Trip Generation

The objective of the generation of trips is to predict the number of trips generated by and attracted to each zone in a study area by purpose. The generation of trips is carried out by relating the number or frequency of trips to the characteristics of the individuals, the zone and the network of transport. The area containing the home end of home-based trips or the origin end of non-home-based trips is considered to have produced the trip, while it is considered to have attracted the trip to the destination area where an out-of-home activity will be performed. There are generally four types of trips:

- Home based trips
    - Where one end of the trip is home. (work to home, home to school)
- Non home-based trips
    - Where no end of the trip is home (office to mall)
- Person-type based trips
    - Trips dependent on socio-economic factors such as income, car ownership, etc.
- Time based trips
    - Trips made during peak and off-peak periods.

Arrangement of survey

The internal and external zones of the study area were randomly generated using python. In this study, the internal zones are defined as 'x' and the external zones are defined as 'y'. Code from the python interface is given below:

```
Python 2.7.16 Shell
File Edit Shell Debug Options Window Help
Python 2.7.16 (v2.7.16:413a49145e, Mar  4 2019, 01:30:55) [MSC v.1500 32 bit (Intel)] on win32
Type "help", "copyright", "credits" or "license()" for more information.
>>> import random
>>> random.seed(49)


>>> [random.randint(15,20) for _ in range(1)]
[17]
>>> random.seed(49)


>>> [random.randint(5,10) for _ in range(1)]
[7]
```

Here, x=17 (internal zones), and, y=7 (external zones)

For trip production model, 5 independent variables were chosen; trips produced, no. of workers in house, no. of students, household size and car ownership. For trip attraction, two independent variables were chosen; no. of school/college and commercial area.

A sample of the production and attraction sheet are shown below:

Internal Zone Trip Production					
Zone	**Trips produced**	**No. of workers in house**	**No. of students**	**Household size**	**Car ownership**
1	4	2	2	6	2
	6	2	1	7	1
	6	2	3	6	2
	5	2	2	7	1
	4	2	3	5	0
	7	2	2	6	2
	9	2	3	6	0
	4	2	1	7	2
	4	2	2	4	2
	9	1	3	7	0
	7	1	2	5	1

Internal Zone Trip Attraction			
Zone	**Trips Attracted**	**No. of School/College**	**Commercial Area %**
1	3	3	37
	3	2	46
	4	3	48
	6	3	40
	5	1	57
	2	4	56
	5	2	47
	4	2	42
	3	3	36
	6	3	34

Results

Statistical analyses were carried out to check correlation between dependent and independent variables as well as among independent variables for the both the attraction and production models. The results are following:

Table 1 Results for Trips Produced

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.08907
R Square	0.00793
Adjusted R Square	-0.01852
Standard Error	2.33542
Observations	155.00000

y	No. of trips produced
x1	No.of workers in house
x2	No. of students
x3	Household size
x4	Car ownership

y= 0.2529**x1-**0.0001**x2+**0.0184**x3+**0.1814**x4+**5.2065

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4	6.5426	1.6357	0.2999	0.8777
Residual	150	818.1284	5.4542		
Total	154	824.6710			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	5.2065	1.2236	4.2552	0.0000	2.7889	7.6242	2.7889	7.6242
No. of workers in house	0.2529	0.3562	0.7100	0.4788	-0.4510	0.9568	-0.4510	0.9568
No. of students	-0.0001	0.2324	-0.0003	0.9998	-0.4593	0.4592	-0.4593	0.4592
Household size	0.0184	0.1681	0.1092	0.9132	-0.3138	0.3505	-0.3138	0.3505
Car ownership	0.1814	0.2250	0.8064	0.4213	-0.2631	0.6259	-0.2631	0.6259

Table 2 Results for trips attracted

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.1744
R Square	0.0304
Adjusted R Square	-0.0036
Standard Error	1.2967
Observations	60

y	Trips Attracted
x1	No. of School/College
x2	Commercial Area %

y= 0.1316**x1-**0.0198**x2+**4.4536

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	3.0065	1.5033	0.8940	0.4147
Residual	57	95.8435	1.6815		
Total	59	98.85			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	4.4536	0.8645	5.1519	0.0000	2.7226	6.1847	2.7226	6.1847
No. of School/College	0.1316	0.1637	0.8037	0.4249	-0.1963	0.4595	-0.1963	0.4595
Commercial Area %	-0.0198	0.0174	-1.1375	0.2601	-0.0546	0.0150	-0.0546	0.0150

Growth Factor Model

For external zones, growth model factor was used to estimate future trips for a design period of 20 years while considering three factors; household size, population and vehicle.

