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Trip Characteristics of Rural Households in Davao City: A Neural Network Approach to Trip Generation Modelling

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Abstract*— Building a generalized rural travel demand perspective helps create policies that better address rural mobility and inclusive national development. However, studies on rural transport planning are limited which builds a gap in understanding trip behavior in rural areas. Therefore, this study was conducted to investigate the trip characteristics of rural households in a remote community. This study specifically aimed to collect socio-economic, and demographic information of rural households in Davao City through a household survey and develop a trip generation modelling to describe the relationship between these factors with trip frequency. Hence, a trip diary consisting of trip frequency, trip purpose, and mode choice information was required. The data revealed that the average household size is 3.96 which is mostly composed of extended family members, students, and working members. This signifies school and work as the primary purpose of trips on a typical day in the rural community. Further, different income classes were compared according to each trip characteristics. Results showed that, regardless of income class, most households own at least one motorcycle due to insufficient inaccessibility and poor road infrastructure. Walking was reported to be one of the preferred mode choices in addition to public utility vehicles, especially for low-income class and middle-income class households located in an inaccessible and remote portion of the community. Finally, an Artificial Neural Network was structured to investigate correlations between socio-economic and demographic factors with trip frequency, which revealed that household size, number of students, number of workers, and number of members between 7 and 59 years old showed strong positive correlations. In conclusion, it is no doubt that public transportation has become the preferred mode choice for rural residents. It is therefore important for the government to improve transportation facilities and include rural communities in policymaking to accommodate transport demand.

Keywords: artificial neural network, trip frequency, trip generation modelling, trip purpose, mode choice.

I. INTRODUCTION

During Unravelling the issue of inaccessibility is one of the primary goals of the Association of Southeast Asian Nations to transform the rural landscape and provide solutions to both social and economic problems. In Southeast Asia, the lack of

Transportation facilities is one of the factors that hinder rural residents from accessing private and public services. This indicates that effective transportation facilities help solve social issues and assist the implementation of efficient government and private programs. Aside from that, improved transportaton facilities can pave the way for substantial investment to come in which may help to decongest urban areas by discouraging rural-urban migration [1].

In the Philippines, an archipelagic country of more than 7,600 islands, rural areas still dominate contributing 94.6% of the total land area wherein 52% of the overall population lives [2]. Hence, the Philippines has been focusing on enhancing urban-rural linkages through massive programs such as the Build Build Build Program and the Public Utility Vehicle Modernization Program to assist the movement of goods and to rationalize the routing system of PUVs to optimize rural and urban connectivity. Nevertheless, the implementation of any transportation-related program requires complex procedures to thoroughly obtain trip behavioral patterns that describe the extent of travel demand in a certain region. However, travel demand modeling is largely applied to urban transport planning, which is very

Apparent in limited rural transport studies. Despite being constrained, its application in rural studies is also found beneficial to offer a broad understanding of mobility needs, thereby allowing policymakers to create user-centric transport solutions [3].

Further, the location of an individual is associated with his/her socioeconomic status – such as income, educational attainment, and occupation which influences one's travel behavior [4]. This means that a more comprehensive understanding and extensive comparative study amongst socioeconomic groups are needed to build a generalized rural travel demand perspective that is useful in creating policies that better address rural mobility and inclusive national development. Thus, this study aimed to provide a profound understanding of the travel characteristics of rural households by considering their socioeconomic status. In this study, a detailed investigation of trip characteristics in terms of trip frequency, trip purpose, and mode choice was carried out to understand the travel behavior of rural residents of different

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income classes. In addition, a trip generation modelling using an artificial neural network was performed to further explain the association of these socio-economic and demographic factors with trip frequency.

II. LITERATURE REVIEW

This section provides a discussion about the existing travel behavior studies in rural areas. Furthermore, the factors affecting trip generation and the common approaches to trip generation modeling are included in this discussion.

A. Rural Area Studies

Accessibility has been the most concerning focus for various existing research about rural area transportation studies [5]. In general, how travel behavior manifests in rural areas is influenced by the trips needed to get the basic needs and services. Study shows that market accessibility affects the trip frequency of rural residents. The farther the market from the community, the lesser the trips generated [6]. In addition, rural residents prefer to access nearby hospitals for immediate care than high-quality medical care which would cost more travel time and expenses [7].

