body of research on the topic, researchers can identify gaps in knowledge and develop new methods and approaches for forecasting travel demand.

- Study Area

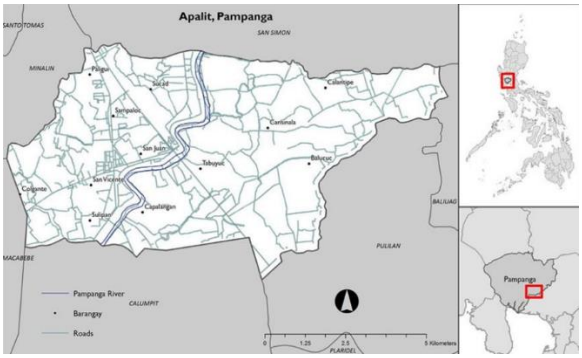


Figure 1. Map of Apalit

The study was conducted in Pampanga, particularly in the municipality of Apalit. It is composed of 12 barangays, namely Balucuc, Calantipe, Cansinala, Capalangan, Colgante, Paligui, Sampaloc, San Juan, San Vicente, Sucad, Sulipan, and Tabuyuc (PSA, 2020). Being classified as a first-class municipality by the Department of Trade in Industry, Apalit rank first in the presence of an investment promotion unit in the 2021 Ranking indicators conducted by DTI. With the growing economy and population, the road network of Apalit has been left astray, ranking 456th at the Road Network 2021 Ranking indicators conducted by DTI.

Apalit, Pampanga, is an interesting case for studying travel demand forecasting. Also, as per the LGU of Apalit, there has yet to be a drafted Local Public Transport Route Plan in the municipality. LPTRP is a requirement of the LTFRB under the PUVMP for issuing a new public transport franchise.

- Specific Objectives

specific goals are set to achieve the overall goal:

1. To provide and collect quantifiable information about the residents' sociodemographic profile, trip information, and characteristics.
2. To produce an Origin-Destination matrix for horizon year 2023 for trip generation through the Person Trip Survey.
3. To distribute and forecast the person trip travel demand for the year 2043 using Fratar Method.

- Statement of the Problem

With the growing concern about traffic congestion due

to the modernization and growing population of the present generation. The study aimed to seek answers to the following questions:

1. What are the current demographics and travel behavior of commuters in the Apalit, Pampanga
2. How can travel demand be forecasted in Apalit, Pampanga?
3. How can the forecasted travel demand be used to inform the development of local public transport routes plan?
4. Does the current transportation system in the study area be sufficient after 20 years?

- Significance of the Study

This study would be helpful to the citizens of Apalit, Pampanga, by forecasting the right public transport in the area. In addition, this study would be a benefit to the following:

- For the Locale. This study can help the community be aware of the Local Public Transport Route Plan of Apalit, Pampanga. It can improve community mobility, and it may improve public transport in the area.

- For the Local Government Unit. The output of this study contributes to future transportation planning in the local government unit, allowing transportation authorities to assess public transport.

- For the Economic Impact. The output of this study might contribute to the economic growth of the municipality of Apalit by providing connections to the administrative centers and transportation hubs in the municipality.

- For the Future Researchers. This study could be used as a resource and guide for researchers in the future who conduct comparable, if not identical, research. The study will also be improved and expanded to give new related literature sources.

- Scope and Limitations

The exclusive focus of the researchers was on producing a study that served as the foundation for the local government's provision of a route plan for PUVs that would reduce traffic congestion and enable efficient, practical, and secure access and mobility throughout the municipality's proximity.

The scope of this research project on Travel Demand Forecasting in Apalit, Pampanga, was to predict daily travel demand for different modes. The study focused on the municipality of Apalit, located approximately 30 kilometers north of Manila and has a population of 117,160 people. The research was conducted within the context of the PUV Modernization Program, a government initiative to improve public transport services in the Philippines.

The limitations of this research project included the availability of data and the potential challenges of forecasting future travel demand. The research was based on some primary and secondary data sources, such as census data, transportation statistics, and the length and volume capacity of the road, which may need to be improved in terms of reliability and completeness. In addition, the forecasting model's accuracy depended on the quality and availability of data, as well as the assumptions and limitations of the forecasting method used.

- Conceptual Framework

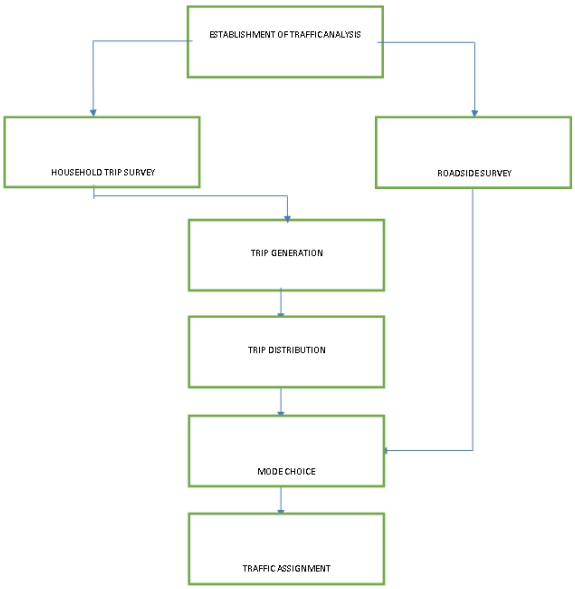


Figure 2. Four-step modeling process

The figure above illustrates the framework for the study. The study was started by collecting

demographic and geographic data used as the basis for formulating the Traffic Analysis Zones. After the TAZs had been identified, the household information and person trip surveys were conducted through the house-to-house survey. The results of these surveys were able to create an Origin-Destination matrix. Roadside interviews were also conducted in different areas in the Apalit, for the data was used to model the modal split. After the modal split, the traffic assignment is generated using the all-or-nothing method.

II. METHOD

- Methodological Framework

Roads are pathways to a brighter economy and with this study the researchers aimed to forecast the travel demand along Apalit, Pampanga with the use of the classic 4 step travel demand model.

- Research Design

The study used the four-step modeling process, an inductive process in which the researchers collected data from the PSA and other Local government units. The study is a quantitative approach that would identify the basis of the local public transportation route plan under the PUV modernization program.

This approach was utilized by data gathering, which would be taken from the LGU or other Local Government units to gather the variable needed for the study to determine the local public transportation route plan. Surveys were conducted with municipality residents to gather information about their travel patterns and preferences for more accurate travel demand forecasts in Apalit, Pampanga.

The data that were collected were analyzed using a combination of statistical and modeling techniques. Statistical analysis was used to identify trends and patterns in the data, while modeling techniques were used to develop forecasts of future travel demand. The results of the analysis were used to develop recommendations for the allocation of resources and the development of transportation infrastructure in the area.

- Research Locale & Respondent Sampling

The study was conducted in the Municipality of Apalit where the target population are Local Commuters from the Municipality.

According to the census gathered by the Local Government Unit of Apalit (2020), the municipality is divided into 12 barangays: Balucuc, Calantipe, Cansinala, Capalangan, Colgante, Paligui, Sampaloc, San Juan, San Vicente, Sucad, Sulipan, and Tabuyuc. Balucuc consists of10, 897 citizens, Calantipe consists of 3,998 citizens, Canisnala consists of 7,856 citizens, Capalangan consists of 7,394 citizens, Colgante consists of 78,307 citizens, Paligui consists of 3,925 citizens, Sampaloc consists of 13,408 citizens, San Juan consists of 8,861 citizens, San Vicente consists of 23,686 citizens, Sucad consists of 7,775 citizens, Sulipan consists of 11,693 citizens and lastly Tabuyuc consists of 9,390 citizens (PhilAtlas, 2022). A total of 117,160 citizens live in the municipality of Apalit (2020).

The population in different areas was forecasted using linear regression analysis for 2023 and 2043. The study area was divided into four traffic analysis zones with the basis of land use as the main consideration due to the need for more available information about the other attributes of the locals.

For this study, purposive sampling was used for its non-probabilistic nature, and due to the difficulties in conducting the survey, 1 percent of the total households in the study area was used. Hence, the total household surveyed was 273 households.

- Research Instrument

FORM 1 HOUSEHOLD INFORMATION (IMPORMASYON NG TAHANAN)

INSTRUCTION (DIREKSYON) : To be completed by HEAD of HOUSEHOLD (Nararapat sagutan ng PUNONG MAY BAHAY ng TAHANAN)

NAME (PANGALAN): _____

Family Name (Apelydo), First Name (Unang Pangalan), M.I

ADDRESS OF HOUSEHOLD (TIRAHAN): _____ _____

No. (Kodigong Postal) Street (Lansangan)

_____ _____

Barangay City/ Municipality (Lungsod/ Munisipalidad)

HOW MANY PEOPLE RESIDE IN YOUR HOUSEHOLD (ILANG TAO ANG NAKATIRA SA IYONG TAHANAN):

	Under 7 YRS. OLD (7 GULANG PABABA)	7 YRS. OLD AND ABOVE (7 GULANG AT PATAAS)	HOUSEHOLD HELPERS (MGA KATULONG SA TIRAHAN)
MALE (LALAKE)			
FAMALE (BABAE)			
TOTAL			