Table 3 Growth factor model for ext. zones

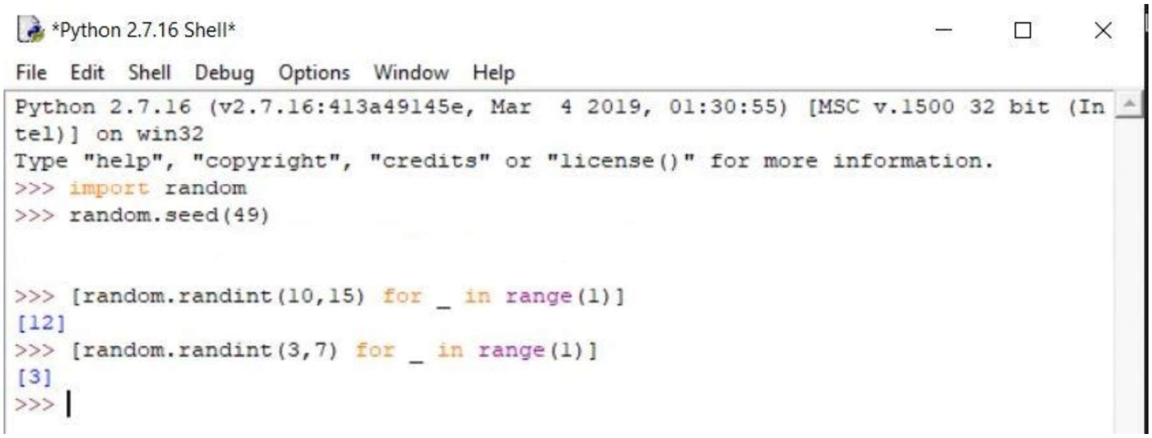
External Zone Growth Factor Model									
Name of external zone	Current year population	Design Year Population	Current Average Household	Design Average Household	Current Average Vehicle	Design Average Vehicle	Growth factor, fi	Number of current trips	Number of trips after 20 years
11	812	1304	432	801	2	3	5	485	2425
12	662	1428	438	504	1	2	5	424	2120
13	793	1373	401	816	1	2	8	298	2384
14	552	1516	492	561	2	3	5	402	2010
15	720	1247	484	849	3	4	5	501	2505
16	735	1351	334	480	2	3	4	398	1592
17	801	1343	428	590	1	2	5	302	1510

Trip Distribution

The distribution of trips is a model of the number of trips occurring between each zone of origin and the zone of destination. The estimated number of trips originating in each zone of origin (trip development model) and the estimated number of trips terminating in each zone of destination are used (trip attraction model). Thus, a model of travel between zones - trips or connections - is trip distribution. To see if the model produces a good approximation, the modeled trip distribution can then be compared to the actual distribution.

Arrangement of survey

For trip distribution, the number of internal zones were defined as ‘x’ and the number of external zones were defined as ‘y’. The number of zones were randomly generated using python with the result shown below:



```
*Python 2.7.16 Shell*
File  Edit  Shell  Debug  Options  Window  Help
Python 2.7.16 (v2.7.16:413a49145e, Mar  4 2019, 01:30:55) [MSC v.1500 32 bit (In
tel)] on win32
Type "help", "copyright", "credits" or "license()" for more information.
>>> import random
>>> random.seed(49)


>>> [random.randint(10,15) for _ in range(1)]
[12]
>>> [random.randint(3,7) for _ in range(1)]
[3]
>>> 
```

As we can see, the random number generator in python produced 12 internal zones (x) and 3 external zones (y).

Results

The production and attraction in each zone were randomly generated using Microsoft Excel. The estimation of the future trips was calculated using a doubly constraint growth model. The result and analysis are given below:

	Zone	Production	ΣOi	Attraction	ΣDj
Internal	1	184	2496	187	2496
	2	201		199	
	3	166		162	
	4	198		195	
	5	199		197	
	6	160		161	
	7	141		139	
	8	120		123	
	9	132		135	
	10	200		197	
	11	177		182	
	12	171		168	
External	13	116		114	
	14	137		140	
	15	194		197	

