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Improvement of Trip Attraction Model in Surabaya by Considering Geographical Weighting of City Centre Activity Function

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***Abstract*— It is challenging to have a trip attraction model that fits Surabaya's surveyed data due to unclear city centre structure. These include the centrum of concentric, corridors of sectoral, or several centres of multiple-nuclei structures. Also, the layout of residential areas has unconventional patterns. This is because the planned housing development area is wrongly inserted on kampong and sometimes lies in city centre. This paper examines the influence of single-centre districts, corridors, or multiple suburb centre structures on trip attraction. The analysis was conducted using origin-destination data from the household interview survey by The Transportation Board of Surabaya and several houses digitized from a relevant year's satellite image. The distance and position information was taken from the Google Earth application. The zonal analysis trip attraction model based on the sub-district zoning system was analysed using fixed trip production data and simulated independent variables. The independent variables included the zonal activity areas such as shops, offices, and industries in sub-district, while the dependent variables consisted of the straight distances from the sub-district to city centres. Several models were tested based on the dependent and independent variables. The results show that the combined zonal activity area and spatial variables have a stronger influence on zonal trip attraction than the conventional model using zonal labor and student variable, mainly based on the urban geographical pattern.**

***Keywords*— transportation; trip attraction; Surabaya; concentric; sector; multiple-nuclei.**

I. INTRODUCTION

The trips attracted by morning activities are vital in transportation planning since the influence the government's infrastructural implementation. The common variables used to predict zonal trip attractions are jobs and school capacities. Data on jobs and schools are readily available in many forms. Previously, other potential variables, such as building floor areas were difficult to be counted, hence neglected.

The distance between residential areas and activity centres also influences the number of trips attracted by zones [1]. Also, the city's distance, based on the CBD plan, influences trip attraction [2]. Therefore, the consideration of these factors is vital for city trip attraction. Sources of satellite images are commonly used in viewing activity centres in the city. An example is Google Earth, which is equipped with measuring tools [3].

The positions of activity centres and residential zones in an urban structure influence zonal trip attraction, especially the concentric, sectoral or multiple-nuclei structure, as mentioned in planning theory. In developing countries, however, poor urban planning results in inappropriate city layouts.

Current studies on trip attraction models cover a wide range of analyses. In most cases, however, conventional approaches are used, resulting in information that is difficult to interpret, such as socio-economic data. Furthermore, trip generation models ignore certain information, such as geographic position and spatial data. For instance, a study conducted in India used conventional methods and land-use area data to examine the trip attraction of the commercial mid-size town of Kerala [4]. Other studies employ the Artificial Neural Network-based approach for a trip attraction model [5].

II. MATERIAL AND METHOD

A. Location

Surabaya is a prominent city in East Java Province of Indonesia, situated in South-East Asia (Fig. 1). It covers 351 km2, with a population of more than 3 million inhabitants in 2018 (2.9 million in 2011).

The city is divided into 31 administrative subdistricts (Fig. 2). A dense area's planning strategy in one of Surabaya city centres shows the mixed complexity of the old city area [8]. However, several areas are considered activity centres in slightly varying degrees, as shown in Fig. 3.

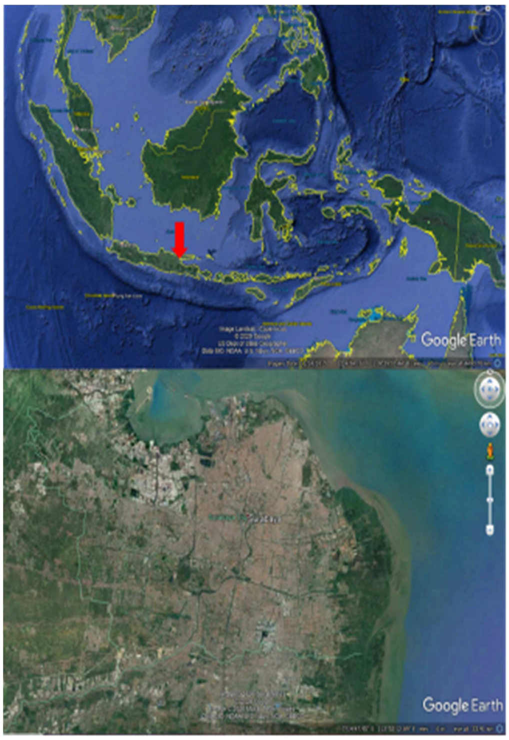

Fig. 1 Location and Surabaya city of Indonesia (top) [6] and the city (bottom) [7]

There is an old town in Surabaya, functioning as a regional trading centre. However, several other places are currently serving as trading centres with many activities. A new city centre began with retail businesses about 40 years ago, although many places around it have since attracted more visitors. There is several shopping centres in the west, east, and south of Surabaya. Therefore, solving the problem of trip attraction of Surabaya city requires several approaches.