WHAT IS THE TOTAL MONTHLY HOUSEHOLD INCOME (ANO ANG KABUWANG KITA NG TAHANAN); CHECK ONE (MAGMARKA NG ISA)	HOW MANY VEHICLES ARE OWNED BY HOUSEHOLD MEMBERS (ILANG BEHIKULO MAYROON ANG BAWAT MGA MIYEMBRO NG TAHAN)	HOW MANY VEHICLES WERE GARAGED AT OR NEAR YOUR HOUSE BY HOUSEHOLD MEMBERS (ILANG BEHIKULO ANG NAKAGARAHE SA INYO O MALAPIT SAINYONG TAHAN NA PAGMAMAY ARI NG MGA MIYEMBRO NG TAHAN)
BELOW ₱ 500 ☐ 501 to 1000 ☐ 1001 to 1500 ☐ 1501 to 2000 ☐ 2001 to 2500 ☐ 2501 to 3000 ☐ 3001 to 3500 ☐ 3501 to 4000 ☐ 4001 to 5000 ☐ 5001 to 7000 ☐ OVER ₱ 7000 ☐	TYPE NO. OF UNITS BICYCLE MOTORCYCLE JEEPNEY JEEP CAR VAN/PICK – UP TRUCK TRICYCLE OTHER SPECIFY NONE (check) ☐	TYPE NO. OF UNITS BICYCLE MOTORCYCLE JEEPNEY JEEP CAR VAN/PICK – UP TRUCK TRICYCLE OTHER SPECIFY NONE (check) ☐

FORM 2 HOUSEHOLD MEMBER INFORMATION (IMPORMASYON NG MEYMBRO NG TAHANAN)

INSTRUCTION (DIREKSYON) : To be completed for every HOUSEHOLD MEMBER aged 7 and over (Nararapat sagutan ng bawat MEMYBRO NG TAHANAN na mula 7 gulang pastas)

NAME (PANGALAN): _____

Family Name (Apelydo), First Name (Unang Pangalan), M.I

AGE (GULANG): _____ SEX (KASARIAN) MALE ☐ FEMALE ☐

WORK ADDRESS (PUNONG TANGAPAN): _____

No. (Kodigong Postal), Street (Lansangan) , Barangay

_____

City/ Municipality (Lungsod/ Munisipalidad)

SCHOOL ADDRESS (PAARALAN): _____

No. (Kodigong Postal), Street (Lansangan) , Barangay

_____

City/ Municipality (Lungsod/ Munisipalidad)

OCCUPATION (URI NG TRABAHO)	EMPLOYMENT SECTOR (SECTOR NG TRABAHO)	MONTHLY INCOME (BUWANANG SAHOD)	STATE TYPE OF DIVERS LICENSE HELD (URI NG DRIVERS LICESE NA MAY ROON)
___ SERVICE WORKER	___ SERVICE INDUSTRY	___ BELOW 300	___ STUDENT
___ ADMINISTRATIVE & EXEC. WORKER	___ SCHOOL	___ 301 to 500	___ NON-PROF.
___ SALES WORKER	___ UNIVERSITY	___ 501 to 700	___ PROFFESIONAL
___ FACTORY WORKER CRAFTS MAN	___ GOVERNMENT	___ 701 to 900	___ NONE
___ TRANSPORTATION WORKER	___ AGRICUTURAL MINING	___ 901 to 1000	
___ STUDEN/ ELEMENTARY	___ MANUFACTURING	___ 1001 to 1500	
___ STUDENT/ HSCHOOL, & UNIV.	___ PUBLICUTILITY COMPANY	___ 1501 to 2000	
___ HOUSEWIFE	___ CONSTRUCTION	___ 2001 to 2500	
___ JOBLESS	___ TRANSPORTATION COMMUNICATIONS	___ 2501 to 3000	
___ OTHER, SPECIFY	___ HOME BASED	___ 3001 to 3500	
	___ COMMERCE	___ 3501 to 4000	
	___ OTHER, SPECIFY	___ 4001 to 5000	
		___ ABOVE 5000	

Please list all the places you visited on survey day (isulat ang lahat ng lugar na iyong pinuntahan sa araw ng kuwestionaryo):

1.	6.
2.	7.
3.	8.
4.	9.
5.	10.

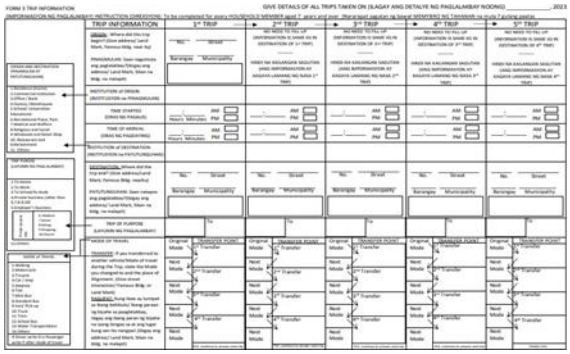


Figure 4. Sample Household Information Survey

This study adapted the three forms that were used in the study of JICA in the Philippines, which is the MUCEP. The forms were general enough and included almost all modes of transportation. The questionnaire was simple, direct, should take minimum time, and caused a minimum burden to the respondent. The traditional household survey has three major sections: household characteristics (Form 1), personal characteristics (Form 2), and trip details (Form 3).

- Household characteristics - This section includes a set of questions designed to obtain socioeconomic information about the household. Relevant questions include the number of members in the house, the number of employed people, the number of jobless people, the age and gender of the members in the house, the number of two-wheelers in the house, the number of cycles, the number of automobiles in the house, and so on.
- Personal characteristics - This section contains questions aimed to categorize household members (those over the age of 7) based on the following factors: relationship to the head of the home (e.g., wife, son), sex, age, possession of a driver's license, educational level, and activity.
- Trip data - This part of the survey aims at detecting and characterizing all trips made by the household members identified in the first part. A trip is typically described as any movement of more than 300 meters from one point to another with a specific purpose. Trips are classified according to factors such as origin and destination, trip purpose, trip start and end hours, mode of transportation used, walking distance, public-transport line, and transfer station or bus stop (if available).
- Roadside Interviews - These provide trips not registered in a household survey, especially external-internal trips. This entails asking a sample of drivers and passengers in vehicles passing through a certain location questions. Unlike a home survey, the respondent will be asked a few questions such as origin, destination, and purpose of trip. Other information such as age, gender, and income can also be included, however it should be remembered that at the roadside, drivers will not be willing to spend much time on the survey. The roadside interviews will be utilized for the calibration of the logit model

- Data Collection

Once the questionnaire is ready, the next step is to conduct the actual survey with the help of enumerators. Enumerators must be trained by briefing them about the survey details and how to conduct it. They were assigned to random households and given the questionnaire. They must first get permission to be surveyed from the household. They may select a typical working day for the survey and ask the household members about the details required in the questionnaire. They may take care that each household member should answer about their travel details, except for children under 12 years. Trip details of children under seven years are normally ignored. Because the survey might occur at any time, participants must answer a question regarding their trip details from the previous day. The method used in the study is the face-to-face method, which is the most convenient to gather data.

- Data Analysis and Evaluation

The raw data collected in the survey must be processed before direct application in the model. This is necessary because of various errors in the survey, both in the selection of sample houses and in filling out details.

The study area, Apalit, composed of 12 barangays, were divided into four zones based on land use and the distance of one barangay to another. The land use was classified based on the activity in each municipality. For example, if San Vicente, a barangay of Apalit, has commercial land use, its neighboring barangay Sulipan is also used for commerce. Both barangays would then be considered as a Zone.

- Data Correction - Several investigations have discovered a few critical mistakes that must be fixed, which are listed below:

i. *Household size correction* - it may be possible that while choosing the random samples, one may choose either larger or smaller than the average size of the population as observed in census data and should be corrected accordingly,

ii. *Socio-demographic corrections* – it is possible that there may be differences between the distribution of the variables sex, age, etc. between the survey, and the population as observed from the census statistics. This correction is done after the household size correction.

- Sample Expansion - The second step in the data preparation is to amplify the survey data to represent the total population of the zone. This is done with the help of the expansion factor which is defined as the ratio of the total number of households addressed in the population to that of the surveyed. A basic expansion factor Fi for the zone i could take the following form.

$$Fi = \frac{a}{b}$$

Where a is the total number of households in the original population list, b is the total number of addresses selected as the sample.

- Validation Of Results - Three validation tests are usually adopted to have confidence in the data collected from a sample population. The first considers the consistency of the data through a field visit normally done after the data entry stage. The second validation is performed by selecting a computational check of the variables. For example, if a person's age is shown with unrealistically high figures such as 150 years. The final step is a logical examination of the data's internal consistency. For example, a person under 18 is not eligible to obtain a driver's license. Once these corrections are done, the data is ready for modeling.

PHASE 1 TRIP GENERATION Trip Production Trip Attraction 2. TRIP DISTRIBUTION	
PHASE 2	MODE CHOICE TRIP ASSIGNMENT Route Assignment PUV Assignment

Figure 5. Four Stages Transportation/Land Use Model

I. Trip purpose

The activity at each end of the trip defines the purpose of the trip; traveling to work or shopping is two excellent examples of how this affects travel demand. It is divided into two categories: excursions that start and end at home and travels that do not. Home-based journeys are those in which the journey's starting and end points are the same, or, to put it another way. The journey is a return trip. Non-home-based trips are those in which the starting and end points differ. The outcome of everyone's collective decision on their daily activity, the time, location, mode of transportation, and route to take is what is known as the travel demand model. All of these are arbitrary decisions. Therefore, individuals are free to select from various tools and available options. All of these factors are immeasurable. Thus, the only thing we can do is

use the logit Model to assess trip patterns appropriately.

II. Vehicle Availability

The number of vehicles a household owns or has access to have a significant impact on the impact of travel demand, trip generation, trip distribution, and the mode of transportation of each member living in the household. Thus, the researchers utilized the Vehicle Availability Model to generate a more accurate travel demand.

1. TRIP GENERATION

Trip generation is done to calculate how many trips each zone has broken down by purpose. Home-based and non-home-based travel objectives are separated into two categories. The researchers will use Trip Production and Trip Attraction to estimate the number of trips. The figure 4 below illustrates how trip generation work by purpose.

