Calibration of the Gravity Model for Estimation of UPLB Employee Trips using Origin-Destination Data

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Abstract: The study includes calibrating the gravity model, and projecting trips using the calibrated model and the fratar method up to 30 years, assuming constant socio-economic conditions and spatial separation. Actual data was obtained from interview of University of the Philippines Los Baños (UPLB) employees and used to calibrate the model. The socio-economic factor in the gravity model was expressed as a function using multiple linear regression and was assumed to be effective for all zonal trips. Using the origin-destination data, it was found that the nature of attraction and generation of trips of the UPLB employees lie on their work classification. Results show that there seem to be a large difference between the total trips generated by fratar and gravity model, with the former being the larger. In the gravity model, the growth rate of trips per year corresponds to 1.59%, whereas for fratar method, it is 2.83% on an average.

***Key words*:** Gravity model, Model fitting, Transportation, UPLB employees

1. INTRODUCTION

Efficient transportation of utilities is a necessity in urban development. Planners set constraints and define (an) optimum condition(s) for the network of interest. Depending on the liberty of time and resources, these optimum conditions are either defined or approximated through theoretical methods, heuristics, or simulations wherein the methods' reliability is checked by comparing it to actual data. Since constraints and optimum conditions are identified, these variables can be combined to develop models.

Models are idealizations of processes and phenomena, or techniques of thinking that are governed by a set of assumptions (Davis *et al.*, 2006; Cascetta, 2009). Models are then fueled by origin-destination (O-D) matrices. Origin-Destination (O-D) matrix is a generally-used method for strategic planning and management of terrestrial infrastructure networks. In O-D Matrices, trip distributions can be obtained or estimated. FHA (1983) stated the importance of estimating trip distributions in the transportation planning process, as it provides the planner with a systematic procedure for estimating zonal interchanges that can be used for both "land use and transportation facilities." Trip distribution is an integral part of the transportation planning process.

The population of faculty in the University of the Philippines Los Baños (UPLB) as of December 2015 is roughly 3700, according to Human Resource Development Office (HRDO) in UPLB. The trips by the employees also contribute to traffic flow, thus affecting the economy of the areas where trips originated and ended (e.g. distribution of goods and services, of Los Baños and a neighboring town).

This study aims to help planners or people in development positions in UPLB, in terms of constructing effective transportation networks, and determining impacts of new institutions or proposed buildings to transportation, economy, environment, and other aspects of concern. Also, it aims to open studies of trip estimation in UPLB and to advance knowledge-base in Transportation Engineering, specifically in trip estimation and modeling, in the Department of Civil Engineering. The data obtained and used in the study was intentioned to be the baseline data that can be used for the UPLB land use master plan.

The main objectives of this study were to calibrate the gravity model in the UPLB setting, and estimate UPLB employee trips using the calibrated gravity model. Specifically, it aims to: (1) calibrate the friction factor for the gravity model; (2) express the socio-economic adjustment factors as a function using multiple linear regression; (3) check if the function satisfied the assumptions for a regression model; and (4) project trips up to 30 years using the fratar and the gravity model.

2. CONCEPTUAL FRAMEWORK

2.1 Developing Models

Developing models are different for specific scenarios, but can be generalized into six basic steps: (1) specification, (2) estimation, (3) implementation, (4) calibration, (5) validation, and lastly, (6) application.

For specification, trips are assumed to be dependent on demographic and socio-economic factors which would be enumerated in section 3.1.

In this study, the Gravity model was used for estimating employee trips in UPLB for the following reasons: (1) the study focused on the trip distribution of UPLB employees. Thus, the gravity model and the entropy model are the best choices for trip distribution estimation; (2) a macroscopic approach in viewing zone relationships was considered due to data gathering costs. If a microscopic approach was considered, this would imply more variables to consider thus, contributing to an increase in survey pages and more time in conducting the survey; (3) the origin-destination data is a baseline data. Thus, Bayesian estimators are not applicable yet since, they require *a priori* data; and (4) time constraints for completing the study within the allotted time was considered.

2.2 Modified Gravity Model

The modified gravity model was used to suit the conditions and assumptions made for the study. Equation 1 shows the modified gravity model in which the number of employees is multiplied by their average frequency. More or less, the frequencies are average due to the assumption that a larger percentage of the employees work five days in a week.

Another important variable considered in the study is the trip attraction of employees. According to FHA (1983), the trip attraction can be expressed as a function of the gravity model. In the UPLB setting, the trip attraction can be defined as the slots available for employment wherein the number of employees in a given destination zone shall be limited to the capacity of inclusive institutions.

$$T_{ij} = \frac{A_j F(C_{ij})_{ij} K(s.f.)_{ij}}{\sum_{allzones,n} A_x F_{ij} K(s.f.)_{ix}} \times P_i \times f_{ij} \quad (1)$$

where T_{ij}: trips produced at i and attracted to j

P_i: total trip production at i

A_j: total trip attraction at j

$F(C_{ij})_{ij}$: calibration term for interchange ij, (friction factor) or travel time factor and is computed using $e^{-c\times(C_{ij})}$

C_{ij}: impedance variable

c: non-negative calibration constant

$K(s.f.)_{ij}$: socio-economic adjustment factor for interchange ij dependent on variables, $s.f.$

i: origin zone,

j: destination zone

n: number of zones

f_{ij}: average frequency of employees

The socio-economic adjustment factor for trips were estimated using multiple linear regression by ordinary least squares (OLS) approach. The OLS approach was used since it is less mathematically rigorous than maximum likelihood approach. The model is developed by stepwise regression, backward elimination approach (Gujarati *et al.*, 2009).