A weak planning and development regulation of the city makes its centre to be unclearly defined. It is common for a smaller city to have a centrum, or several developed new centres, forming a monocentric or polycentric city [9].

Fig. 2 Subdistrict administration in Surabaya (background [7])

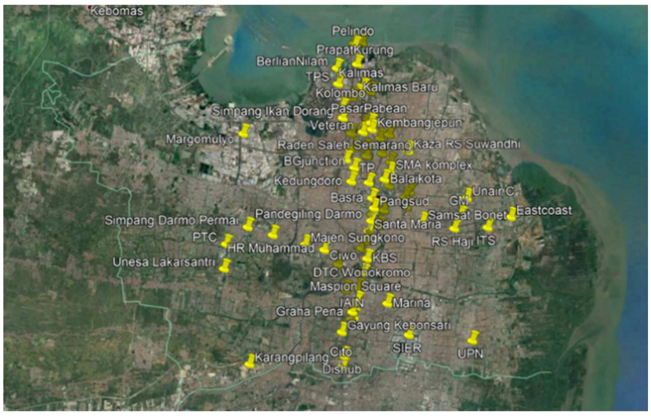

Fig. 3 Activity centres spreading in Surabaya (background [7])

Trip data was collected through the Surabaya home interview survey, conducted in 2011 [10]. It is currently the latest data available. The data on housing and the average distance between residential areas and city centre distance was collected by measurements using Google Earth.

B. City Centres Definition

City centres have structures that are theoretically classified as a concentric, sector and multiple-nuclei models. The concentric model is also known as the Burgess Model or the core frame model [11]. Sector model is referred to as Hoyt Model [12], while the multiple-nuclei model is known as Hariss-Ullman Model [13]. There is an airport 5 km outside of the city border. However, an aerotropolis concept does not shape the city structure yet [14].

C. Data for Geographical and Spatial Variables

A trip attraction model is categorized as a zonal base or land-use function base. The common variable for zonal analysis is labour and school capacity. This study explored other variables with a potentially high influence on trip attraction from the Google Earth application. A digitation on Google Earth combined with TCX converter software produced a set of digitized coordinates. Therefore, the floor area data of some functions in activity centres were prepared in a spreadsheet of Microsoft Excel for Office 365. Data compilation included zonal trip data and spatial data, which are average distances between residential and centres, as shown in Table 1.

Excel software calculates mathematical and numerical analysis and statistical operations once the data is prepared in Tools in Excel spreadsheets. For instance, straight distance is a calculation from the digitized attraction centre coordinates to the average digitized housing coordinate of every zone couple.

D. Trip Atrraction Models Considering Geographical Weighting

Spatial non-stationary local conditions are inserted in a more global equation using geographical weighting methods, such as in regression or linear models [16]. Combining local and global variables gives a better result, such as bike-sharing trip production and attraction [17].

In the transportation field, the model is developed based on numerical analysis instead of the statistical approach, as seen in the double-constrained gravity model calibration [18].

This approach is useful for inserting geographical variables, especially in calculating weighted-variable. Trip attraction model is enhanced using geographical variables, including location effect of residence area inside or outside the city centre. The average distance from the activity centre, in this case, is also treated as geographical variables.

The Generalized Reduced Gradient Nonlinear method is beneficial in this case [19]. Excel Solver subroutine in Microsoft Excel for Office 365 works based on 3 options, including the GRG nonlinear. This option is based on Generalized Reduced Gradient methods, an algorithm for solving nonlinear general structure's nonlinear programs. It is powerful in handling these problems. Iteration stops when then the relative value is less than 0.0001 for the last 5 iterations.

E. Calibration

There are some statistical methods of comparing the sets of a modeled trip with surveyed trip distributions independent of each other. For instance, the chi-square calculation between modeled and observed trips ($\chi 2$) is mentioned [20] and reviewed [21]. The formula is:

$$\chi^2 = \sum \frac{\left(T_j - T_j^*\right)^2}{T_j^*} \quad (1)$$

Where:
Tj = observed trip attraction value of zone j
T*j = modelled trip attraction value of zone j

III. Results and Discussion

A. Geographical Weighting

This research built trip attraction models using digitized data of floor areas of different functions, such as street shopping, office and bank, school and university, industry and warehouse, and large shopping malls. The research also utilized the distance of residential to the city centre. Since Surabaya's city centre is somehow loosely defined, 3 types of urban forms were incorporated in several models, including the centre of concentric, corridors of the sector, and satellites of multiple-nuclei forms. Activity functions within and outside the 3 centres were weighted in the models and distance from city centres to residential. The models utilized linear and nonlinear approaches.