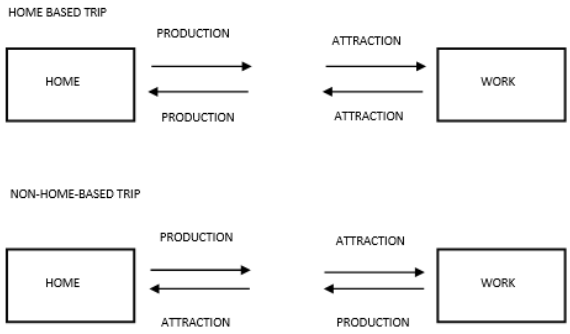


Figure 6. Trip Generation

1.1 Trip Production

The number of trips is estimated using records for each household. The standard procedure for trip production models is to produce tables of trip rates by two or more variables, such as household size and income. After separating the households according to the two criteria, an estimate of the trip rate for the two components taken together will be made.

1.2 Trip Attractions

Trip attractions are more challenging to quantify than trip production because they are typically based on local data or household surveys that do not include control totals for the locations of the attractions. The researchers will use a linear regression equation to estimate the parameter at a group level, such as group zones.

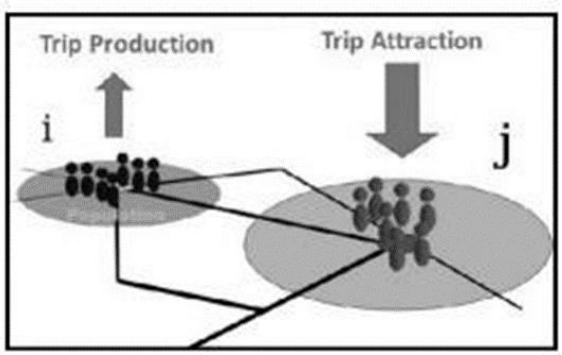


Figure 7. Trip Attraction

2. TRIP DISTRIBUTION

Figure 8. Trip Distribution

The second stage of the modeling process, addressing the number of trips generated during trip production, is known as trip distribution.

In the figure above is the trip generation model incorporates the trip generation outputs, such as the production and attraction by the trip purpose for each Zone and measurements of travel impedance between each pair of zones derived from the transportation networks. Researchers employed a gravity model to calculate the trip distribution.

- Fratar Method - assumes that the trips tij will increase in proportion to Ei and in proportion to Ej. Multiplication of the existing flow by two growth factors will result in the future trips originating in zone i being greater than the future forecasts and so a normalizing expression is introduced which is the sum of all the existing trips out of zone i multiplied by the by the growth factor at the destination end of the trip

$$t_{ij}^{'} = t_{ij} * \frac{G_i}{g_i} * \frac{A_j}{a_j} * \frac{\Sigma^k t_{ik}}{\Sigma^k (A_k / a_k) t_{ik}}$$

where t'_{ij} : future trip zone i to j
t_{ij} : present trip from zone i to j
G_i : future production of zone i
g_i : present production of zone i
A_j : future attraction of zone j
a_j : present attraction of zone j
k : total zones

- the procedure must be iterated by substituting t'_{ij} for t_{ij}, for $\Sigma_j t'_{ij}$ for g_i, $\Sigma_i t'_{ij}$ for a_j
- agreement between 1 to 5 percent is achieved by successive iterations

3. MODE CHOICE

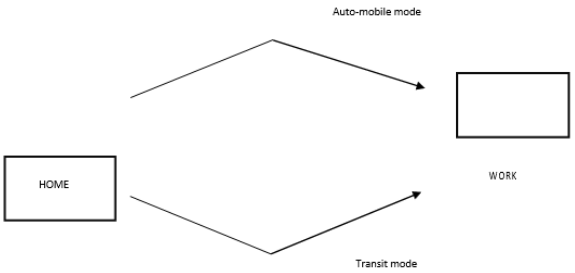


Figure 9. Mode Choice

In models where people by trips by all modes make up the unit of travel, mode selection is necessary. In this instance, the researchers must use mode choice as a component of their investigation. The trip distribution tables created in mode choice were divided into trips for each mode examined in the model. The figure above shows that the model choices were grouped into the automobile, public transportation, and non-motorized modes. Auto modes are categorized according to the automobile occupancy level, whereas transit modes are categorized as linked trips that comprise walking and driving from one point to another. The two non-motorized modes are classified as bicycles and walking. To begin analyzing the model, the researchers were first estimated the likelihood that each modal alternative were selected for each travel by the travelers. The probability depended on several explanatory variables, such as modal-level service characteristics, travel characteristics, and geographical elements of where the journey occurred.

4. TRIP ASSIGNMENT

Trip Assignment is classified into two parts. Route assignment and PUV assignment. The figure below illustrates how route assignment and PUV assignment will take place in this study.

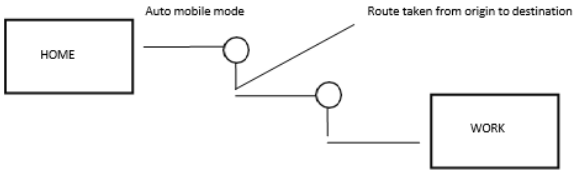


Figure 10. Trip Assignment

Route Assignment is the procedure used for every origin-to-destination interchange in vehicle travel. Identifying the paths via the network for each origin and destination will serve as the basis for the route allocation. If the assignment procedure is mode-specific, single-occupancy vehicles may be chosen based on different standards than multi-occupant vehicles and the like.

III. RESULTS AND DISCUSSIONS

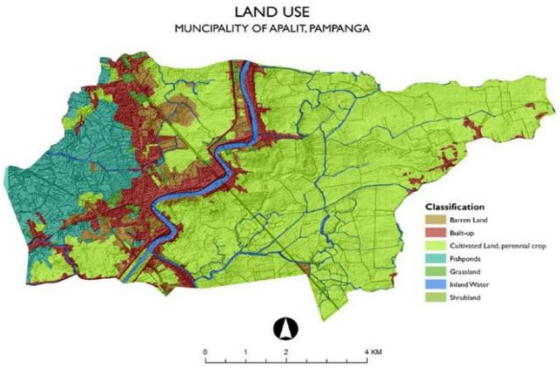


FIGURE 11. LAND USE IN APALIT PAMPANGA

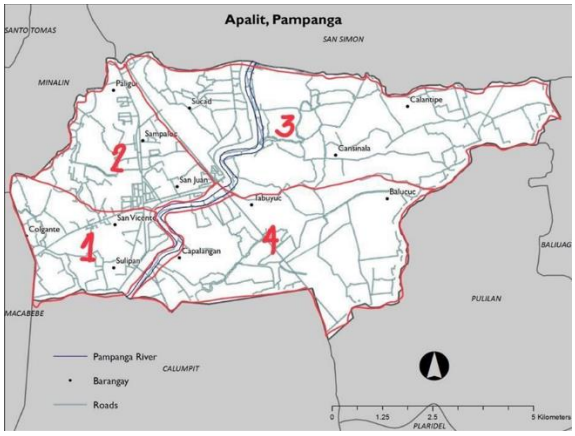


FIGURE 12. DIVISION OF ZONES IN APALIT PAMPANGA

Figure 12 shows the division of four zones in Apalit at the base of its land use in Figure 8. Zone 1 is composed of Colgante, San Vicente and Sulipan. Zone 2 is

composed of Sampaloc, San Juan and Paligui. Zone 3 comprises Sucad, Cansinala, and Cantilipe, and lastly, Zone 4 comprises Capalangan, Tabuyuc, and Balucuc. Three factors have decided the separation of the Zone. The Pampanga River is located in the middle of Apalit, which the researchers considered as a screen line, the distance of each barangay to one another, and lastly, the land use of each barangay. These three factors determined which barangay ended up in which Zone. For instance, Zone 1, composed of Colgante, San Vicente, and Sulipan, has similar land use. San Vicente and Sulipan are used as commercial land where various businesses are established within this area of Apalit. Although Colgante is an agricultural land rather than a land of commerce, it still ends up being in Zone 1 because it is closer to San Vicente and Sulipan than the next barangay, Sampaloc. Zone 2 also has a similar case to Zone 1 in which Sampaloc and San Juan are used as Institutional land where the municipality, hospital, and school are mainly located, and similar to Colgante, Paligui is also used as agricultural land. However, since the distance of Paligui is closer to the Sampaloc than other barangay, it became part of Zone 2. Sucad, Cansinala, and Cantilipe, which are located in Zone 3, are considered residential land. Lastly, it leaves us with Zone 4, Balucuc, Capalangan, and Tabuyuc used in the agricultural sector.

Table 1. Household Size of Pampanga

MUNICIPALITY	HOUSE HOLD	POPULATION	HOUSEHOLD SIZE
Apalit	27,391	117,160	4.27731
Arayat	32,005	144,875	4.52663
Bacolor	11,679	48,066	4.11559
Candaba	27,052	119,497	4.41730
Floridablanca	30,994	135,542	4.37316
Guagua	29,853	128,893	4.31758
Lubao	40,593	173,502	4.27418
Mabalacat City	74,707	293,244	3.92525
Macabebe	17,956	78,151	4.35236
Magalang	28,072	124,188	4.42391
Masantol	13,465	57,990	4.30672
Mexico	40,498	173,403	4.28176
Minalin	11,180	48,380	4.32737
Porac	33,367	140,751	4.21826
City of San Fernando (Capital)	86,217	354,666	4.11364
San Luis	12,836	58,551	4.56146
San Simon	13,635	59,182	4.34044
Santa Ana	13,567	61,537	4.53578
Santa Rita	11,433	48,209	4.21665
Santo Tomas	11,218	42,846	3.81940
Sasmuan	6,202	29,076	4.68817
HOUSEHOLD SIZE OF PAMPANGA			4.30538

Table 1 shows Pampanga's population, corresponding to the number of households per municipality. The average household size in Pampanga is 4.30538. The average household size is tabulated using the data that is gathered from the household survey and population surveyed. The municipality of Apalit, which is part of Pampanga, has a household size of 4.27731 which is only less than 0.03102 than the household size of Pampanga. This shows that Pampanga is 3.1% large in population and household ratio.