2.3 Fratar Method

This method was used to compare the projection results to the calibrated gravity model. This model is similar to the uniform growth factor method, but takes into account the effect of distribution growth.

The study has three general phases, namely: (1) acquiring O-D data, (2) calibrating the gravity model, and (3) projecting trips. Figure 1 shows framework of the study. Phase 1 included the identifying data to be gathered, sorting, and converting them into useful forms. Phase 2 included the implementation and calibration of the gravity model and its parameters. Lastly, phase 3 included the verification of the model and comparing projection results to fratar method trip projection.

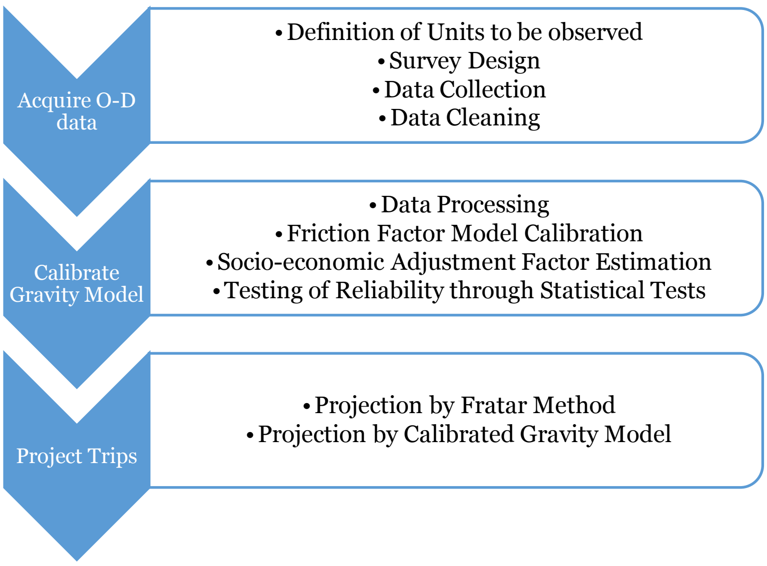

Figure 1. Framework of the Study

3. METHODS

3.1 Survey Design

Cascetta (2009) stated that the survey design includes determining the sample size, the sampling strategy, and questions in the survey (questionnaire) which is the most critical part of the study. Quality of data must be the priority in modeling since the model is only as good as its assumptions.

For this study, the total population size, N, is 3721 which was obtained using the data requested from HRDO. The precision required or margin of error, d, was set at 0.04. The estimated percentage of population, p, was assumed to be 0.5 if percentage is not clear. And z was set at 1.96, corresponding to a 95% confidence level. The actual sample size was higher than the computed sample size needed with replacement (set as 10%) with only 316.

The sampling technique used in the study is by random sampling. The strata of the population were patterned to the set land use plan of UPLB, and is generated using QGIS 2.14 (Figure 2). The area was divided into 10 zones that are shown in Table 1. These zones shall be the destination zones of the matrices, while the origin zones shall be obtained from the survey results.

The questionnaire contained information related to demographics and socio-economic data of employees such as: (1) present address and its characteristics, (2) age and gender distribution, (3) educational attainment, work classification in UPLB, annual income, (4) willingness to stay in UPLB, (5) vehicle ownership, (6) purpose and frequency of travel, (7) travel cost, and (8) route and mode choice. Purpose of travel was assumed to be home to work and work to home only. However, for the purpose of capturing patterns such as trips in between home and work, purpose of travel was still included.

Figure 2. QGIS 2.14 rendered photo of the zoning of destination points

Table 1. Zoning for Destination Points

Zone Number	Zone Name
I.	Arts and Sciences and Development Studies
II.	Agricultural Sciences Complex
III.	Veterinary Medicine Complex
IV.	Engineering and Agro-Industrial Technology Complex
V.	International Linkages and Graduate Studies Complex
VI.	Forestry Complex
VII.	UP Rural High School Complex
VIII.	Science and Technology Park
IX.	Limnological Station
X.	Veterinary Medicine Hospital

3.2 Modeling Approach

An algorithm was developed in order to estimate the socio-economic adjustment factor (K-factor) for each O-D pair via iteration process until convergence from the actual value, or an error of less than 0.00005 was obtained. Figure 3 shows the algorithm used in the iteration process.

The goal of the algorithm is to minimize the errors for the O-D pair with maximum error, at a given iteration set, until the tolerance value of 0.00005 is achieved. In essence, the iteration process was composed of the following phases: (1) determination of the O-D pair with the maximum error per origin zone, (2) updating the value of K-factor for the corresponding O-D pair with maximum error, (3) re-computing the errors, and (4) repeating the process until convergence or less than 0.00005 error for all O-D pairs in an origin zone is achieved.