B. Trip Atrraction without Considering Geographical Weighting and Spatial Variable

Trip attraction model used zonal variables as a street shopping place, office and bank, school and university, industry and warehouse, and large shopping mall. Considering distance as spatial variables, the results gave trip attraction model Tj in equation (2) and Chi-square 927423.

$$T_j = 99483 - 0.0008\, X_1 + 0.005 X_2 - 0.008\, X_3 - 0.0003\, X_4 - 0.004\, X_5 - 6163\, X_6 \quad (2)$$

C. Trip Atrraction Considering Geographical Weighting based on The Concentric Model

The concentric model in Surabaya is shown in Fig. 4. The city activity centres consist of zones 19, 20, 26, 27, and 28, while the rests are peripheries.

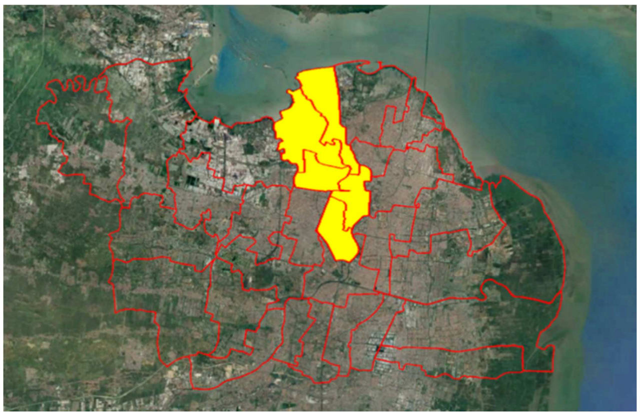

Fig. 4 Subdistrict close to the centre of concentric model (background [7])

Incorporating spatial variables into 2 groups of the concentric model's geographical types produces trip attraction model Tjk in equation (3) and Chi-square value 876407. However, this is only slightly better than equation (2) and is not influenced by distance

D. Trip Atrraction Considering Geographical Weighting based on Sector Model

When the sector model is applied in Surabaya as in Fig. 5, sectoral activity centres consist of zones 3, 4, 8, 9, 10, 11, 12, 15, 17, 19, 20, 26, 27, and 28, while the rests are peripheries. The sector centres are north-south and east-west corridors of the city.

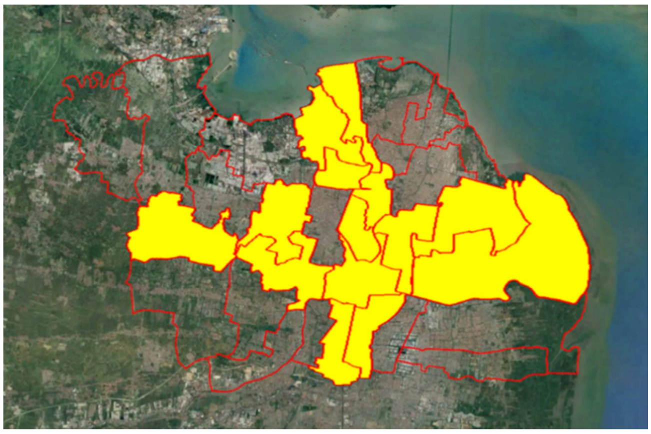

Fig. 5 Subdistricts close to centres of sector model (background [7])

Incorporating spatial variables into 2 groups of geographical types of sector model produces trip attraction model Tjk in equation (4), with a Chi-square value of 660445. There is a significant increase in accuracy compared to equation (2), and the trip attraction is influenced by distance.