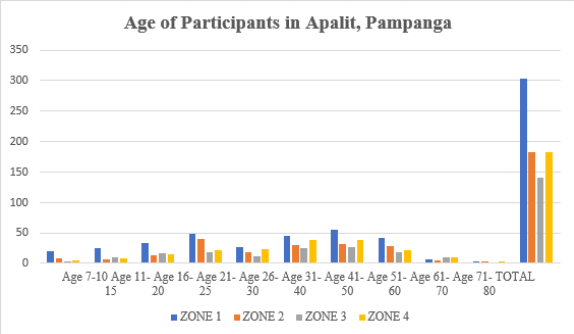
Table 2. Surveyed Household Size of Apalit, Pampanga

JRVEY IN APALIT	IOUSE HOLD SURVEYED	OPULATION SURVEYED	HOUSEHOLD SIZE
ZONE 1	101	467	4.623762
ZONE 2	61	297	4.868852
ZONE 3	47	241	5.127659
ZONE 4	63	291	4.619047
	HOUSEHOLD SIZE OF SURVEY IN APALIT		4.809830

Table 2 shows the population of participants in Apalit corresponding to the number of households per Zone. The average household size of the participants in Apalit is 4.809830. The average household size is tabulated using the data gathered from the household survey and the population surveyed. The result from tabulating the household size was the outcome of the purposive convince sampling that the researchers used during the on-site study.

Table 3. Age of the Participants in Apalit, Pampanga

AGE	ZONE 1	ZONE 2	ZONE 3	ZONE 4
7-10	20	8	3	5
11-15	25	7	10	8
16-20	33	13	17	14
21-25	48	39	19	21
26-30	26	19	12	23
31-40	45	30	24	38
41-50	55	31	26	38
51-60	42	28	19	22
61-70	6	5	10	10
71-80	3	3	1	3
4TOTAL	303	183	141	182



Graph 1. Age of the Participants in Apalit, Pampanga

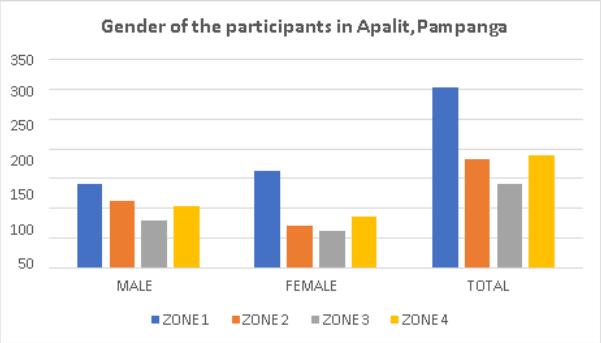
Table 3 shows the surveyed age in Apalit, Pampanga. The outcome of these results is caused by many factors, such as the occupation of each residence in those households, the availability of the participants at the time of conducting the survey, and the location of the survey. The leading age group in each Zone is the following in Zone 1, aged 41-50 of 55 who go to the market. Next is the age 21-25 of 48; most of these are students who go to university. Those aged 31-40 of 45 go to work. Zone 2 age 21-25 of 39 some are employees that attend their work, but most are university students. The next group includes those between the ages 41-50 of 31 who perform daily tasks like work and market shopping.

Last, those between the ages 31-40 of 30 who are all employed and attending their employment. In Zone 3, ages 41-50 of 26 are employees who attend their jobs, and few go to market. Ages 31-40 of 24 follow the first Zone. These are workers who must be present at their

work. Finally, those ages 21-25 and 51-60 of 19 are generally understudies who go to college and home-based workers who only go to the market for shopping. Lastly, in Zone 4, ages 31-40 and 41-50 of 38 are workers attending their jobs. Next is the ages 26-30 of 22 who also go to their work. To end, ages 51-60 of 22 are mostly home-based workers who only do their leisure like shopping, etc.

Table 4. Gender of the participants in Apalit, Pampanga

GENDER	ZONE 1	ZONE 2	ZONE 3	ZONE 4
MALE	140	112	79	104
FEMALE	163	71	62	85
TOTAL	303	183	141	189



Graph 2. Gender of the Participants in Apalit, Pampanga

Table 4 shows the surveyed gender in Apalit, Pampanga in where Zone 1 consists of 140 male, and 163 female, Zone 2 consists of 112 male and 163 female, Zone 3 consists of 79 male and 62 female and lastly zone 4 consists of 104 male and 85 female.

The outcome of these gender results is caused by many factors, such as the occupation of each residence in those households, the availability of the participants at the time of the survey, and the location where the survey is being conducted. For instance, since Zone 1 is mainly used for commercial land, most of the residents that the researchers surveyed are housewives or have home-based jobs, resulting in females having a greater than result in the male. On the other hand, Zone 2 is an intuitional land use. Therefore, the majority of the occupation that the research has surveyed are the male husband with a job with exceedingly flexible time, such as tricycle drivers in, where they can have lunch in their own homes. Meanwhile, Zone 3 and 4 have been conducted during the holy week and weekends. Because of this, the majority of the household member is present. However, most male participants are more likely to agree to take our survey than female participants because of various reasons such as household chores.

Table 5. Average Number of Trips of the Participants base on Gender

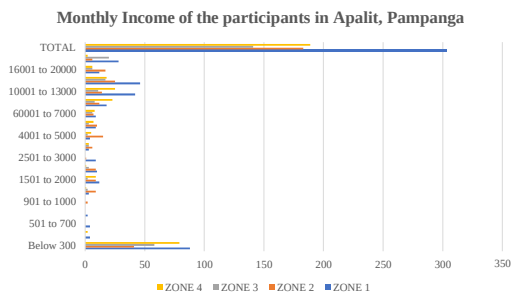
GENDER	TRIP 1	TRIP 2	TRIP 3	TRIP 4	AVERAGE TRIP
MALE	435	435	14	11	2.06
FEMALE	381	381	2	1	2.01

Table 5 shows that the average number of trips for males is 2.06, while the average number for female participants is 2.01. The outcome of the table shows that male participants tend to travel more than female respondents due to their work location. Meanwhile, the majority of female participants are mainly made up of housewives or has home-based job making the majority of their trip purpose to go shopping. Since the location of commerce is located in the center, which is San Vicente, it only takes one trip to all other barangay to get there.

Table 6. Monthly Income of the Participants in Apalit, Pampanga

MONTHLY INCOME	ONE 1	ONE 2	ONE 3	ONE 4
Below P 300.00	88	41	58	79
301 to 500	4	0	0	2
501 to 700	4	0	0	0
701 to 900	2	0	0	0
901 to 1000	0	2	0	0
1001 to 1500	3	9	2	1
1501 to 2000	12	9	2	9
2001 to 2500	10	9	3	1
2501 to 3000	9	1	0	0
3001 to 4000	3	6	3	3
4001 to 5000	4	15	2	5
5001 to 6000	9	10	3	7
6001 to 7000	9	7	6	8
8001 to 10000	18	12	8	23
10001 to 13000	42	14	11	25

13001 to 16000	46	25	17	18
16001 to 20000	12	17	6	6
above P20000.00	28	6	20	2
TOTAL	303	183	141	189

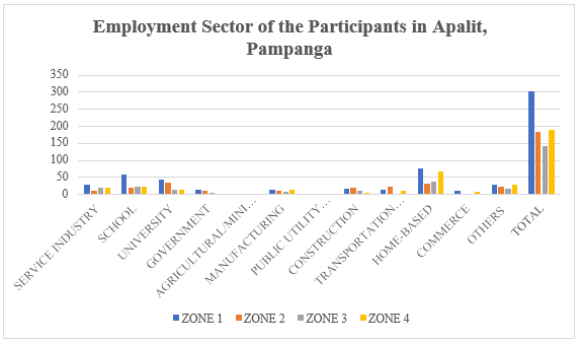


Graph 3. Monthly Income of the Participants in Apalit, Pampanga

Table 6 shows the surveyed monthly income in Apalit, Pampanga, where the number of participants in all zones is mainly children, students, and housewives. Therefore, their monthly income is below 300. The second highest monthly income for Zone 1, Zone 2, is from 13001 to 16000 per month. Zone 3 second highest monthly income is between 20000 and above, and lastly, as for Zone 4, the second highest monthly income is 10,001 to 13,000. The result of the second-highest monthly income varies depending on the participants' salaries with respect to their job and the employment sector, as you can see in Table 7 below.

Table 7. Employment Sector of the Participants in Apalit, Pampanga

EMPLOYMENT SECTOR	ZONE 1	ZONE 2	ZONE 3	ZONE 4
SERVICE INDUSTRY	28	9	20	20
SCHOOL	58	21	24	23
UNIVERSITY	43	33	13	12
GOVERNMENT	13	10	4	2
AGRICULTURAL/MINING	1	1	0	1
MANUFACTURING	14	10	9	12
PUBLIC UTILITY COMPANY	2	1	0	1
CONSTRUCTION	17	19	12	5
TRANSPORTATION COMMUNICATIONS	14	22	3	11
HOME-BASED	76	30	39	67
COMMERCE	10	3	1	6
OTHERS	27	24	16	29
TOTAL	303	183	141	189

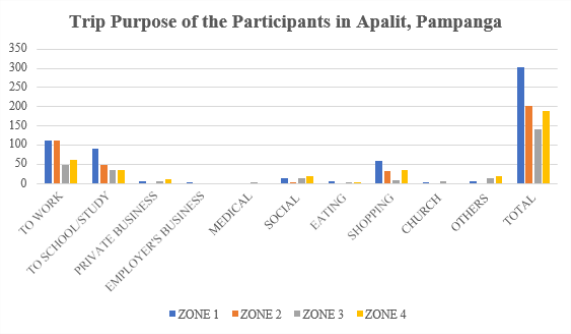


Graph 4. Employment Sector of the Participants in Apalit, Pampanga

Table 7 shows the Employment Sector of the Participants in Apalit, Pampanga. The result shows that the majority of the participants in all zones are home-based. The following results are based on the characteristics of the participants that are either housewives or have a home base job. Schools and universities are the second and third highest employment sectors in all zones. This shows that most of the participants are students. The outcome of these employment results is caused by the availability of the participants at the time of conducting the survey and the location of the survey.