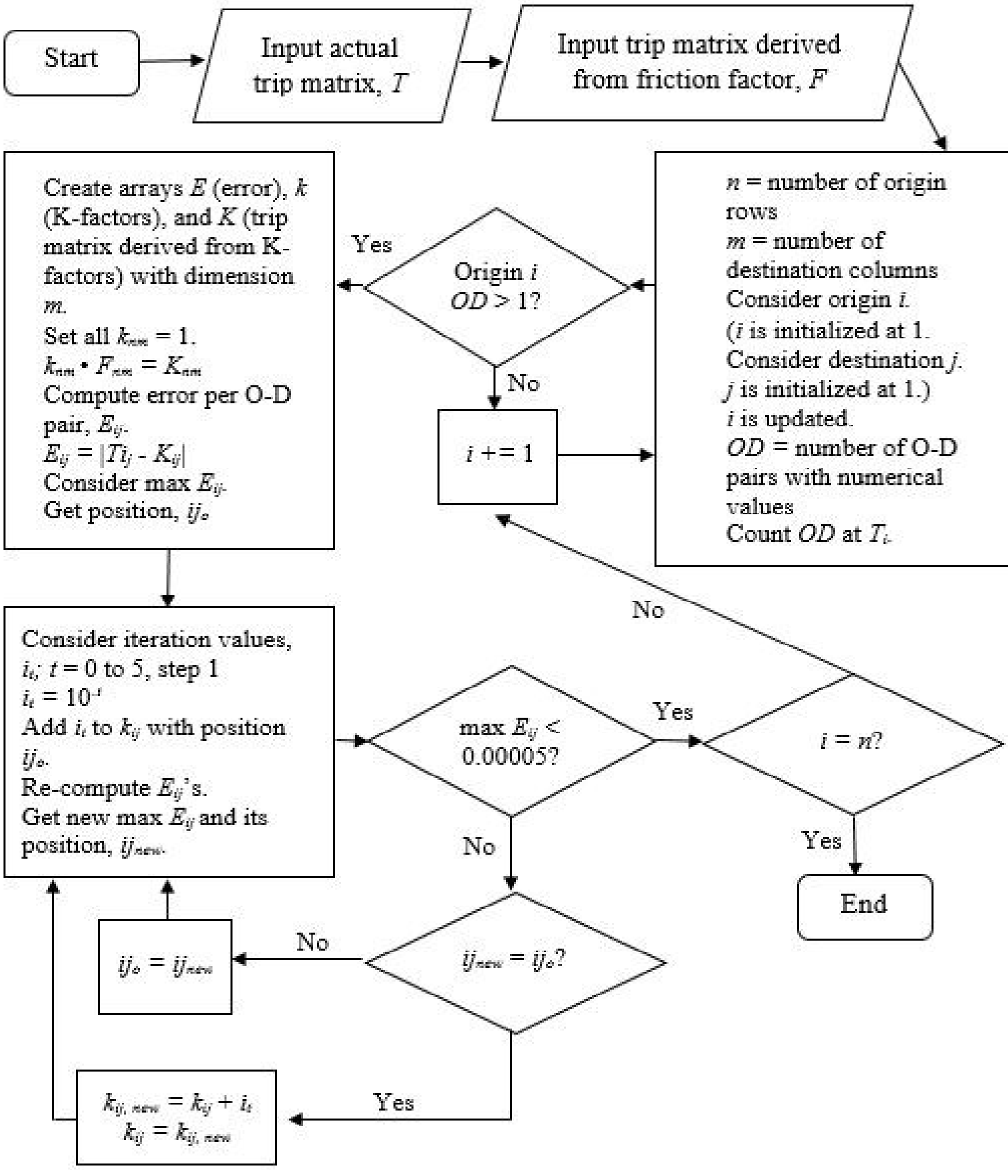

Figure 3. Algorithm for the Iteration process in K-factor Estimation

Likewise, the friction factor model in exponential form was also calibrated by constructing first the trip matrix derived from the skim matrix. The appropriate skim matrix was the minimum time of travel (FHA, 1983). To validate the reliability of the calibration factor, the average trip length of the derived trip matrix was compared to the observed average trip length by percent error. The observed average trip length was derived from the actual O-D daily trip matrix. In general, the average trip length was computed using the ratio of the dot product of matrices, T and F, and the sum of all values in matrix T where T is the trip matrix and F is the skim matrix.

The statistical software used for running the statistical tests (OLS approach) was STATA 12.0. The program was licensed and available for use in the Institute of Statistics. In order to use the OLS approach, the assumptions listed in Table 2 must be satisfied (Gujarati *et al.*, 2009).

Table 2. Statistical Tests used in STATA 12.0

Assumption	Statistical Test Used or Verification Method
Linear Functional Form	Pairwise graphs between the dependent and independent variable
Zero Mean of Disturbance	One -sample t-test
Uncorrelatedness of the Regressors to the Disturbance Term	Pairwise correlation between error and independent variable
Homoscedasticity	Breusch-Pagan/Cook-Weisberg test
Non-autocorrelation	Pairwise correlation between error and lagged error
Normality	Shapiro-Wilk W-test; Standardized normal probability graph
Multicollinearity	Mean Variance Inflation factors (VIF)

3.3 Trip Projection

The present trip distribution, and a future trip demand and attraction are necessary in the Fratar method. In this study, the future trip generation and attraction were assumed to grow in a linear fashion. The growth rates used for the projection were taken from the Department of Public Works and Highways (DPWH) traffic growth rate table. However, for simplification of projection computation, the growth rates were limited into two: (1) passenger car for private transport trips, and (2) passenger utility for public transport trips with growth rates 3.199 and 2.528, respectively. The daily trip matrix was split into private and public trip distributions then, applied with the growth factor to yield the future trip generation and attraction.

In the Fratar method, the trip distribution was further adjusted since the actual sum of trips on either the origin zones or the destination zones was not equal with the target generation and attraction. A balancing factor was introduced as the ratio of the target and actual trip ends. The process was repeated until all the balancing factors approached unity.

In estimating the projected population of employees, the growth rate was obtained by taking the slope of historical employees growth rate in UPLB for the last 5 years. The growth rate was assumed to be constant for simplification of analysis.

4. RESULTS AND DISCUSSION

4.1 Calibration of the Friction Factor

Results of the survey shows that there are forty-one origin zones identified and are listed in Table 3. The obtained calibration factor, C, that was fitted in the skim matrix of minimum travel time was 0.075132. As suggested by FHA (1983) that the friction factor skim matrix must be the travel time since travel time is a good spatial parameter in the gravity model.