The lack of accessibility has influenced rural residents' mobility. For instance, a study of the travel behavior of elderly women in rural and small urban areas was conducted which revealed that individual factors and social environment factors, as well as physical environment factors, played a huge impact on the mobility of elderly women [8]. Another study focused on the travel behavior of students studying in a rural university in Asia. It was observed that a very high social interdependency among the students affects their mode choice, such as being a passenger or driving their friend's car, which simulation of a model of the travel behavior of the students a difficult and complicated task [9].

Ability can describe individual's mode preferences. For instance, rural women who cannot drive motorcycles are more likely to rely on walking to get to their destinations [10]. This is not true for elderly who prefer riding cars to meet their travel needs [11]. However, due to limited poor road facilities combined with unfortunate economic conditions, limits rural residents from owning a car, resulting in inconveniences [5].

B. Trip Generation Modeling

The trip generation model, being the first step in the travel demand modelling process, holds the critical stage in measuring transportation demand. Generally, it fundamentally explains the relationship between land use and socioeconomic characteristics to the generated trips in mathematical concepts.

In formulating a mathematical model for trip generation, a validated independent variable that influences an individual's travel decision-making process must be chosen comprehensively. The critical aspect of choosing the right factors has been long examined by transport planners for years. As mentioned in various literature, socio-demographic attributes, land-use patterns, and built environment characteristics are the most widely used variables for estimating household trips, including factors such as income, car ownership, household structure, and family size [4].

Income is important in travel behavior analysis since it is the primary factor that determines individual choices of travel. This manifests the intense effect of urbanization which conveys improvement of living standards and increased economic activities and thus leads to the exponential surge in car ownership levels in most countries [12]. It was recognized that car ownership depends more on long-term income while trip generation depends on daily disposable income [13]. Employment status and educational attainment are also observed to have a significant influence on travel behavior because having higher education and engaging in private jobs is more likely to hire ride-sourcing services in a developing country [14]. Employed individuals move to a certain location nearest to their workplace so that they would have less travel time. Changes in travel behavior uncovered that relocating to a neighborhood closer to the destination with alternative transport options could result in less driving and more walking [15].

Household size exhibited an important function in trip generation modeling. The odds of a household making any walk trips increase with the household size and workers in households and decrease if households are living in single-family homes or have higher annual incomes [16]. Furthermore, household size contributes to vehicle ownership, which means that the likelihood of owning a 4-wheeled vehicle increases as family size and income increase [17]. The study further identified a strong correlation between car ownership and cellphone ownership. While cell phones are likely not a direct cause of a desire to buy a car, they could be interpreted as a proxy for independent travel needs.

Various techniques were proposed to model trip generation, such as simple regression, multiple regression, trip rate, cross-classification, and multiple classifications. Among these techniques, multiple regression (MR) is the most popular technique used for trip generation modeling. In MR, the number of trips is assumed to have a linear relationship with multiple explanatory variables [18].

Multiple regression is applied to estimate household trips of motorcyclists for non-mandatory activities [19]. Using the technique, the authors were able to identify statistically significant explanatory variables for this purpose which are license ownership, housewife, school-age children, middle-income household, and lower education level. In addition, a study applied regression to investigate the hospital trip behavior as home-based hospital trips within the scope of trip production and attraction (trip generation) models [20]. Another study used the technique in predicting the traffic generated by hotels in Bali, Indonesia using the land area of each hotel, the parking area, the total floor area of the building, the area of the meeting room, the number of rooms, the average number of tourists staying, the average length of

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stay of tourists, the number of employees at each hotel and the number of supporting facilities for each hotel as independent variables [21]. However, it was found in the study that only the total floor area of the building has a significant correlation to the traffic generated.

C. Neural Network Approach to Trip Generation Modeling

Although the regression method is commonly used in trip generation modeling, the popularity of using the neural network approach is competing in terms of efficiency and accuracy. The use of neural networks provides a series of advantages, which includes informal statistical training, detecting complicated nonlinear relationships between variables, and detecting the interactions between the predictors [22]. For instance, the neural network model was found to be more accurate than its regression counterpart in which the former garnered an 83.72% accuracy, while the latter garnered a 72.46% accuracy in predicting trip production [23]. The resulting output displayed the relationship between the trip generation and family size and composition, gender, number in the family, and car ownership.