Table 8. Trip Purpose of the Participants in Apalit, Pampanga

TRIP PURPOSE	ZONE 1	ZONE 2	ZONE 3	ZONE 4
TO WORK	111	113	49	62
TO SCHOOL/STUDY	91	49	35	35
PRIVATE BUSINESS	6	2	5	12
EMPLOYER'S BUSINESS	3	0	0	0
MEDICAL	2	0	4	1
SOCIAL	15	4	14	20
EATING	7	0	4	3
SHOPPING	59	33	9	36
CHURCH	4	0	6	0
OTHERS	5	2	15	20
TOTAL	303	203	141	189



Graph 5. Trip Purpose of the Participants in Apalit, Pampanga

Table 8 shows the Employment Sector of the Participants in Apalit, Pampanga. The result shows that most zones have a trip purpose of working. The following result is based on the characteristics of the participants, which are employees and workers. The second majority trip purpose of all Zone is to school or study. The following result is based on the characteristics of the participants, which are students from schools or universities. Lastly, the third majority trip purpose of all zones is to shop. The following result is based on the participants' characteristics, which are either housewife.

Table 9. Surveyed Trip Distribution of Each Zones

	Zone 1	Zone 2	Zone 3	Zone 4
Zone 1	171	58	2	1
	171	4	0	0
	0	0	0	48
	0	0	0	1
Zone 2	58	0	0	0
	76	43	5	8
	0	43	0	12
	0	0	0	0
Zone 3	2	5	0	0
	27	23	33	5
	1	23	1	0
	0	0	32	5
Zone 4	1	8	5	0
	49	12	5	70
	0	0	0	70
	0	0	0	0

Table 9 shows the tabulated result of trip distribution between the zones. The result shows that the participants often travel to Zone 1 and Zone 2, mainly because of their land use and the population density in those zones.

Table 10. Surveyed Trip Attraction and Trip Generation of Each Zones

O\D	Zone 1	Zone 2	Zone 3	Zone 4	Trip Generation/Production
Zone 1	342	62	2	50	456
Zone 2	134	86	5	20	245
Zone 3	30	51	66	10	157
Zone 4	50	20	10	140	220
Trip Attraction	556	219	83	220	

Total Present Trip Generation: 1078
Total Present Trip Attraction: 1078

Table 10 shows the surveyed trip generation and trip attraction from all the zones in the year 2023. By summing up the trip distribution between the zones in Table 9, the researchers generated total trip attraction and distribution in Apalit, Pampanga, which is 1078, and just like Table 9, the highest generated trip distribution and trip attraction is Zone 1, followed by Zone 2 and Zone 4 the result shows that the participants often go to Zone 1 and Zone 2 because of commercial and public land meanwhile the result is also being affected by the number of populations in that certain area.

Table 11. Surveyed Total number of members between household

	>7	TOTAL NO. OF MEMBERS IN HOUSEHOLD
COLGANTE	82	82
SAN VICENTE	241	264
SULIPAN	113	121
PALIGUI	41	43
SAMPALOC	140	147
SAN JUAN	95	107
CALANTIPE	36	45
CANSINALA	89	98
SUCAD	92	98
BALUCUC	115	115
CAPALANGA N	69	74
TABUYUC	98	102
TOTAL	1211	1296

Table 12. Surveyed Ratio between Total number of members between household and total number of members in a household above 7 years old.

TOAL NUMBER OF MEMBERS >7	1211
TOTAL NO. OF MEMBERS IN HOUSEHOLD	1296
ERS>7 AND TOTAL NO. OF MEMBERS	0.93441

TABLE 13. Expansion Factor of Population

	SPONDENTS FOR EACH BARANGAY			OTA L	EXPANSION FACTOR
ZONE 1	165	81	57	303	140.3126
ZONE 2	27	90	44	161	161.0377
ZONE 3	18	57	57	132	148.1394
ZONE 4	75	48	66	189	90.60811

Table 13 shows the expansion factor of the surveyed population in each barangay. The expansion factor is used to get the trip distribution in 20 years. To get the expansion factor, the researchers get the ratio of surveyed population over the total population in 2023 and multiply it by the ratio of surveyed number of participants above seven years old and surveyed total household members.

Table 14. Present Trip Distribution of Each Zone

	Zone 1	Zone 2	Zone 3	Zone 4
Zone 1	23994	8139	281	141
	23994	562	0	0
	0	0	0	6736
	0	0	0	141
Zone 2	9341	0	0	0
	12239	6925	806	1289
	0	6925	0	1933
	0	0	0	0
Zone 3	297	741	0	0
	4000	3408	4889	741
	149	3408	149	0
	0	0	4741	741
	91	725	454	0
	4440	1088	454	6343
	0	0	0	6343
	0	0	0	0

Table 15. Present Trip Attraction and Trip Generation of Each Zones

O\D	one 1	Zone 2	Zone 3	one 4	Trip Generation/Producti on
Zone 1	0	8701	281	7018	16000
Zone 2	21580	0	806	3222	25608
Zone 3	4446	7557	0	1482	13485
Zone 4	4531	1813	908	0	7250
Trip Attraction	30557	18071	1995	11722	

Total Present Trip Generation: 62345
Total Present Trip Attraction: 62345

Table 15 shows the trip attraction and trip generation of each Zone in 2023. The result shows that the highest-generated trip attraction among the four zones is Zone 1. This outcome is because Zone 1 is a commercial land use in which many supermarkets, malls, and shops are located. Aside from that, Zone 1 is the most populated Zone among all the four-Zone, making it the highest trip attraction. The second highest-generated attraction is Zone 2. This outcome is because Zone 2 is where hospitals, schools, churches, and the municipality are located. The third highest population attraction is Zone 4, so the trip attraction in Zone 4 is greater than Zone 3 has something to do with the population since Zone 4 has a larger population density than Zone 3, making Zone 4 the third highest trip attraction among all four zones.

Table 16. Calibrated Population after every 5 years in each zone

YEAR	ZONE 1 POPULATION			TOTAL POPULATION
2023	8,519	25,075	11,905	45,499
2028	9096	26874	13118	49088
2033	9,672	28,674	14,331	52,677
2038	10246	30473	15545	56264
2043	10,826	32,272	16,758	59,856
	O/D FACTOR 2028			1.078881
	O/D FACTOR 2033			1.136283
	O/D FACTOR 2038			1.236599
	O/D FACTOR 2043			1.315545

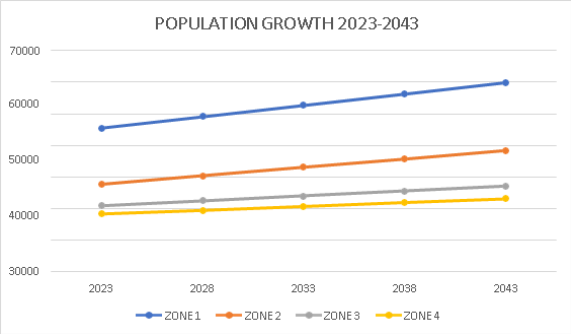
YEAR	ZONE 2 POPULATION			TOTAL POPULATION
2023	3,691	14,455	9,601	27747
2028	4124	16080	10209	30413
2033	4,558	17,706	10,816	33080
2038	4991	19332	11424	35747
2043	5,424	20,957	12,031	38412
	O/D FACTOR 2028			1.096083
	O/D FACTOR 2033			1.161185
	O/D FACTOR 2038			1.288322
	O/D FACTOR 2043			1.384366

YEAR	ZONE 3 POPULATION			TOTAL POPULATION
2023	4,321	8,254	8,352	20927
2028	4631	8802	9054	22487
2033	4,942	9,349	9,756	24047
2038	5253	9897	10458	25608
2043	5,564	10,445	11,160	27169
	O/D FACTOR 2028			1.074545
	O/D FACTOR 2033			1.129829
	O/D FACTOR 2038			1.223682
	O/D FACTOR 2043			1.298275

YEAR	ZONE 4 POPULATION			TOTAL POPULATION
2023	11,326	7,730	10,597	18327
2028	12038	8117	11399	19516
2033	12,751	8,504	12,201	20705

2038	13436	8891	13003	21894
2043	14,175	9,278	13,805	23083
	O/D FACTOR 2028			1.064877
	O/D FACTOR 2033			1.114851
	O/D FACTOR 2038			1.194631
	O/D FACTOR 2043			1.259508

Table 16 shows the calibrated population growth after 5,10, 15, and 20 years in each Zone which is based on the last census that the government conducted in the year 1990 up to the latest census in the year 2020. The result shows only minimal population growth in each Zone, in which Zone 1 has the highest percentage of population, followed by Zone 2, Zone 3, and lastly, Zone 4.



Graph 6. Calibrated Population Growth every 5 years.

TABLE 17. Origin and Destination Factor for the year 2028

Zone	ZONE 1	ZONE 2	ZONE 3	ZONE 4
Origin Factor (generation)	1.08	1.1	1.07	1.06
Destination Factor (attraction)	1.08	1.1069	1.07	1.06

1.08
1.1
1.07
1.06

TABLE 18. Future person trip O/D Table = Present person trip OD Table x Growth Factors

O\D	one 1	Zone 2	Zone 3	one 4	Trip Generation/Production
Zone 1	x	x	x	x	17280
Zone 2	x	x	x	x	28169
Zone 3	x	x	x	x	14429
Zone 4	x	x	x	x	7688
Trip Attraction	33002	20003	2135	12426	

Total Present Trip Generation: 67566
Total Present Trip Attraction: 67566

Since the total future trip attraction and the total future trip generation are equal after using the growth factors.

We can already formulate the trip distribution using the Fratar method. We shall start by iterating the Rows, then the Column repeat.