To check the adequacy of the friction factor, F_{ij}, the observed average trip length must be close to the average trip length generated by the friction factor alone. In the computation, the average trip length via F_{ij} is 13.52 min having 2.03% error relative to the observed average trip length in the daily employee trip O-D of 13.80 min.

Applying the friction factors and assuming the K-factors to be unity, large percentage errors were observed by comparing the computed to the actual trip matrix, requiring K-factors to be utilized. Two observations were noted from the data—zonal interchanges (ZIs) with large and small differences in the generated trip and actual target trip. The ZIs with large differences could be broken down into two categories that are ZIs with high, and low impedances. ZIs with high impedances are expected to have low demand. However, it was observed that ZIs with large differences and high impedances have a very high actual demand relative to what was expected. This result could be due to employees qualifications that address the needs of the University (e.g. high educational attainment). For ZIs with large differences but low impedance, the high disparity could be explained by the limitations of a certain destination zone (i.e. employee demand), and as well as the inability of the population of an origin zone to meet the criteria of a certain destination zone (i.e. educational attainment).

Table 3. Origin Zones of UPLB Employees

Zone Number	Origin Zone	Zone Number	Origin Zone	Zone Number	Origin Zone
1	Lipa, Batangas	15	Lecheria, Calamba	29	Maahas, Los Banos
2	Imus, Cavite	16	Looc, Calamba	30	Malinta, Los Banos
3	Calo, Bay	17	Masili, Calamba	31	Mayondon, Los Banos
4	Masaya, Bay	18	Mayapa, Calamba	32	Putho, Tuntungin, Los Banos
5	Paciano Rizal, Bay	19	Milagrosa, Calamba	33	San Antonio, Los Banos
6	Puypuy, Bay	20	Palo-Alto, Calamba	34	Timugan, Los Banos
7	San Agustin, Bay	21	Real, Calamba	35	Pagsanjan
8	San Antonio, Bay	22	Dayap, Calauan	36	Pila
9	San Isidro, Bay	23	Ilayang Palina, Liliw	37	Rizal
10	Sto. Domingo, Bay	24	Anos, Los Banos	38	San Pablo
11	Marinig, Cabuyao	25	Bambang, Los Banos	39	San Pedro
12	San Isidro, Cabuyao	26	Batong Malake, Los Banos	40	Siniloan
13	Bucal, Calamba	27	Bayog, Los Banos	41	Duhat, Sta. Cruz
14	Halang, Calamba	28	Lalakay, Los Banos		

4.2 Socio-economic Adjustment Factor Function

After several trials and runs in the program and by backward elimination stepwise regression analysis, the model that best satisfied the K-factors was developed and is shown in Equation 2. Table 4 also shows the constant values and their corresponding significance.

$$\ln(iK_{ij}) = \beta_0 + i\beta_5 x_{5,ij} + i\beta_6 x_{6,ij} + i\beta_7 x_{7,ij} + i\beta_8 x_{8,ij} + i\beta_{16} x_{16,ij} + i\beta_{17} x_{17,ij} + i\beta_{29} x_{29,ij} \quad (2)$$

where i: origin zone numeric value

K_{ij}: socio-economic adjustment factor for interchange ij

β_z: derived coefficient corresponding to a variable z

$x_{5,ij}$: ratio of employees from zone i to j that are 18 to 25 years of age

$x_{6,ij}$: ratio of employees from zone i to j that are 26 to 35 years of age

$x_{7,ij}$: ratio of employees from zone i to j that are 36 to 45 years of age

$x_{8,ij}$: ratio of employees from zone i to j that are 46 to 60 years of age
$x_{16,ij}$: ratio of employees from zone i to j whose highest educational attainment is Masters
$x_{17,ij}$: ratio of employees from zone i to j whose highest educational attainment is Doctorate
$x_{29,ij}$: ratio of employees from zone i to j that receives an annual income greater than 500,000 PhP from UPLB

The multiplier, i, which is also the origin zone i, was used to linearize the values of K-factors and regressors. Also, by taking the natural logarithm of the transformed K-factors, iK_{ij}, the linearity of the function was improved. It was noted that the constant, β17, has a significance value of 8.1% which is greater than the set significance value of 5%. The variable corresponding to β_{17} was still considered in the model development since it is instrumental in the linearity of the function.

Table 4. Coefficient Values in the K-factor Function

Coefficient	P > |t|	Value
β_5	0.000	0.0436361
β_6	0.000	0.0535161
β_7	0.000	0.0440570
β_8	0.000	0.0702082
β_{16}	0.035	0.0382547
β_{17}	0.081	0.0353332
β_{29}	0.001	-0.0553021
β_0 *(constant)*	0.000	2.5766050

The value of K_{ij} cannot be negative since it was estimated in the form of a natural logarithm. The O-D pairs that were found to be dependent on the K-factor function are shown in Table 5.

Table 5. K-factor-dependent O-D Pairs

O	D	O	D	O	D	O	D	O	D
3	1	10	1	24	5	29	1	32	6
3	8	10	2	24	8	29	4	32	8
4	1	10	6	24	9	29	6	32	10
4	2	12	1	26	1	29	8	33	1
4	3	12	6	26	2	31	1	33	2
4	4	18	1	26	3	31	2	33	4
4	8	18	2	26	4	31	3	33	6
4	9	22	1	26	5	31	5	33	10
4	10	22	2	26	6	31	6	34	1
5	1	22	3	26	7	31	7	34	4
5	2	22	5	26	8	31	9	38	4
5	7	24	1	26	9	32	1	38	6
5	8	24	2	26	10	32	2	38	7
6	1	24	3	27	1	32	3		
6	8	24	4	27	4	32	4		

The result of regression analysis using STATA 12.0 has the following statistical parameters: (1) number of observations = 73, (2) adjusted R-squared = 0.4954, (3) root MSE = 0.72062, and (4) Probability > F = 0.0000. The obtained R-squared was satisfactory for modelling variables that is behavioral in nature. Since the Probability > F is almost equal to zero, the null hypothesis that all of the model coefficients are zero is rejected, proving that the variables are significant. The root MSE obtained in this regression was the smallest value upon finite trials made.