Another comparative study was introduced using Radial Basis Function Neural Network and Multiple Linear Regression model in trip generation modelling, and the resulting analysis showed a higher Coefficient of Determination (R^2) of the neural network, 0.913, compared to that of the regression model with an R^2 value of only 0.552. The Mean Absolute Percentage Error of the neural network turned out to be 0.421, which was lower than that of the regression model with such a value of 0.810. The result displayed the higher accuracy of the neural network approach in contrast to the regression model [24]. This entails the advantage of a neural network over the regression model in better understanding travel behavior, and thus it becomes widely used in engineering and social science research.

III. METHODOLOGY

To investigate trip characteristics of rural households, quantitative analysis of collected data through descriptive and correlative approaches was considered. The data-gathering activities and analyses involve collecting rural households' trip information and finding a correlation between their socio-economic background and trip characteristics. In addition, this study also involves a comparative analysis of different income classes - low-income class (LIC), middle-income class (MIC), and high-income class (HIC) - in terms of trip characteristics. This was done by stratifying household data based on their monthly income.

A. Study Area

Despite being the third major city in the Philippines, Davao City enjoys both urban and rural ambiance as it is the center of commerce, at the same time a home to various agricultural products and natural sceneries in the southeastern part of Mindanao Island. It comprises a total land area of 2,444 square km, three times larger than the entire Metro Manila, making the city the largest in the Philippines in terms of land area. It has a total population of 1,776,949 based on the 2020 Census of Population and Housing[25], which ranks the third most populous urbanized city in the country and first outside the National Capital Region.

1) Rural Barangay in Davao City

A barangay is the smallest administrative division of a municipality or a city in the Philippines. To come up with a rural barangay to represent Davao City in this study, the Comprehensive Zoning Ordinance of Davao City [26] has set specific guidelines that classify barangays into urban and rural classifications. A barangay is considered urban if it meets any of the following criteria: it has a population size of 5000 or more, it has at least one establishment with a minimum of 100 employees, it has 5 or more establishments with a minimum of 10 employees and 5 or more facilities within the two-kilometer radius from the barangay hall. Otherwise, the barangay is classified as rural.

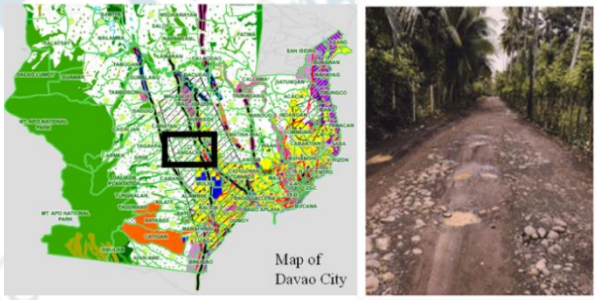

Fig. 1 Barangay Angalan Location and Road Infrastructure

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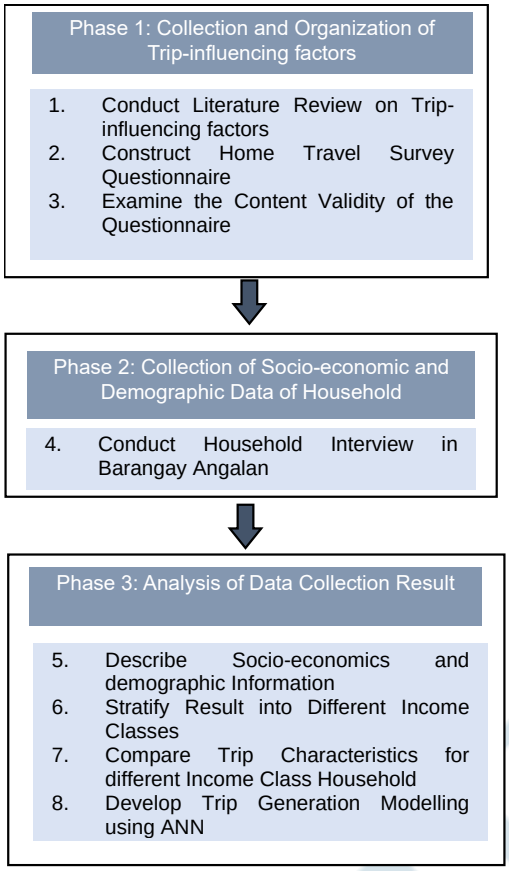

Fig. 2 Research Methodology

Barangay Angalan, classified as rural, was selected as the site in this study (see Fig. 1). It is 22 km from the town proper and has a land area of 495 hectares and a population of 2,741 [25]. The major source of income is from agriculture, mainly from Copra. Most of the road infrastructure within the barangay is unpaved and public transportation is insufficient with only a few tricycles roaming around the barangay. The barangay is divided into 19 small communities called *Purok*. At least half of these *Puroks* are in remote locations within the barangay with few to no public transportation.