TABLE 19. First Iteration (Row): X values = Present person trip OD Table x Adjusted Destination Growth Factors

O\D	ZONE 1	ZONE 2	ONE 3	ZONE 4	Actual Total	esired Total	Row factors
ZONE 1	0	9631.1369	300.67	7439.08	17371	17280	0.99476786
ZONE 2	23306.4	0	862.42	3415.32	27584	28169	1.02120276

ZONE 3	4801.68	8364.8433	0	1570.92	14737	14429	0.97907077
ZONE 4	4893.48	2006.8097	971.56	0	7872	7688	0.97664466
Trip Attraction	33001.56	20002.7899	2134.65	12425.32			

TABLE 20. First Iteration (Column): X values x Row factors

O/D	ZONE 1	ZONE 2	ZONE 3	ZONE 4	Actual Total
ZONE 1	0	9581	299	7400	17280
ZONE 2	23801	0	881	3488	28169
ZONE 3	4701	8190	0	1538	14429
ZONE 4	4779	1960	949	0	7688
Actual Total	33281	19730	2129	12426	
Desired Total	33002	20003	2135	12425	
Column Factor	0.9916	1.0138	1.0028	1.0000	

TABLE 21. Second Iteration (Row): X values x Column factors

O\D	ZONE 1	ZONE 2	ZONE 3	ZONE 4	Actual Total	Desired Total	Row factors	
ZONE 1	0	9713	300	7400	17413	17280	0.99237837	
ZONE 2	23601	0	883	3488	27972	28169	1.00706046	**-0.0070605**
ZONE 3	4662	8303	0	1538	14502	14429	0.99493191	**0.00506809**
ZONE 4	4739	1987	952	0	7678	7688	1.0013548	**-0.0013548**
Trip Attraction	33001.56	20002.7899	2134.65	12425.32				

TABLE 22. Second Iteration (Column): X values x Row factors

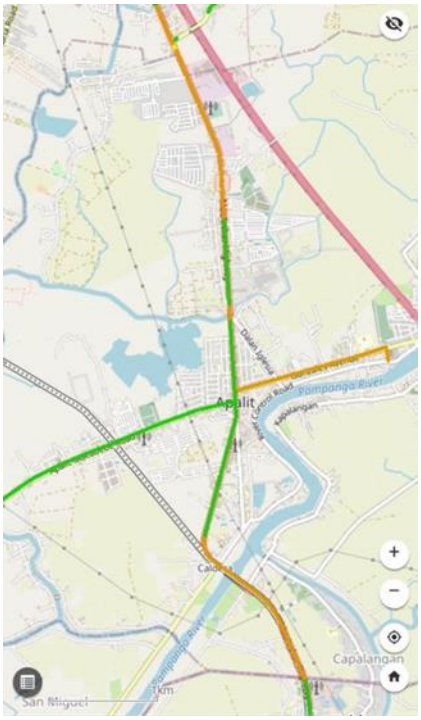
O/D	ZONE 1	ZONE 2	ZONE 3	ZONE 4	Actual Total
ZONE 1	0	9639	298	7343	17280
ZONE 2	23767	0	889	3512	28169
ZONE 3	4638	8261	0	1530	14429
ZONE 4	4745	1990	953	0	7688
Actual Total	33151	19889	2140	12386	
Desired Total	33002	20003	2135	12425	
Column Factor	0.9955	1.0057	0.9976	1.0032	
	0.00451	-0.00570	0.00245	-0.00319	

TABLE 23. Trip Distribution using two (2) iterations via Fratar Method

O\D	ZONE 1	ZONE 2	ZONE 3	ZONE 4	Trip Generation/Production
ZONE 1	0	9694	297	7367	17358
ZONE 2	23660	0	887	3523	28071
ZONE 3	4617	8308	0	1535	14460
ZONE 4	4724	2001	950	0	7676
Trip Attraction	33002	20003	2135	12425	

Total Future Trip Generation: 67564
Total Future Trip Attraction: 67564

The iteration stops here since the column and row factors are up to the required least 1±0.05 threshold



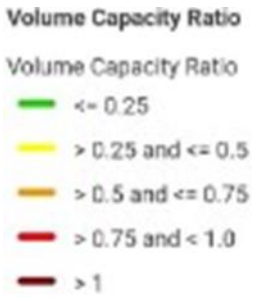


Figure 13. Volume Capacity Ratio

Table 23 shows the trip distribution in Apalit, Pampanga, after five years in 2028 using the Fratar method. The result shows that the trip attraction and generation after five years is 67564. The highest trip-generating Zone is Zone 2, which produces 28,071 trips. This shows that the population of Zone 2 will grow after five years, producing more trips. Meanwhile, the highest trip-attracting Zone is Zone 1, which attracts 33002. Since Zone 1 is a commercial land use, it is no doubt that this Zone will attract more trips in the following year since the iteration of the row and column factors reached the threshold of 1±0.05. This shows that even after ten years, the road in Apalit, Pampanga, can still be used with minimal traffic congestion.

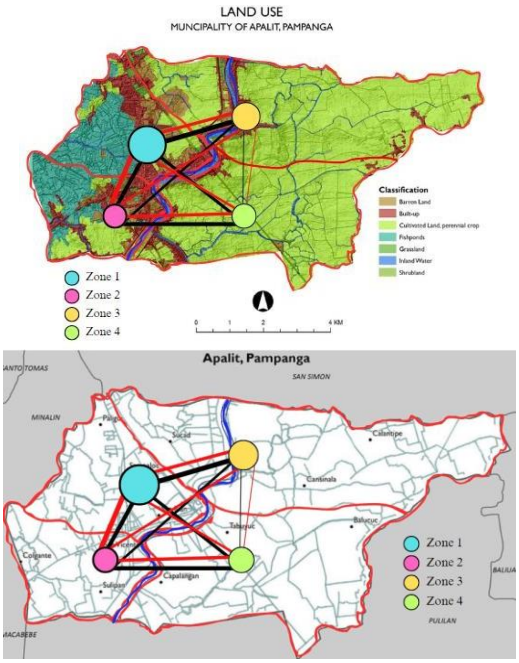


Figure 14. Trip Attraction and Trip Distribution between zones in year 2028

TABLE 24. Origin and Destination Factor for the year 2033

Zone	ZONE 1	ZONE 2	ZONE 3	ZONE 4	
Origin Factor (generation)	1.14	1.16	1.12	1.11	1.16
Destination Factor (attraction)	1.14	1.16305	1.12	1.11	1.12 1.11

TABLE 25. Future person trip O/D Table = Present person trip OD Table x Growth Factors

O\D	Zone 1	Zone 2	Zone 3	Zone 4	Trip Generation/Production
Zone 1	x	x	x	x	18240
Zone 2	x	x	x	x	29706
Zone 3	x	x	x	x	15104
Zone 4	x	x	x	x	8050
Trip Attraction	34835	21018	2235	13012	

Total Present Trip Generation: 71100
Total Present Trip Attraction: 71100

TABLE 26. First Iteration (Row): X values = Present person trip OD Table x Adjusted Destination Growth Factors

O\D	ZONE 1	ZONE 2	ONE 3	ZONE 4	Actual Total	esired Total	Row factors
ZONE 1	0	10119.69805	314.72	7789.98	18224	18240	1.0008561
ZONE 2	24601.2	0	902.72	3576.42	29080	29706	1.02151488
ZONE 3	5068.44	8789.16885	0	1645.02	15503	15104	0.97428637
ZONE 4	5165.34	2108.60965	1016.96	0	8291	8050	0.97094292
Trip Attraction	34834.98	21017.47655	2234.4	13011.42			

TABLE 27. First Iteration (Column): X values x Row factors

O/D	ZONE 1	ZON E 2	ZON E 3	ZONE 4	Actual Total
ZONE 1	0	10128	315	7797	18240
ZONE 2	25130	0	922	3653	29706
ZONE 3	4938	8563	0	1603	15104
ZONE 4	5015	2047	987	0	8050
Actual Total	35084	20739	2225	13053	
Desired Total	34835	21017	2234	13011	
Column Factor	0.992 9	1.013 4	1.004 4	0.996 8	

TABLE 28. Second Iteration (Row): X values x Column factors

O\D	ZONE 1	ZONE 2	ON E 3	ZONE 4	Actual Total	esired Total	Row factors	
ZONE 1	0	10264	316	7772	18353	18240	0.9938547 4	0.0061452 6
ZONE 2	24952	0	926	3642	29520	29706	1.0062921 3	-0.0062921
ZONE 3	4903	8678	0	1598	15179	15104	0.9950631 7	0.0049368 3
ZONE 4	4980	2075	992	0	8046	8050	1.0004594 1	-0.0004594
Trip Attraction	34834.9 8	21017.476 5 5	2234. 4	13011.4 2				

TABLE 29. Second Iteration (Column): X values x Row factors

O/D	ZONE 1	ZONE 2	ZONE 3	ZONE 4	Actual Total
ZONE 1	0	10201	314	7724	18240
ZONE 2	25109	0	932	3665	29706
ZONE 3	4879	8635	0	1590	15104
ZONE 4	4982	2076	992	0	8050
Actual Total	34970	20913	2239	12979	
Desired Total	34835	21017	2234	13011	
Column Factor	0.9961	1.0050	0.9981	1.0025	
	0.00386	**-0.00502**	**0.00194**	**-0.00252**	

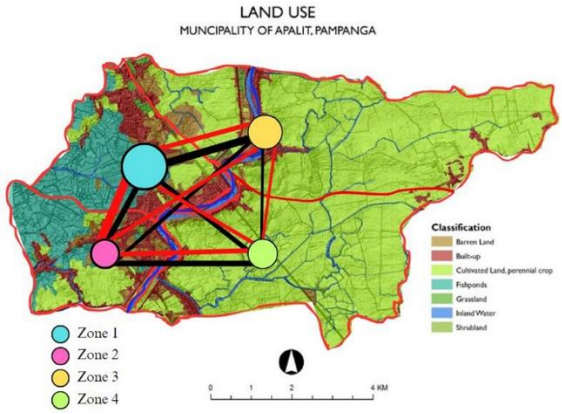
TABLE 30. Trip Distribution using two (2) iterations via Fratar Method

O\D	ZONE 1	ZONE 2	ZONE 3	ZONE 4	Trip Generation/Production
ZONE 1	0	10253	314	7744	18310
ZONE 2	25012	0	930	3674	29616
ZONE 3	4860	8679	0	1594	15133
ZONE 4	4963	2086	990	0	8039
Trip Attraction	34835	21017	2234	13011	

Total Future Trip Generation: 71098
Total Future Trip Attraction: 71098

- The iteration stops here since the column and row factors are up to the required least 1±0.05 threshold

Table 30 shows the trip distribution in Apalit, Pampanga, after ten years in 2033 using the Fratar method. The result shows that the trip attraction and trip generation after ten years is 71,098. The highest trip-generating Zone is Zone 2, which produces 29,616 trips. This shows that the population of Zone 2 will grow after ten years, producing more trips. Meanwhile, the highest trip-attracting Zone is Zone 1, which attracts 34835. Since Zone 1 is a commercial land use, it is no doubt that this Zone will attract more trips in the following year since the iteration of the row and column factors reached the threshold of 1±0.05. This shows that even after ten years, the road in Apalit, Pampanga, can still be used with minimal traffic congestion.