TABLE I

ZONAL AND SPATIAL DATA OF SURABAYA

Zone	Subdistrict	X1	X2	X3	X4	X5	X6
1	Karangpilang	187165	25683	30650	1435104	0	8.5
2	Jambangan	47776	63690	188235	15243	0	7.8
3	Gayungan	65004	1240443	196615	33026	267540	7.8
4	Wonocolo	244091	149529	985400	46381	0	7.1
5	Tenggilismejoyo	111889	66842	4488	928360	0	8.0
6	Gununganyar	187920	115892	812641	255668	0	10.0
7	Rungkut	583389	62377	442046	1095619	0	9.2
8	Sukolilo	170910	199743	815684	29417	0	9.6
9	Mulyorejo	456550	266418	982854	47621	72580	9.0
10	Gubeng	871625	335172	442791	19856	4360	6.3
11	Wonokromo	440979	491538	840876	287959	577642	6.2
12	Dukuhpakis	557747	295566	112399	92821	396998	6.3
13	Wiyung	231995	70577	106809	62892	0	7.8
14	Lakarsantri	102284	46577	110349	20833	0	9.3
15	Sambikerep	169035	36261	37104	82374	481746	9.1
16	Tandes	170470	221312	248205	2541091	0	8.5
17	Sukomanunggal	395264	300619	200617	446864	0	6.7
18	Sawahan	380251	189063	45068	34439	0	5.8
19	Tegalsari	301442	212668	22011	19148	404520	5.7
20	Genteng	517050	1717379	140320	7965	396545	6.0
21	Tambaksari	322547	193996	133236	207642	151735	7.2
22	Kenjeran	56600	49240	137939	333258	0	8.8
23	Bulak	0	3264	45524	129611	0	9.5
24	Simokerto	380554	38563	30540	36233	137010	6.9
25	Semampir	515547	1435461	242511	1947882	0	8.0
26	Pabeancantikan	625193	311300	65627	482532	546728	7.6
27	Bubutan	1510162	354711	78034	164073	189510	6.1
28	Krembangan	150001	1405630	106113	123574	107279	7.1
29	Asemrowo	46111	454513	25959	8393014	0	6.4
30	Benowo	78667	9400	62492	1061936	0	10.1
31	Pakal	88394	7974	68980	173891	0	12.2

Where:
Tj = Daily trip attraction in 2011(trips) [11]
X1= floor area of street shopping place (m2)
X2= floor area of office and bank (m2)
X3= floor area of the school and university (m2)
X4= floor area of industry and warehouse (m2)
X5= floor area of mall and shopping centre (m2)
X6= Average distance to residential (km)

$$T_{jk} = \frac{(A_k.X_{1jk} + B_k.X_{2jk} + C_k.X_{3jk} + D_k.X_{4jk} + E_k.X_{5jk})}{(3.65.X_{6j}^{0})} \quad (3)$$

for k=1 (concentric centres) A1=0.03; B1=0.006; C1=0.21; D1=0; E1=0.5
k=2 (periphery) A2=0.36; B2=0.08; C2=0.16; D2=0.08; E2=0

$$T_{jk} = \frac{(A_k.X_{1jk} + B_k.X_{2jk} + C_k.X_{3jk} + D_k.X_{4jk} + E_k.X_{5jk})}{(4.34.X_{6j}^{0.46})} \quad (4)$$

for k =1 (sector centres) A1=0.23; B1=0.18; C1=0.38; D1=0.15; E1=0.12
k =2 (periphery) A2=1.31; B2=0; C2=1.61; D2=0.12; E2=2.22

Trip Atrraction Considering Geographical Weighting based on Multiple-nuclei Model. The Multiple-nuclei model in Surabaya is shown in Fig. 6, in which multi-nuclei centres consist of zones 1, 3, 6, 7, 9, 11, 15, 19, 20, 26, 27, 28, and 29, while the rests are peripheries.

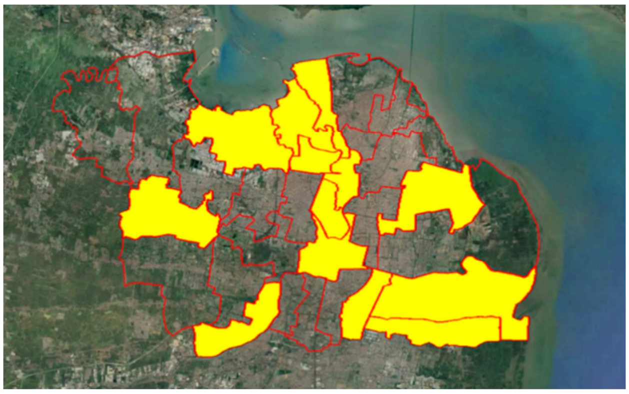

Fig. 6 Subdistrict close to centres of multiple nuclei model (background [7])

- Geographical group 1 is sub-districts in the city centre of the concentric model,

