CHAPTER 13: GIS DATA PROCESSING

13.1 Hierarchical Structure of GIS Data Processing

The geographic database development has completed and data analysis phase based on this database can be started. A GIS application uses the database and system functions in applying the manipulation techniques as follows;

- Performing polygon overlay
- Creating buffer zones
- Using boundary operations
- Manipulating tabular data
- Performing model based simulations

Those are spatial data manipulation in a particular manner required to support the information requirements of the planning expert in BEIP study team. Applications applied in this study involve simple spatial overlay, combinations of data using GRID base, so far as to complex mathematical computation, in both graphic and tabular formats. The GIS analytical process can be schematically illustrated on Fig. 13.1, then divided into three hierarchical stages (primary, secondary and tertiary) according to the degree of spatial data manipulation and the BEIP planning progress.

13.2 Primary Data Analysis

This stage of spatial analysis comprises the initial overlay manipulation of basic map data layers in order to identify new spatial relationships between the various geographic units and features. It includes the cross tabulations of the area, length, density, average and frequency calculation for some specific geographic features per some specific geographic units. Existing land use, for example, was overlaid with administrative boundaries so as to calculate the area of each land use type per each district or sub-district unit (see Table 13.1). On the other hand, the existing socio-economic data stored in the attributes files were manipulated so that new information can be processed from the geographical point of view(see Table 13.2 and 3). In the same way, the following data manipulations were performed, and various cross tabulations were produced as a result of primary data analysis. These table data are showing the existing urban condition of the BMA and having a meanings of planning indicator.

- Existing land use + Administrative boundaries
- Existing land use + Sewage zone
- Existing land use + Water service area
- Existing land use + Inundated area by 1983 flood
- Existing land use + Flood protection zone
- Existing land use + Land subsidence zone
- Land use zoning system + Existing land use
- Land use zoning system + Administrative boundaries
- Road network + Administrative boundaries
- Statistical mapping using attributes (ex. demography)

The results of the above geographic analysis can be communicated with maps, reports, or both. A map is best used to display geographic relationships whereas a report is most appropriate for summarizing the tabular data and documenting any calculated values. The selection of criteria for the model analysis will be formulated based on the interpretation and evaluation of the results of those primary data analysis.