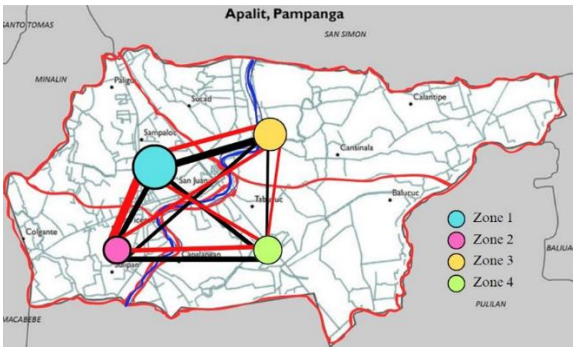


FIGURE 15. TRIP DISTRIBUTION APALIT PAMPANGA IN THE YEAR 2033

TABLE 31. Origin and Destination Factor for the year 2038

Zone	ZONE 1	ZONE 2	ZONE 3	ZONE 4
Origin Factor (generation)	1.2	1.3	1.2	1.19
Destination Factor (attraction)	1.2	1.3441	1.2	1.19

1.2
1.3
1.2
1.19

TABLE 32. Future person trip O/D Table = Present person trip OD Table x Growth Factors

O\D	Zone 1	Zone 2	Zone 3	Zone 4	Trip Generation/Production
Zone 1	x	x	x	x	19200
Zone 2	x	x	x	x	33291
Zone 3	x	x	x	x	16182
Zone 4	x	x	x	x	8630
Trip Attraction	36669	24290	2394	13950	

Total Present Trip Generation: 77303
Total Present Trip Attraction: 77303

TABLE 33. First Iteration (Row): X values = Present person trip OD Table x Adjusted Destination Growth Factors

O\D	ZONE 1	ZONE 2	ZONE 3	ZONE 4	Actual Total	Desired Total	Row factors
ZONE 1	0	11695.0141	337.2	8351.42	20384	19200	0.94193214
ZONE 2	25896	0	967.2	3834.18	30697	33291	1.08448995
ZONE 3	5335.2	10157.3637	0	1763.58	17256	16182	0.93775297
ZONE 4	5437.2	2436.8533	1089.6	0	8964	8630	0.96277709

Trip Attraction	36668.4	24289.2311	2394	13949.18

TABLE 34. First Iteration (Column): X values x Row factors

O/D	ZONE 1	ZONE 2	ZONE 3	ZONE 4	Actual Total
ZONE 1	0	11016	318	7866	19200
ZONE 2	28084	0	1049	4158	33291
ZONE 3	5003	9525	0	1654	16182
ZONE 4	5235	2346	1049	0	8630
Actual Total	38322	22887	2416	13678	
Desired Total	36668	24289	2394	13949	
Column Factor	0.9569	1.0613	0.9911	1.0198	

TABLE 35. Second Iteration (Row): X values x Column factors

O\D	ZON E 1	ZONE 2	ZON E 3	NE 4	Actual Total	esired Total	Row factors	
ZONE 1	0	11691	315	8022	20028	19200	0.95867098	**0.04132902**
ZONE 2	26872	0	1040	4240	32152	33291	1.03541862	**-0.03541862**
ZONE 3	4787	10109	0	1687	16582	16182	0.97585493	**0.02414507**
ZONE 4	5009	2490	1040	0	8538	8630	1.01071745	**-0.01071745**
Trip Attraction	36668.4	24289.2311	2394	13949.18				

TABLE 36. Second Iteration (Column): X values x Row factors

O/D	ZONE 1	ZONE 2	ZONE 3	ZONE 4	Actual Total
ZONE 1	0	11208	302	7691	19200
ZONE 2	27824	0	1076	4391	33291
ZONE 3	4672	9865	0	1646	16182
ZONE 4	5063	2517	1051	0	8630
Actual Total	37558	23589	2429	13727	
Desired Total	36668	24289	2394	13949	
Column Factor	0.9763	1.0297	0.9856	1.0162	
	0.02369	**-0.02970**	**0.01439**	**-0.01618**	

TABLE 37. Trip Distribution using two (2) iterations via Fratar Method

O\D	ZONE 1	ZONE 2	ZONE 3	ZONE 4	Trip Generation/Production
ZONE 1	0	11540	297	7815	19653
ZONE 2	27165	0	1061	4462	32687
ZONE 3	4561	10158	0	1672	16391
ZONE 4	4943	2591	1036	0	8570
Trip Attraction	36668	24289	2394	13949	

Total Future Trip Generation: 77301
Total Future Trip Attraction: 77301

- The iteration stops here since the column and row factors are up to the required least 1±0.05 threshold

Table 37 shows the trip distribution in Apalit, Pampanga, after 15 years in 2038 using the Fratar method. The result shows that the trip attraction and generation after 15 years is 77301. The highest trip-generating Zone is Zone 2, which produces 32687 trips. This shows that the population of Zone 2 will grow after 15 years, which produces more trips; meanwhile, the highest trip-attracting Zone is Zone 1, which attracts 36668. Since Zone 1 is a commercial land use, it is no doubt that this Zone will attract more trips in the following year since the iteration of the row and column factors reached the threshold of 1±0.05. This shows that even after 15 years, the road in Apalit, Pampanga, can still be used with minimal traffic congestion.

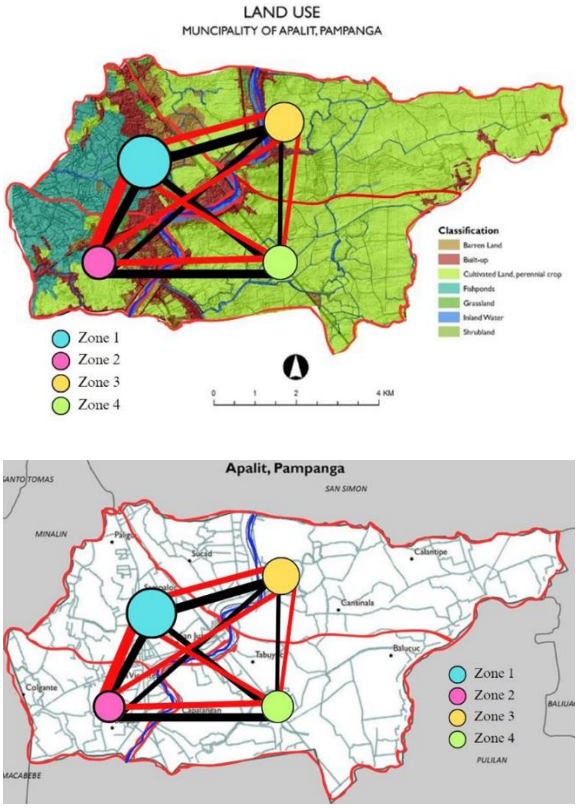


Figure 16. Trip Attraction and Trip Distribution between zones in year 2038.

TABLE 38. Origin and Destination Factor for the year 2043

Zone	ZONE 1	ZONE 2	ZONE 3	ZONE 4
Origin Factor (generation)	1.3	1.4	1.3	1.25
Destination Factor (attraction)	1.3	1.454	1.3	1.25

1.3
1.4
1.3
1.25

TABLE 39. Future person trip O/D Table = Present person trip OD Table x Growth Factors

O\D	one 1	Zone 2	Zone 3	one 4	Trip Generation/Productio n
Zone 1	x	x	x	x	20800
Zone 2	x	x	x	x	35852
Zone 3	x	x	x	x	17531
Zone 4	x	x	x	x	9065
Trip Attraction	3972 5	26276	2594	1465 3	

Total Present Trip Generation: 83248
Total Present Trip Attraction: 83248

TABLE 40. First Iteration (Row): X values = Present person trip OD Table x Adjusted Destination Growth Factors

O\D	ONE 1	ZONE 2	ONE 3	ONE 4	Actual Total	esired Total	Row factors
ZONE 1	0	12651.254	365.3	8772.5	21789	20800	0.95460776
ZONE 2	28054	0	1047.8	4027.5	33129	35852	1.08218405
ZONE 3	5779.8	10987.878	0	1852.5	18620	17531	0.9415055
ZONE 4	5890.3	2636.102	1180.4	0	9707	9065	0.93388121
Trip Attraction	39724.1	26275.234	2593.5	14652.5			

TABLE 41. First Iteration (Column): X values x Row factors

O/D	ZONE 1	ZONE 2	ZONE 3	ZONE 4	Actual Total
ZONE 1	0	12077	349	8374	20800
ZONE 2	30360	0	1134	4358	35852
ZONE 3	5442	10345	0	1744	17531
ZONE 4	5501	2462	1102	0	9065
Actual Total	41302	24884	2585	14477	
Desired Total	39724	26275	2594	14653	
Column Factor	0.9618	1.0559	1.0033	1.0121	