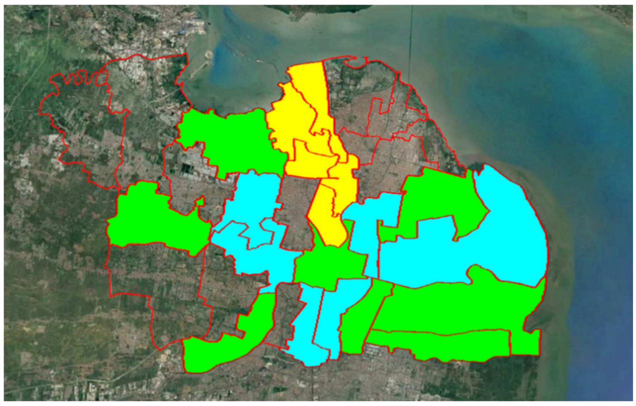

Fig. 7 Subdistrict with 4 geographical groups (background [7])

- Geographical group 2 is sub-districts in the corridors of the sector model, excluding the traditional concentric centres and sub-district having malls,

$$T_{jk} = \frac{(A_k.X_{1jk} + B_k.X_{2jk} + C_k.X_{3jk} + D_k.X_{4jk} + E_k.X_{5jk})}{(6.02.X_{6j}^{0})} \quad (5)$$

for k =1 (concentric centres) A1=0.19; B1=0.08; C1=0.11; D1=0.07; E1=0.41
k =2 (periphery) A2=0.67; B2=0; C2=0.31; D2=0.23; E2=1.47

$$T_{jk} = \frac{(A_k.X_{1jk} + B_k.X_{2jk} + C_k.X_{3jk} + D_k.X_{4jk} + E_k.X_{5jk})}{(3.10.X_{6j}^{0.74})} \quad (6)$$

for k =1 (centrum) A1=0.13; B1=0.04; C1=0.68; D1=0; E1=1.62
k =2 (corridors) A2=0.0002; B2=0.61; C2=0.61; D2=0.50; E2=0
k =3 (satellites) A3=1.65; B3=0; C3=0; D3=0.10; E3=0
k =4 (peripheries) A4=1.5; B4=0; C4=3.45; D4=0.25; E4=0

The weighting of 2 groups of geographical types using the multi-nuclei model produces trip attraction model Tjk in equation (5) and a Chi-square value of 592442, which is even better than the equation (4).

E. A trip Attraction Using 4 Geographical Groups Weighting

Exploring geographical weighting and spatial as enrichment of Trip Attraction model is achieved by adding geographical group using city structure knowledge and considering the distance from the city centre to residentials.

There are 4 groups, as is shown in Figure 7, categorized as follows:

- Geographical group 3 is sub-districts having malls and industrials of the multiple-nuclei model, and
- Geographical group 4 is sub-districts in the periphery area.

The weighting of 4 groups of geographical types, including centre, corridor, satellite and periphery, and distance between centres and residential, produce trip attraction model in equation (6), with relatively higher accuracy, indicated by a Chi-square value of 367657.

F. Resume of Trip Attraction Using Geographical Weighting

The study resume is shown in Table 2. It indicates that the chi-square value is better when there is more geographical grouping. Unlike the gravity type trip distribution model, this model is strongly theoretical, using the City Structure Model of concentric, sector or multiple-nuclei.

TABLE II
CHI-SQUARE AND BETTERMENT OF ACCURACY

City Centres Assumption	Chi-Square	Betterment of accuracy (%)
Not considered	927423	0
Concentric Model	876407	6
Sector Model	660445	29
Multiple-nuclei Model	592442	36
Centrum, Corridors, Satellites	367657	60

Accuracy is increased when geographic weighting is applied, or the spatial variable is used. Combining geographic weighting and spatial variables to the model produce better chi-square. Grouping of zones into 4 groups based on the degree of activities as centrum, corridors, satellites, and peripheries increases accuracy than 2 groups of centre and peripheries.

Using a geographical grouping of 4 groups and spatial position to the city centre using the sector model produces the highest accuracy. Chi-square reduction without geographic waiting increases the accuracy by 60%.

IV. CONCLUSIONS

Using the same data based on the city centre concept, the Trip Attraction Model involving geographical weighting produces different accuracy degrees. Among several models, a geographical grouping of 4 city centre groups yields the best accuracy. This method produces an accuracy increase of up to 60% (Surabaya case). Furthermore, it is better than the conventional method since the data is digitized and measured from Google Earth. However, due to the digitizing and measuring process's time-consuming nature, highly trained labour should be incorporated into this method.

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