Table 4 Base Year Trip Matrix

Base Year Trip Matrix																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	*oi*	*bj*	ai	
1	9	20	11	23	19	11	20	24	20	26	13	16	13	12	15	252		a1	0.73
2	11	11	10	25	27	16	15	14	25	11	27	21	27	16	10	266		a2	0.76
3	6	17	25	14	15	10	18	19	11	14	13	22	17	21	26	248		a3	0.67
4	5	26	23	20	28	22	21	20	15	20	24	11	19	15	28	297		a4	0.67
5	12	5	5	6	5	14	15	13	10	14	11	14	10	15	5	154		a5	1.29
6	6	13	7	15	13	9	11	5	13	7	16	7	15	10	11	158		a6	1.01
7	8	20	14	14	17	10	7	8	15	13	20	8	8	6	13	181		a7	0.78
8	10	16	11	26	15	18	15	13	23	14	23	20	20	16	15	255	1	a8	0.47
9	11	12	21	20	14	21	19	13	22	12	25	16	22	14	19	261		a9	0.51
10	8	6	12	7	19	18	10	9	20	19	15	11	9	10	20	193		a10	1.04
11	8	13	12	12	7	14	12	9	9	15	9	8	12	15	6	161		a11	1.10
12	13	19	10	10	11	11	10	12	7	6	9	16	6	17	19	176		a12	0.97
13	15	16	7	6	11	9	10	7	12	10	13	13	10	5	10	154		a13	0.75
14	5	18	18	13	6	15	16	19	8	17	13	11	11	14	13	197		a14	0.70
15	5	6	6	5	7	8	10	6	16	6	14	15	6	16	9	135		a15	1.44
dj	132	218	192	216	214	206	209	191	226	204	245	209	205	202	219	**3088**			

Table 5 Final Matrix

Trial 3																		ERROR
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	*Oi1*	*Oi*	
1	10.91	16.74	8.64	19.67	15.93	7.61	11.81	14.01	10.56	22.14	8.71	11.26	6.68	7.03	12.31	184.0	184	
2	14.15	9.77	8.34	22.69	24.02	11.74	9.40	8.67	14.01	9.94	19.20	15.69	14.73	9.94	8.71	201.0	201	
3	6.76	13.22	18.26	11.13	11.69	6.43	9.87	10.31	5.40	11.08	8.09	14.39	8.12	11.43	19.83	166.0	166	
4	5.55	19.94	16.56	15.68	21.51	13.94	11.36	10.70	7.26	15.61	14.74	7.10	8.95	8.05	21.06	198.0	198	
5	26.18	7.53	7.07	9.24	7.54	17.43	15.94	13.66	9.50	21.46	13.27	17.74	9.25	15.81	7.39	199.0	199	
6	10.20	15.26	7.71	17.99	15.29	8.73	9.11	4.09	9.63	8.36	15.03	6.91	10.81	8.21	12.66	160.0	160	
7	10.08	17.39	11.43	12.44	14.81	7.19	4.29	4.85	8.23	11.50	13.92	5.85	4.27	3.65	11.09	141.0	141	
8	7.93	8.76	5.66	14.55	8.23	8.15	5.79	4.97	7.95	7.80	10.08	9.21	6.73	6.13	8.06	120.0	120	
9	9.41	7.09	11.65	12.08	8.29	10.25	7.92	5.36	8.20	7.21	11.82	7.95	7.98	5.79	11.01	132.0	132	**5.33**
10	13.75	7.12	13.37	8.49	22.58	17.64	8.37	7.45	14.97	22.93	14.25	10.98	6.56	8.30	23.26	200.0	200	
11	14.64	16.43	14.24	15.50	8.86	14.62	10.70	7.93	7.18	19.29	9.11	8.50	9.32	13.26	7.43	177.0	177	
12	20.33	20.52	10.14	11.04	11.90	9.81	7.62	9.04	4.77	6.59	7.78	14.53	3.98	12.84	20.12	171.0	171	
13	18.08	13.32	5.47	5.10	9.17	6.19	5.87	4.07	6.30	8.47	8.66	9.10	5.11	2.91	8.16	116.0	116	
14	5.85	14.53	13.65	10.73	4.85	10.01	9.11	10.70	4.08	13.97	8.40	7.47	5.46	7.91	10.29	137.0	137	
15	12.48	10.34	9.71	8.81	12.08	11.39	12.16	7.21	17.40	10.52	19.31	21.74	6.35	19.29	15.21	194.0	194	
dj3	186.30	197.98	161.88	195.13	196.75	161.12	139.31	123.03	135.42	196.86	182.38	168.41	114.31	140.55	196.58			
Dj	187	199	162	195	197	161	139	123	135	197	182	168	114	140	197			

For the I-I trips, gravity model was used to estimate the future trips. The cost function considered in this model was polynomial.