B. Methodological Framework

The conduct of the study followed three equally important phases (see Fig. 2). First, the study involves collecting trip-influencing factors from literature and previous household travel surveys. These are socio-economic and demographic factors as well as trip information of rural households. The construction of the questionnaire carries a thorough analysis pertaining to which of these factors entails primary influence on the trip behavior of households in the Philippine setting. Generally, existing travel studies, such as from the Japan International Cooperation Study (JICA) [27] which had done several transportation studies in the Philippines, were referred to. The second phase involves distributing the household travel questionnaire to rural areas in Davao City. The goal of which is to collect socio-economic and demographic information (e.g., household size, age, gender, income, computation, educational attainment, occupation etc.) of all households in the chosen barangay. The collection of data also involved the administration of a travel diary to household members 7 years of age and above. The travel diary section consisted of trip information of the household on a typical weekday (e.g., origin and destination of trips, time of departure and arrival, trip purpose, transportation mode, etc.). According to Philippine Statistics Authority, the number of households in Barangay Angalan reached 647 in the 2020 census. However, a total of 914 households were surveyed in 2023 – an expected variance due to the increase in population over the last three years. Lastly, the third phase involves the analysis of the collected data from household interviews.

Descriptive statistics were used to describe trip characteristics in this study. The analysis was done by; first, stratifying households into income classes (see Table I). Trip characteristics – trip frequency, trip purpose, and mode choice – were graphically described and represented. Trip frequency defines the number of home-based trips produced by households on a typical day. Home-based trips are all accounted for whether the home is the origin or the destination of the journey. In other words, it is where one of the trip ends is home [28]. Trip purpose, on the other hand, describes the main activity at the destination of the trip (e.g., work, school, shopping, etc.), while mode choice is the preferred mode of transportation used during the trip (e.g., walking, bicycle, jeepney, etc.). Finally, Artificial Neural Network (ANN) is applied to develop a trip generation modelling that associates trip production with the socio-economic and demographic factors.

Table 1: Social Classes in the Philippines

Income Class	Monthly Income
Low (LIC)	Less than ₱ 21, 914
Middle (MIC)	₱ 21,914 - ₱ 131,484
High (HIC)	More than ₱ 131,484

Source: Philippine Institute for Development Studies [29]

C. Construction of Artificial Neural Network Model

Applying ANN involves eight steps: (1) determine data to use; (2) determine input variables; (3) separate data into training and test sets; (4) define the network architecture; (4) select a learning algorithm; (5) transform variables to network inputs; (6) train the model; and (7) validate and test the model.

The architecture of the ANN in this study involved three layers: one input layer, one hidden layer, and one output layer (see Fig. 3). The number of neurons in the input layer is decided using the Pearson correlation coefficient, while the output layer is composed of only one node. On the other hand, there were no definite rules as to the determination of the number of neurons in the hidden layer. However, some rules of thumb have been followed by researchers. The number of

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neurons is (1) between the average number of inputs and outputs and their sum, or (2) cannot be less than twice the number of input nodes.

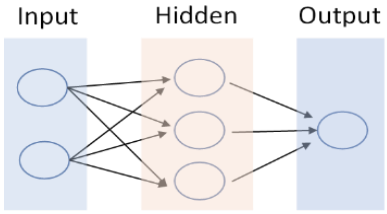

Fig. 3 ANN Structure

IV. RESULTS AND DISCUSSION

Data were collected from 914 households or approximately 95% of the household population in Barangay Angalan. A descriptive analysis of the collected data pertaining to the socio-economic, demographic, and trip information are presented in the following section.