Figure 4 shows the plot in testing of the linear functional form of the K-factor regression analysis. The plot shows how the *lnytrans* (*ln* (*iKij*)) was plotted as the dependent variable against the regressors $ix_{5,ij}$, $ix_{6,ij}$, $ix_{7,ij}$, $ix_{8,ij}$, $ix_{16,ij}$, $ix_{17,ij}$, and $ix_{29,ij}$. Furthermore, it can be observed that the plot somewhat follow a relationship between a linear and square root function, thus explaining the value of the adjusted r-squared.

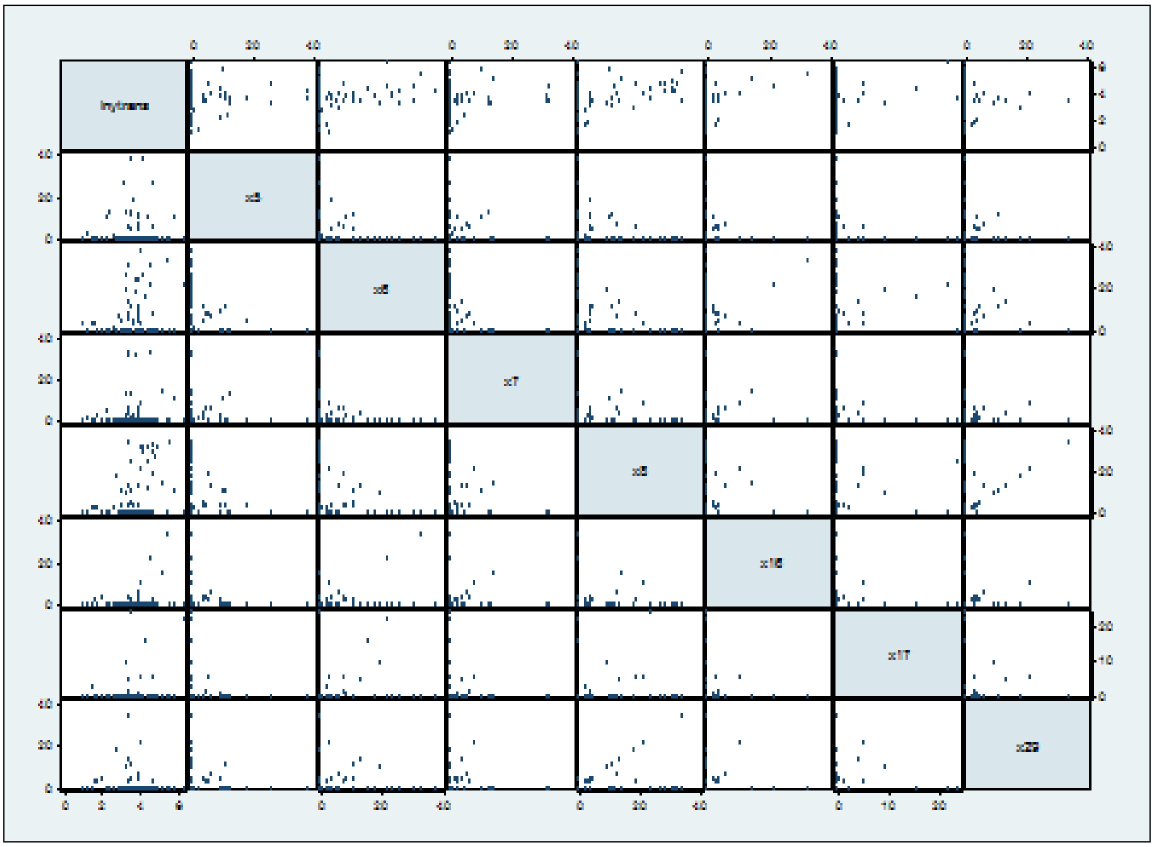

Figure 4. STATA results in testing of the linear functional form of the K-factor regression

Result of the one sample *t*-test shows that the actual mean of the error was reported as 1.12×10^{-9} which is near zero. Also, the t-value is zero, therefore the null hypothesis that the mean is zero was accepted, thereby satisfying this condition. Likewise, the pairwise correlation analysis indicated that there was no correlation between the error and the regressor terms since, their significance values were equal to 1.0000 which is greater than the set significance of 0.0500.

Breusch-Pagan/Cook-Weisberg test for heteroscedasticity was also performed to check if the variance of the mean is constant. The chi-square value was small, and Prob > chi2 is equal to 0.4249 which is greater than the significance level of 0.0500, thereby satisfying the assumption of homoscedasticity of the mean variance.

To check wither the error is normally distributed, a Shapiro-Wilk *W*-test was performed for normal data, and the resulting Prob > z was equal to 0.53096 which is greater than the 0.0500 significance value. Also, the test statistic, *W*, was found to be 0.98485 which is greater than the significance value. Therefore, it can be concluded that the errors were normally distributed. Figure 5 shows the standardized normal probability graph for the errors.