Table 6 Cost matrix for polynomial function

Cost Matrix												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1	1.2	1.4	1.2	1.2	1.0	1.8	1.2	1.4	1.2	1.4	1.1	1.5
2	1.0	1.3	1.6	1.4	1.3	1.1	1.0	1.3	1.6	1.0	1.0	1.2
3	1.8	1.1	1.0	1.2	1.6	1.0	1.8	1.1	1.0	1.8	1.6	1.0
4	1.4	1.1	1.5	1.2	1.0	1.8	1.2	1.0	1.8	1.4	1.0	1.8
5	1.0	1.0	1.2	1.4	1.3	1.1	1.4	1.3	1.1	1.1	1.0	1.6
6	1.8	1.6	1.0	1.2	1.6	1.0	1.2	1.6	1.0	1.5	1.2	1.0
7	1.8	1.1	1.0	1.8	1.0	1.8	1.2	1.0	1.8	1.4	1.1	1.5
8	1.4	1.1	1.5	1.4	1.3	1.1	1.4	1.3	1.1	1.0	1.0	1.2
9	1.0	1.0	1.2	1.1	1.6	1.0	1.2	1.6	1.0	1.8	1.6	1.0
10	1.8	1.1	1.0	1.8	1.8	1.4	1.0	1.2	1.0	1.8	1.2	1.0
11	1.4	1.1	1.5	1.4	1.1	1.1	1.0	1.4	1.3	1.1	1.4	1.3
12	1.0	1.0	1.2	1.1	1.0	1.5	1.2	1.0	1.2	1.6	1.0	1.6

Final Table															
	1	2	3	4	5	6	7	8	9	10	11	12	**Ai**	**Oi**	**Oi1**
1	23.44	17.56	20.90	25.16	31.29	8.91	18.43	10.22	14.87	18.92	25.49	10.89	0.00077	184	226.08
2	18.53	21.91	12.65	19.89	19.92	25.66	28.55	12.76	9.00	39.90	33.19	19.57	0.00077	201	261.52
3	8.81	24.04	25.44	21.27	10.33	24.39	6.92	14.00	18.11	9.67	10.19	22.14	0.00075	166	195.30
4	17.89	29.55	13.89	26.14	32.51	9.25	19.15	20.81	6.87	19.65	32.05	8.40	0.00076	198	236.15
5	30.66	31.25	18.98	16.79	16.82	21.66	12.30	10.77	16.08	27.83	28.02	9.29	0.00066	199	240.42
6	8.78	11.33	25.37	21.21	10.30	24.32	15.54	6.60	18.06	13.89	18.06	22.08	0.00075	160	195.54
7	7.91	21.58	22.84	8.49	23.75	6.76	13.99	15.20	5.02	14.36	19.35	8.83	0.00078	141	168.06
8	10.32	17.04	8.01	11.08	11.10	14.29	8.11	7.10	10.61	22.22	18.49	10.90	0.00070	120	149.27
9	21.52	21.94	13.32	19.09	7.79	18.40	11.75	4.99	13.66	7.30	7.68	16.70	0.00068	132	164.15
10	11.00	30.02	31.77	11.80	10.20	15.54	28.02	14.69	22.61	12.08	22.61	27.64	0.00077	200	237.98
11	16.03	26.48	12.45	17.21	24.07	22.20	24.71	9.52	11.80	28.53	14.65	14.42	0.00073	177	222.06
12	25.26	25.76	15.64	22.41	23.42	9.60	13.79	14.99	11.13	10.84	23.09	7.66	0.00064	171	203.58
Bj	1.279919	1.194463	1.264708	1.276485	1.097014	1.258086	1.313125	1.164794	1.132036	1.293422	1.21586	1.068349			
Dj	187	199	162	195	197	161	139	123	135	197	182	168			
Dj1	200.16	278.47	221.26	220.51	221.50	200.96	201.26	141.65	157.81	225.19	252.86	178.51			

Discussion

The statistical analysis of trip production and attraction model shows that the independent variables such as no. of workers, car ownership, no. of school/college and % of commercial area are not statistically significant. The p-value of the variables are 0.4788, 0.4213, 0.4249 and 0.2601 respectively. As the p-value of the variables are much greater than 0.05, they do not seem to show any significance. This could be due to the randomly generated numbers for the number of trips produced and attracted. An actual survey would have produced a much different and significant result.

In case of trip distribution, the use of doubly constraint growth model provided a very accurate result for the final Origin-Destination matrix. The overall error was calculated to be 5.33 which is very low for a total of 15 zones. For similar work in the future, the Excel datasheet for the doubly constraint growth model could be adjusted and used regardless of the number of zones.