A. Household Demographic and Socio-economic Profile

Fig. 4 shows that most of the household in Barangay Angalan is composed of 3-4 members which constitute 46.46% of the total household population. Overall, the average household size is 3.96 which is slightly lower than the national average of 4.1 [25]. Household size can be further characterized in terms of household composition. For instance, Fig. 5 reveals that most households (55%) have at least one school youth or child. Further, households with at least one child member under 7 years old and at least one senior citizen member represent 34% and 33% of the household population, respectively. Around 24% are with extended family, wherein multiple generations (e.g., grandparents, nieces, nephews, etc.) share the same roof with the nucleus family while having a helper is not very common with only 1.6% of the household population. This is evident in low-income-class households where an economic constraint still exists.

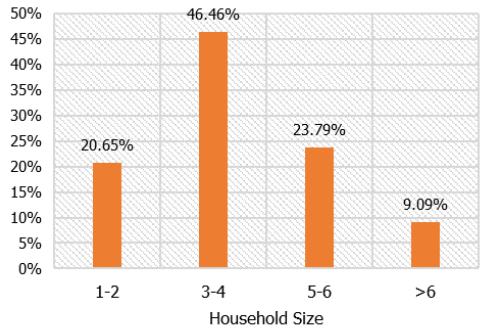

Fig. 4 Household Size Percentage Distribution

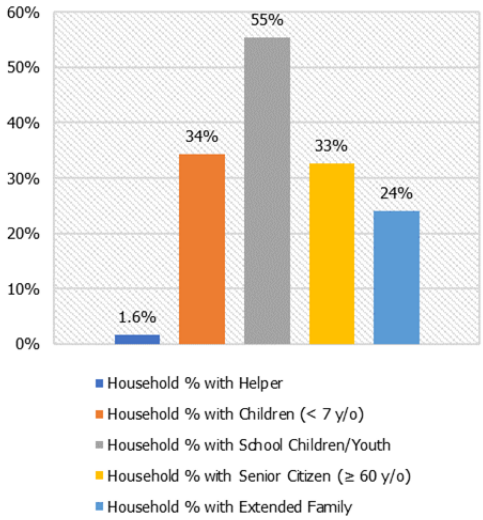

Fig. 5 Household Composition

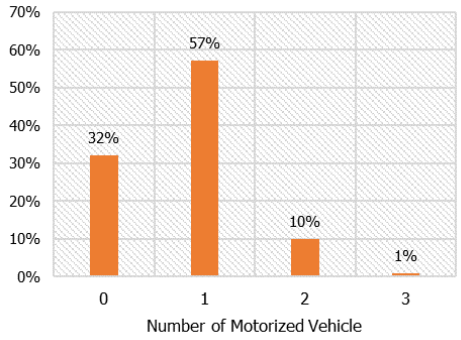

Fig. 6 No. of Motorized Vehicles

Income is an important indicator of travel behavior. However, income characteristics differ along with the built environment. Most households in Barangay Angalan depend on informal employment such as agriculture and service industry for their source of income, this is despite the significant number of unemployed populations. Hence, the LIC household is very dominant in the community (75.20%). On the other hand, the HIC and MIC households only account for 2.29% and 22.51%, respectively, which may be explained by the lack of accessibility and opportunity in the rural community. Moreover, education level influences largely on the income-generating power of households. In Barangay Angalan, the highest educational attainment of most household heads is secondary education which limits them from looking for high-paying jobs.

Literature reveals that vehicle ownership is a factor in trip frequency. Fig. 6 shows that more than half of the household population (57%) own one motorized vehicle, whereas 32% of them do not own at least one motorized vehicle. The motorcycle is the most owned motorized vehicle due to its maneuvering ability whenever used on uneven and rough roads, aside from its affordability.

Overall, this study shows the demographic and socio-economic characteristics of Barangay Angalan. It is

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very evident from the result that the community is still underdeveloped with dominant low-income households. This could be related to the level of education of household heads. Many households own at least one motorized vehicle which may be attributed to underdeveloped road networks in the area.

B. Household Trip Characteristics

This section explains trip characteristics of different household income classes - LIC, MIC, and HIC. Trip characteristics are described by trip purpose, mode choice, and trip frequency.