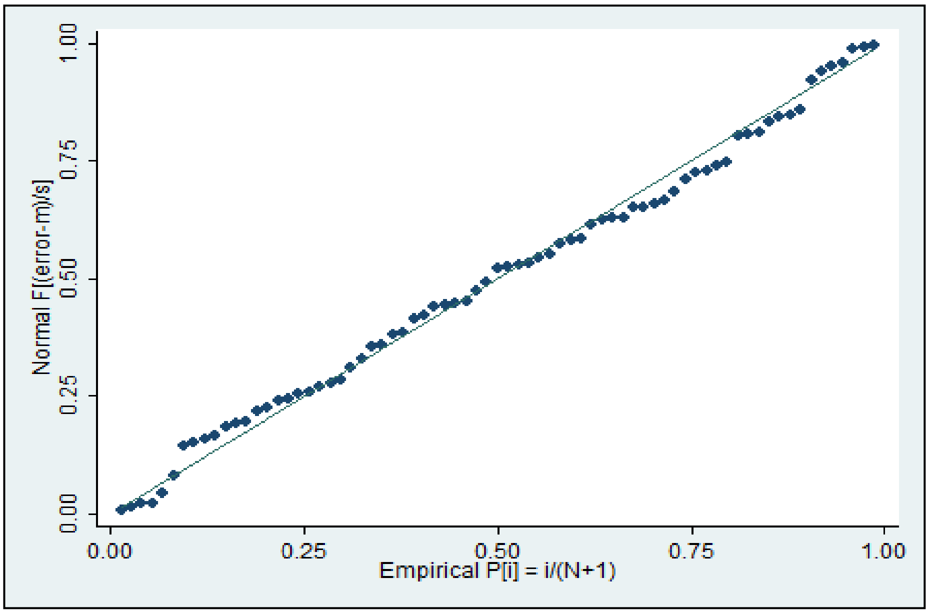

Figure 5. STATA results in testing for normality by a standardized normal probability graph.

All of the assumptions for regression analysis were satisfied. Therefore, the regression obtained is fit to be considered as a regression equation. However, the K-factor function variables seemed to be difficult to obtain since these are information involving age distribution, educational attainment distribution, and annual income distribution which are normally not recorded. If the function will be used to assess the present condition, the process of acquiring the variable data will be tedious since it would involve surveys or a change/addition of data needed for each zone. To remedy the problem presented, it is suggested that the proposed model be used only to predict future condition, given the age, educational attainment, and income distribution is known.

4.3 Observed Nature of Trip Generation in UPLB

Based on the origin-destination data, trip generation in UPLB can be described by the work classification of employees. In general, employees are generated by the opportunities present in a given destination zone. Figure 6 shows a summary of the relationship of work classification and the influencing factors in trip generation. Attributes of the employees separated according to their work classifications were taken into account for the change in trip generation. These attributes are education, their willingness to stay in UPLB, trip frequency per week, and minimum travel time. The data from these attributes were interpreted in relation to trip attraction, volatility, trip contribution, and spatial factors. The following explanations are only inferences based on inspection of the O-D data. Statistical tests can be used to verify the observed relationships. However, the tests were not done since they were not part of the scope of the study. These inferences were done only to provide interpretation of the O-D data. Also, to simplify the explanations, NGWs and FACs will only be compared. Statements about the comparisons of the two may not necessarily apply to the ADMs, REPS, and FAC-REPS.

People become employees for a certain institution if they met the requirements set by that institution. That mentioned, Figure 6 shows that employees under the NGW work class were generated more (or being attracted by) in UPLB as compared to the employees under the FAC work class, in terms of educational requirements. This observation is logical since, the lesser the requirements of employment, the easier it is to become an employee. And the easier it is to become an employee, the more attractive employment in UPLB becomes for the general public. Employees categorized as NGWs have lower requirements as compared to FAC employees. Since this is the case, more people become employees under the NGW work class. The only limit for the attraction is the employee demand per institution under the NGW work class.

Volatility in trip generation was described using the employees' data on willingness to stay in UPLB. Volatility, in the context of trip generation, is the tendency of the trip-makers to either contribute to the present trips or decrease it. In this study, volatility was measured in years. The categories of the employees' willingness to stay can be interpreted as the probability that they will be working in UPLB. The general idea was that, trips are generated by the employees, and if there are no employees, no trips would be generated. It was observed that NGWs are more volatile as compared to FACs. By observation, most FACs aim to be tenured thus, their trip contributions are mostly reliable. For NGWs, they do not have much benefits in the long run thus, they tend to stay lesser in years as compared to FACs. However, the variance of their willingness to stay in years is large for the work classifications therefore, the observation was not strong. Nonetheless, this observation can start more research on the volatility of employee trips per year in UPLB. Sensibility analyses can be performed to see the changes in trip distribution over time.

Trip contribution is related to the trip frequencies of employees. Based on Figure 6, NGWs contribute more trips as compared to FACs. The contribution was expressed in terms of rate where the trip contributions either increase or decrease over time. NGWs contribute constant or more trips over time since the magnitude of their salary is dependent on their work hours. For FACs, their trip contributions tend to lessen over time.

Spatial factors are made to impede the trips done by trip-makers. In Figure 6, NGWs trips are more dependent on spatial factors as compared to FACs. The O-D data shows that many NGWs come from zones with smaller time travels whereas some FACs are not dependent on it. This is probably due to access of FACs to other mode of transport such as cars that lessens travel time (if less congested roads were taken), and annual income (higher than that of NGWs).