TABLE 42. Second Iteration (Row): X values x Column factors

O\D	ZONE 1	ZONE 2	ZONE 3	ZONE 4	Actual Total	Desired Total	Row factors	
ZONE 1	0	12752	350	8476	21578	20800	0.96394706	**0.03605294**
ZONE 2	29200	0	1138	4411	34749	35852	1.0317528	**-0.0317528**
ZONE 3	5234	10924	0	1765	17923	17531	0.97814777	**0.02185223**
ZONE 4	5291	2599	1106	0	8996	9065	1.00765865	**-0.0076587**
Trip Attraction	39724.1	26275.234	2593.5	14652.5				

TABLE 43. Second Iteration (Column): X values x Row factors

O/D	ZONE 1	ZONE 2	ZONE 3	ZONE 4	Actual Total
ZONE 1	0	12292	337	8170	20800
ZONE 2	30127	0	1174	4551	35852
ZONE 3	5119	10685	0	1727	17531
ZONE 4	5331	2619	1114	0	9065
Actual Total	40577	25597	2625	14448	
Desired Total	39724	26275	2594	14653	
Column Factor	0.9790	1.0265	0.9878	1.0141	
	0.02103	**-0.02651**	**0.01218**	**-0.01412**	

TABLE 44. Trip Distribution using two (2) iterations via Fratar Method

O\D	ZONE 1	ZONE 2	ZONE 3	ZONE 4	Trip Generation/Production
ZONE 1	0	12618	333	8286	21237
ZONE 2	29493	0	1159	4616	35268
ZONE 3	5012	10968	0	1751	17731
ZONE 4	5219	2689	1101	0	9009
Trip Attraction	39724	26275	2594	14653	

Total Future Trip Generation: 83245
Total Future Trip Attraction: 83245

- The iteration stops here since the column and row factors are up to the required least 1±0.05 threshold

Table 44 shows the trip distribution in Apalit, Pampanga, after 20 years in 2043 using the Fratar method. The result shows the trip attraction and trip generation after 20 years is 83,245. The highest trip-generating Zone is Zone 2, which produces 35,568 trips. This shows that the population of Zone 2 will grow after 20 years, producing more trips; meanwhile, the highest trip-attracting Zone is Zone 1, which attracts 39724. Since Zone 1 is a commercial land use, it is no doubt that this Zone will attract more trips in the following year since the iteration of the row and column factors reached the threshold of 1±0.05. This shows that even after 20 years, the road in Apalit, Pampanga, can still be used with minimal traffic congestion.

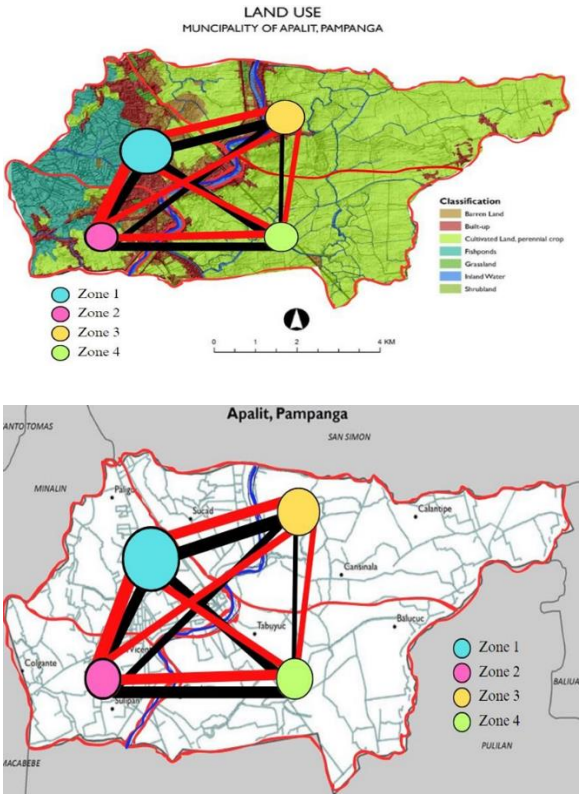
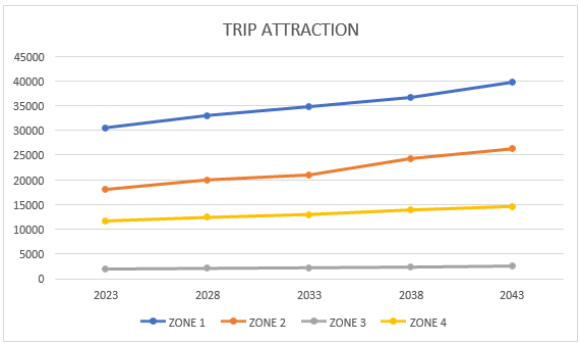
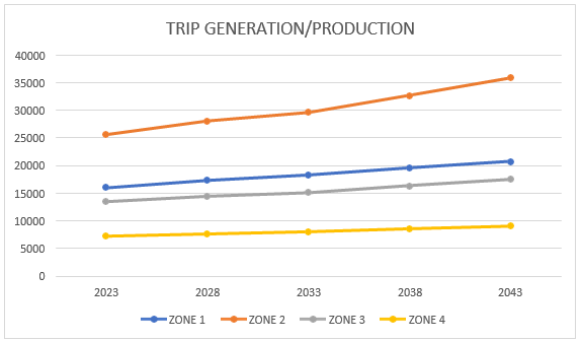


Figure 17. Trip Attraction and Trip Distribution between zone in year 2043



Graph 7. Trip Attraction between zones

Graph 7 shows the trip of attraction in each Zone from the year 2023 up to the year 2043. The result shows that there is a significant increase in trip attraction for Zone 1 and Zone 2, the significant increase in trip attraction can be caused by land use, according to the study conducted by Badi S. Waloejo titled The Influence of Trip Attraction on the Road's Level of Service (LOS) at Traditional Market Land Use shows that the land use of an area is one great factor for trip attraction. Since Zone 1 is a commercial land use in which various establishments such as supermarkets, establishments, restaurants, and others, it is only common that after 20 years, there will be a significant increase in the attraction in Apalit, Pampanga. The same goes with Zone 2 since Zone 2 is a public land use where most hospitals, schools, municipalities, and various kinds of churches have gathered, it is fitting that the attraction for this Zone with increase. There is a minimal increase for Zone 3 and Zone 4 since these zones are mostly agricultural land. No significant attractions are happening in these areas.



Graph 8. Trip Generation/Production between zones.

Graph 8 shows the trip of distribution in each Zone from the year 2023 up to the year 2043. The result shows a significant increase in trip distribution in Zone

2 from the present year up to 20 years, according to Chang et. al., 2014 factors in TAZ demographics such as population, households, employment, car ownership, and income can affect the trip production of a Zone since we tend to neglect the travel inside the zones. Zone 2 became the highest trip production Zone, since it has the second highest populated Zone in Apalit. Most of the citizens in Zone 2 need to travel to other zones, such as Zone 1, to work or buy, resulting in increased trip production in Zone 2. Zone 1 is the second highest generating Zone for a trip generation. Even though Zone 1 is the most populated in the area, it is also the most attractive Zone, and since we tend to neglect the travel inside the Zone there is a significant difference in Zone 1 and Zone 2, compared to the other zones.

IV. SUMMARY, CONCLUSION, AND RECOMMENDATION

- Summary and Conclusion

In order to anticipate future O-Ds, this study used data from a home interview survey on traveler O-D movements as the base year data. It is possible to create fresh O-D matrices after doing a sample of 273 home interviews inside the vicinity of the study area, and to make the result more accurate, 30 household surveys in the cordon lines were considered. The Fratar Method was used to interpret the gathered data to predict future travel demands. However, this study covers only the steps from Trip Generation to Mode Choice. Time plays a major factor in why the study is limited. Data Gathering and Analysis consumed much time, resulting in the researchers' struggles. Authorities in transportation planning may use this data to plan their road system. This is simply pilot research. The researchers considered consecutive five years, 2028, 2033, 2038, and 2048, where research, additional large-scale surveys, and modeling should be done to obtain even more convincing results in the study area. The study's findings are that most commuters are traveling from their respective zones to Zone 1, which is industrial land.

Additionally, females are more active on roads as they shop, socialize, and study. Most participants are Home-based, but the commuters travel for work and study. To further anticipate the travel demand, the researchers considered every five years in the future. This study will be used to develop Local Public Transport Route Plans as it will project the trip attraction and trip generation in the following years. Based on the Volume Capacity Ratio (VCR) of the Apalit, roads can still provide convenience to people in terms of traffic. Although the trip attraction and distribution are increasing, it will only add minimal traffic congestion in traffic in the study area.

Moreover, the Growth rate presented in this study will not greatly affect the VCR of the vicinity. The results from every five years, starting from the present years, from 2023 up to 20 years from now, the year 2043, show that the threshold from trip attraction and distribution from every Zone is less than one, which means traffic congestion will not be present. However, nearly all of the participants said that the construction of roads is a major factor in the heavy traffic in Apalit, Pampanga.

- Recommendations
- Time Consumption

As stated in the summary and conclusion, time constraint was the major hindrance for the researchers. Data gathering and analysis consume a large scale of time. The researchers recommend that future researchers sacrifice their time to show dedication to completing the 4-step model.

- Participants

Researchers cover only 1% of the total households in Apalit, Pampanga. The researchers recommend considering more households to make the data more concrete.

- Local Government Unit

This study can use as a basis for the Local Government Unit to conduct surveys to contribute to Local Public Transport Route Plan. Future travel demands will depend on the data gathered in this research, especially Traffic Generation and Traffic Distribution.

- Period of Data Gathering

Future Researchers should wisely choose the days to conduct surveys. Holidays and Special Events are the perfect occasions to lessen the difficulty of the data-gathering phase. Most people are in public places or "mass gatherings".

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