Fig. 7 shows that most households for all income classes travel for work and school on a typical weekday. Especially, LIC displays a high percentage of trips to work (42.22%) followed by trips to school (39.88%). This is different in the case for the MIC and HIC where the percentage of household members who go out for school and work is almost similar, with approximately 40% of total trips. These numbers are reflected in the household composition discussed earlier. For instance, the high percentage of student trips reflects the number of students in the household, whereas the percentage of work reflects that most household members are engaged in jobs, most particularly in farming and sales work, regardless of their level of income-generating ability. Furthermore, the trip to shop also shows a significant portion. For LIC and MIC, shopping purpose comprises 9.17% and 10.74% of the total trips, respectively, whereas HIC shops more with 20% of the total trips. This data infers that shopping percentage is directly proportional to household income. This means that households with higher incomes tend to go shopping more. In addition, trips to shops are more particular to households owning businesses such as a *sari-sari* store, eatery, and the like where shopping is an everyday errand.

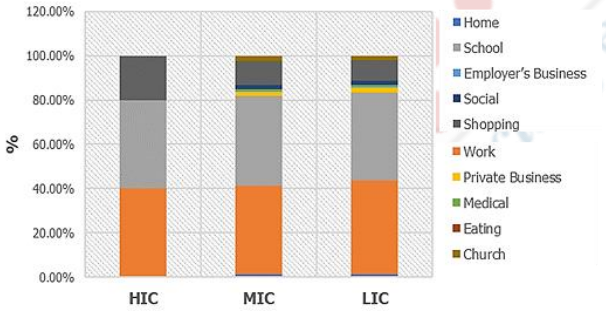

Fig. 7 Trip Purpose for Different Income Classes

There is not much variation in public transportation in Barangay Angalan (see Fig. 8). This is very apparent in the preferred mode choice of trip makers in the area. It is important to note that every household may use at least one mode choice for a single trip, depending on the distance of the destination. For instance, household members need to walk, ride a tricycle and a jeepney before they can get to their destination. Furthermore, a tricycle is the most frequent mode of transportation in the area. The majority of LIC (33.24%), MIC (35.35%), and HIC (44.44%) household members ride a tricycle for a single trip. However, for those households located in isolated *Puroks*, walking is necessary. This is true for LIC (12.16%) and MIC (16.45%) households where most are located in remote locations, whereas most HIC households are situated along the main road, and therefore walking is unnecessary. Motorcycle is also used, often as an alternative to Tricycle. It comprises 29.18% and 22.80% of the total trips from LIC and MIC households, respectively.

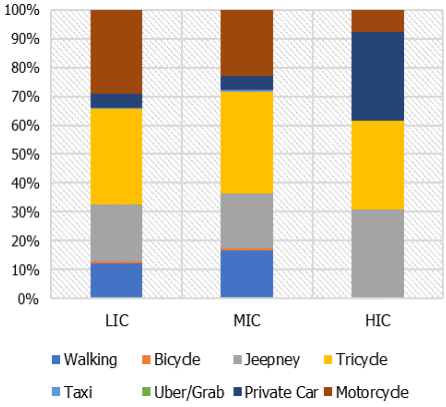

Fig. 8 No. of Motorized Vehicle

Despite the difficulty, a high number of trip-makers still prefer Public Utility Jeepneys for transportation. It is most likely utilized by commuters to other barangay, such as to the town center or other barangay along the Davao-Bukidnon Highway. Unfortunately, the nearest jeepney route is three (3) km away from the barangay which forces commuters to add other transportation modes to their trip activities. Jeepney users are 19.60%, 19.19%, and 30.77% for LIC, MIC, and HIC, respectively. This implies that a significant number of trip-makers travel outside Barangay Angalan.

Overall, this study reveals that public transportation is very in demand in the area for all social classes. The use of private vehicles is not common. However, due to the insufficient number of available modes of transportation, walking to their destination is most likely included in their trip activities. This calls for improving road infrastructure so that public vehicles can access other isolated portions of the community.

Trip frequency is determined by counting the total home-based trips of a household on a typical weekday, including the return trips. This study found that LIC and MIC households travel more with an average number of home-based trips of 4.91 and 6.592 household trips per day, respectively, whereas HIC household has an average home-based trip of 9.4 household trips per day. This implies that higher-income households generate trips more than low-income households. Overall, this gives an average of 5.28 household trips per day for the entire barangay. This number is a function of various factors which will be discussed in the following section.

C. Trip Generation Modelling of Rural Households

Artificial Neural Network (ANN) is applied in this study to develop the Trip Generation Model. In developing the ANN,

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70-15-15 data distribution was considered for training, validation, and testing. Random sampling was considered in the data allocation. This gives 640 samples for the training, 137 for the validation, and 137 for the testing.