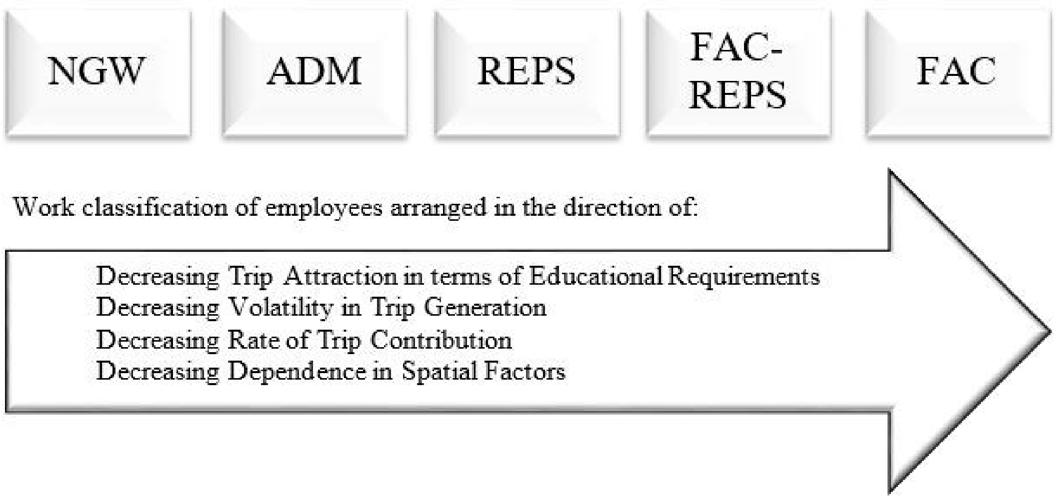

Figure 6. Schematic relationship of the influencing factors in trip generation and work classification*

**Non-government Workers (NGW), Admins (ADM), Representatives (REPS), Faculty-Representatives (FAC-REPS), and FAC (Faculty)*

4.4 Trip Projection Results

Projecting trips via the calibrated gravity model utilized the K-factor function and the friction factors. Then, the obtained employee count was multiplied by the corresponding frequencies of travel. For the population of the origin and destination zones, their growth rate and proportion were assumed to be constant for simplification of analysis. The regular employee population growth rate used was that of year 2015. This was computed by taking the derivative of the fitted parabolic curve shown in Figure 7, and getting the slope of year 2015. The rate computed was approximately 59 regular employees per year, reaching a population count of 5491 employees by year 2045 assuming constant number of NGWs.

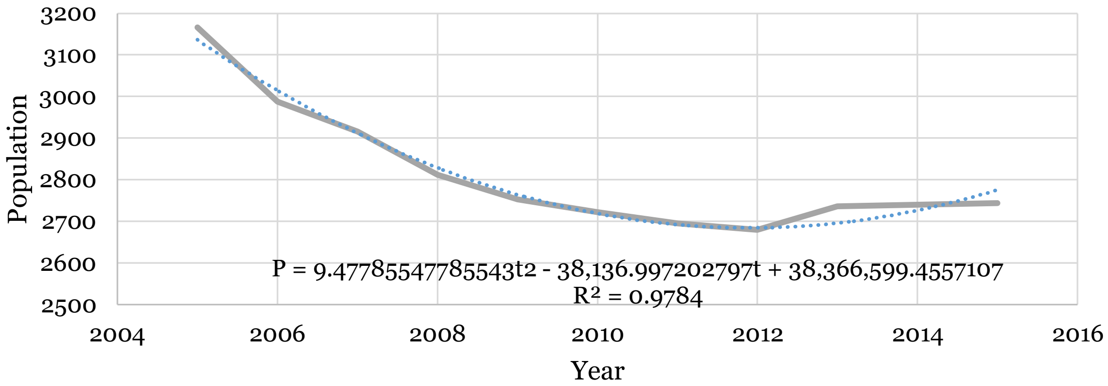

Figure 7. Population of UPLB Regular Employees per year

For projecting trips using the fratar method, the UPLB employee matrix was first broken down into the corresponding public and private transport trip converted to weekly trip matrices. By summing the total trips projected from the public and private transport matrices, the future trip matrix was generated. Comparing the two results, there seem to be a large difference between the total trips generated by fratar and gravity model, with the former being the larger (Figure 8). The difference evidently lies on the method of projection wherein trips were directly amplified in the fratar method, and employees in the gravity method. In the gravity model, the growth rate of trips per year corresponds to 1.59%, whereas for fratar method, it is 2.83% on an average.

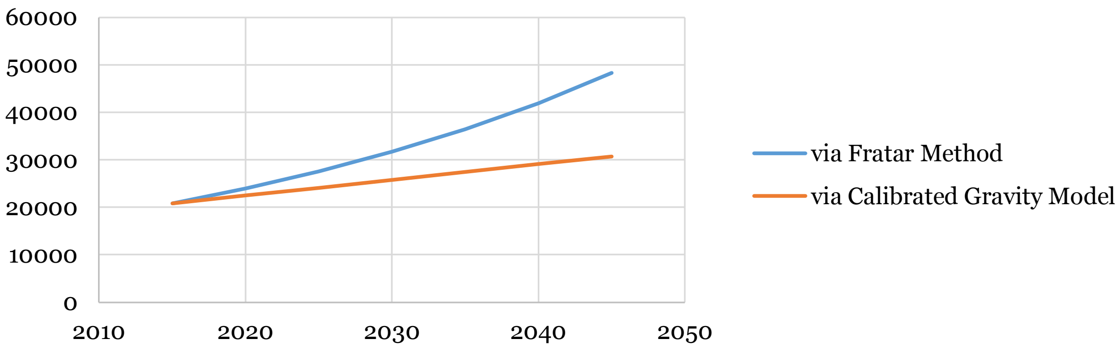

Figure 8. Superimposed Total Trips generated via Gravity Model and Fratar Method

Clearly, the more realistic projection in terms of number of trips generated is the gravity model while the fratar method is more reliable in term of trip distribution. It should be noted that the gravity model did not account for the change in trip distribution because of the assumptions made (i.e. constant K-factors and friction factors). This was made for simplification of analysis, even though in actual, the change in distribution is more probable due to the length of years considered in the projection (i.e. 30 years).