Independent variables used in the ANN were selected based on the Pearson correlation analysis [24]. Using the IBM SPSS v23 software, the correlation, R, of each independent variable with the trip frequency was determined (see Table II). V3, V1, V6, and V5 have R values of more than 0.5. This means that household members who fall under 7 to 59 years old tend to have a more positive effect on trip frequency, which implies that this age group has more frequent trips than children under 7 years old and senior citizens. Furthermore, No. of students and No. of working members show positive associations with trip frequency, which supports the survey results on trip purpose (see Fig. 7). Despite having a low correlation, V4, and V11 show a negative relationship with trip frequency. This infers that age can be a contributing factor to why people travel less. As people become older, the lesser their ability to generate trips.

To check for multicollinearity amongst these four variables, Variance Inflation Factors (VIF) are observed. VIF values of 3.58, 1.42, 1.89, and 2.90 were computed for V3, V5, V6, and V1, respectively, which are all less than 5 indicating the absence of multicollinearity [30]. Therefore, these variables are deemed good for ANN application.

A 4-4-1 ANN is structured using MATLAB R2021a. Correlation values for training, test, and validation are 0.851, 0.851, and 0.835, respectively (see Table III), which are classified as very strong correlations [30]. This means that the model was able to explain 85% of the relationship between the output and input variables. The regression plot (see Fig. 9) describes that there is indeed a linear relationship between the target and output variables. Moreover, the ANN model prediction was 5.43 home-based trips as against 5.28 home-based trips from field results, thereby giving an absolute percentage error (MAPE) of 2.984%.

Table 2: Pearson Correlation

Variable Name	V13 Trip Frequency
V1 Household Size	0.688
V2 Children under 7 years old	0.056
V3 No. of Members 7 to 59 years old	0.762
V4 No. of Senior Citizens (60 years old and above)	-0.134
V5 No. of Working Members	0.581
V6 No. of Students	0.619
V7 No. of Helpers	0.134
V8 No. of Motorized Vehicle	0.254
V9 Income	0.211
V10 Highest Educational Attainment of the Household Head	0.050
V11 Age of the Household Head	-0.085
V12 No. of Driver's License Holders.	0.194

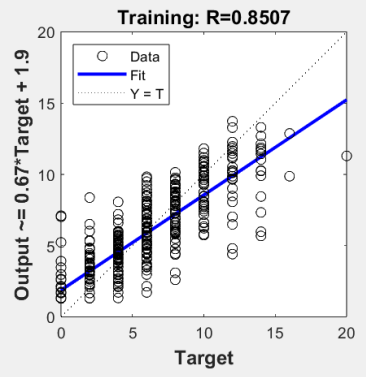

Fig. 9 Training Regression Plot

Table 3: ANN Result

	R	MSE
Training	0.851	3.44
Test	0.851	3.60
Validation	0.835	4.38

V. CONCLUSION

On average, the rural household in Angalan is composed of 3.96 members, and these are mostly students, workers, and children. The economic condition in the community is not ideal, with lesser commercial establishments, and people are only dependent on informal employment such as farming and service work. In fact, the majority of households belong to low-income families, and most household heads are only high school graduates which limits their income-generating capability. Despite the economic dilemma, it has been observed that more than half of the household population owns at least one motorized vehicle, mostly a motorcycle, to suffice the lack of transportation facilities.

The divisions in income level reflect the diverse characteristics of rural household members on how they travel on a day-to-day basis. LIC and MIC households include walking as one of their transportations. Few to no public transport are able to reach remote places within the barangay. Furthermore, a significant number of trip-makers also travel outside of the community, which includes workers, and thus Public Utility Vehicles become the most preferred mode choice. Trip to work and trip to school are the most prominent trip purpose for LIC and MIC households, attributable to the number of students and workers in the family. These contribute to the number of trips that a rural household generates per day. Artificial Neural Network proves a strong correlation between trip frequency with variables household size, no. of students and workers, and no. of members between 7 and 59 years old showing R values of more than 0.8. This entails that in rural communities, households travel more often for practical reasons. Travel for

leisure or other purpose was observed to be limited.

In conclusion, it is no doubt that public transportation is the preferred mode choice for rural residents. It is therefore important for the government to improve transportation facilities and include rural communities in policymaking to accommodate transport demand.

VI. ACKNOWLEDGMENT

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