Furthermore, McKee *et al.* (n.d.) found that population projections are variables of labor force projections. In the case of the study, this is the growth of the employee population in UPLB. They identified that as older age group distributions in an origin zone increases, labor force decreases in a specific destination zone. However, this is not always the case for UPLB since every year, or as frequent as a semester, employees are renewed, and trips made are strongly related to the employees' work classification.

In terms of destination zones, age group distributions vary per zones as these are affected by the culture of the institutions (i.e. tends to hire younger age groups), and the goals of the employees (i.e. to be tenured).

In terms of work classification, NGWs and ADMs tend to maintain their frequency of trips over time since their salaries are dependent on the time they serve (i.e. Daily Time Record (DTR)). Whereas REPS, FAC-REPS, and FACs can be divided into two groups: (1) volatile, and (2) permanent employees. The permanent employees are those who aim for the benefits of long-term employment in UPLB (i.e. to be tenured) whereas, volatile employees are observed to seek employment based on, for instance, work experience.

Educational attainment distributions in UPLB are also dependent on age distributions, especially for FACs, since FACs are expected to pursue higher degrees to continue employment. However, it has been observed that it is not necessarily true for all FACs as can be seen in the O-D data for FACs under the Willingness to stay in UPLB section.

The findings of McKee *et al.* (n.d.) also support the obtained negative slope for the distribution of employees receiving an annual income greater than 500,000 PhP from UPLB. Most probably, it is because of tenured FACs that also belong to older age groups; since they tend to keep their work load to a minimum thus, having lower trip frequencies. For NGWs and ADMs, this does not hold.

5. SUMMARY AND CONCLUSION

This study calibrated the Gravity model in the UPLB setting using origin-destination data. These data were obtained by assisted surveys wherein the sampling strategy is stratified random sampling. The population was sampled with 95% confidence, 4% margin of error, and 0.5 default value for the percentage of the population's attribute of interest. Ten destination zones for UPLB and forty-one origin zones were identified using the origin-destination data. The data were cleaned and converted into useful parameters.

In the model, the friction factor and the K-factors were calibrated. The friction factor was modelled using an exponential form model, with calibration factor, C, is equal to 0.075132—2.03% percent error from the observed average trip length. The K-factor function was modelled using multiple linear regression. Stepwise regression analysis by backward elimination approach was employed in the model development phase. Parsimony of the regression was not achieved (with an adjusted R-squared equal to 0.4954) since it took seven variables for the equation to satisfy the regression assumptions. The statistical tests undertaken by the function were: (1) linear functional form, (2) zero mean of disturbance, (3) uncorrelatedness of the regressors to the disturbance term, (4) homoscedasticity, (5) non-autocorrelation, (6) normality, and (7) multicollinearity.

It has been observed that the trip generation of employees in UPLB and the trip attraction of UPLB in terms of employees are based on and vary with work classification such as, NGW, ADM, REPS, FAC-REPS, and FAC. The work classifications stated are ordered in decreasing trip attraction in terms of educational requirements, decreasing volatility in terms of trip generation, decreasing rate of trip contribution, and decreasing dependence on spatial factors. NGW employees are generated more as compared to FAC employees. NGW employees are more volatile as compared to FAC employees but, this observation is not strong due to high variances. NGW employees are more likely to increase or maintain their trips due to the nature of the salary. FAC employee trips are less dependent on spatial factors.

Employee trips were also projected to 2045 using the calibrated Gravity model and the Fratar method. The Fratar projection has shown a great difference in projection with respect to the Gravity model since the average increase of trips per year in this projection is 1.24% greater than that of the Gravity model. The Fratar method also made minimal changes in the distribution of zonal interchanges comparing to the constant distribution assumption in the Gravity model. Also, it has been emphasized that age group distributions and work classifications of the employees play an important role in the projection of trips. It has been said that FACS, FAC-REPS, and REPS vary on trip frequencies over time compared to ADMs, and NGWs, where trip frequencies are perceived to be constant over time due to their salaries being heavily dependent on time.

Models enable the planners to predict changes in dependent variables of interest to aid in strategic planning and management of terrestrial infrastructure networks. In the case of this study, it was identified the best and doable model (considering data obtained and assumptions of investigated models) for predicting UPLB employee trips was the Gravity model. But a model is only as good as its assumptions. In order to increase the predicting power of the model, the assumptions must be better where they describe a phenomenon more comprehensively. And to have better assumptions, a clearer understanding of the phenomena is needed.

6. RECOMMENDATIONS

To further advance the knowledge-base of this study and to improve or develop other prediction methods or models of UPLB employee trip generation and distribution, it is recommended that the following be considered: (1) other estimators for UPLB employee trips should be considered; (2) an econometric model approach for estimating trips should also be considered; (3) the socio-economic adjustment factor, K-factor, function should be improved by formulating an equation per O-D pair; (4) the friction factor in UPLB should be investigated if it varies with time; (5) the employee attraction should be investigated further; (6) trips contributed by non-UPLB constituents such as tourists, etc. can be considered given a significance for this study is realized; (7) estimate origin-destination tables based on assumptions and models; and (8) perform sensibility analysis for the values of distributions and projections.

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