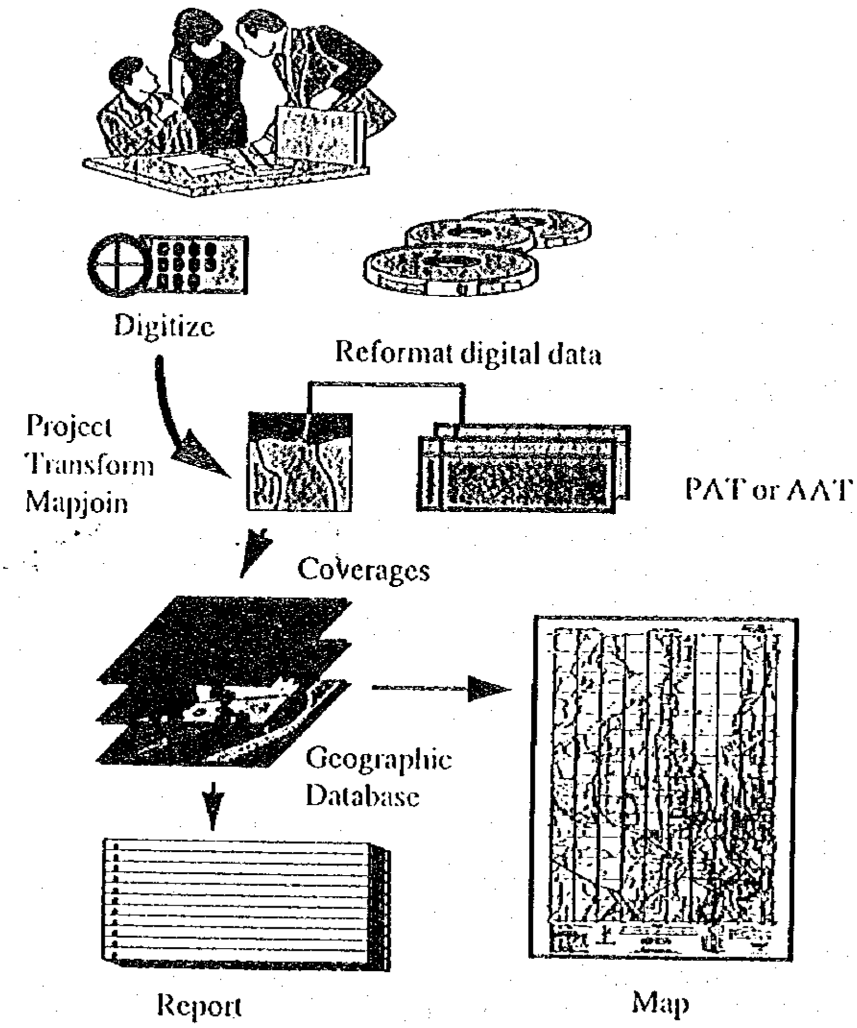

Fig. 13.1 GIS Analysis Procedure

Table 13.1 Land use Statistics by District

DISTRICT NAME	HIGH DENSITY	MID DENSITY	LOW DENSITY	COMM-ERCIAL	INDUS-TRIAL	WARE-HOUSE	GOVERN MENTAL	AGRI-CULTUR	CONSER-VATION	PARK	SCHOOL	RE-LIGION	WATER BODY	TOTAL
Bang Kapi	1.354	14.175	10.415	2.905	0.398	0	0.610	13.434	0	1.584	0.199	0	0	45.074
Bang Khen	0	7.300	8.077	0.836	0	0	8.399	53.256	0	0	0.037	0.438	0	78.343
Bang Kho Laem	0	5.434	0.151	0.552	0.090	0.388	0.115	0.312	0	0.130	0.033	0.100	1.153	8.458
Bang Khun Thian	0	9.663	10.963	0.187	0.910	0.040	0.018	134.339	0	0.011	0.116	0.103	0.203	156.553
Bang Phlat	0	4.089	4.222	0.959	0.038	0	0.016	1.454	0	0	0.085	0.048	0.947	11.858
Bang Rak	0	0.036	0	3.372	0	0	0.274	0	0	0.014	0.205	0.017	0.126	4.044
Bang Sue	7.435	1.289	0.851	0.746	0.693	0	0.161	1.211	0	0	0.091	0.012	0.596	13.085
Bangkok Noi	0.615	3.315	3.379	1.179	0	0	0.882	1.983	0	0	0.168	0.210	0.566	12.297
Bangkok Yai	0.085	3.680	0.157	0.864	0.128	0	0.137	0.653	0	0	0.173	0.175	0.189	6.241
Bung Kum	0.985	18.177	7.535	0.389	0.849	0	0.051	33.332	0	1.736	0.065	0	0	63.119
Chatu Chak	3.519	16.606	2.219	1.368	0.212	0	4.720	0.732	0	2.678	0.419	0	0.005	32.478
Din Daeng	0	6.493	0	1.025	0	0	0.483	0	0	0.128	0.349	0	0	8.478
Don Muang	0.035	15.245	6.451	0.525	0	0	15.586	20.284	0	0	0.447	0	0	58.573
Dusit	0.138	2.674	0.018	0.272	0.144	0	5.185	0	0.897	0.824	0.280	0.119	0.749	11.300
Huai Khwang	0	5.693	3.397	1.227	0	0	0.060	5.925	0	0	0.048	0	0	16.350
Jomtong	0.011	7.869	3.347	0.906	0.393	0	0.050	10.359	0	0	0.097	0.283	0.439	23.754
Khlong San	0	3.900	0	0.984	0.171	0.047	0.138	0.016	0	0	0.124	0.056	0.579	6.015
Khlong Toei	2.309	16.533	0.285	3.147	0.058	0.872	2.590	0.544	0	0.319	0.348	0	0.949	27.954
Lat Phrao	0.521	10.175	5.936	0.620	0.066	0	0.050	11.114	0	0	0.062	0	0	28.544
Latkrabang	0.153	2.314	7.012	0	2.088	0	0	116.979	0	0	0.027	0.020	0	128.593
Minburi	0.052	3.323	7.202	0.529	1.907	0	0.107	163.895	0	0	0.254	0	0	177.269
Nong Chok	0	0.452	5.656	0	0	0	0	234.948	0	0	0.000	0	0	241.056
Nong Khaem	0	5.071	9.530	0.143	0.746	0.012	0.490	30.622	0	0	0.138	0.203	0	46.955
Pathumwan	0.120	0.375	0.024	3.093	0	0	1.709	0.073	0	1.265	1.355	0	0.066	8.080
Phasi Charoen	0.006	16.748	3.523	1.467	0.436	0.196	0.101	33.286	0	0	0.430	0.254	0.175	56.622
Phaya Thai	0	7.989	0	0.289	0	0	0.529	0	0	0.112	0.061	0	0.093	9.073
Phra Khanong	1.424	23.853	0.767	0.789	0.239	1.356	0.332	3.738	0	0	0.520	0	0.924	33.942
Phra Nakhon	0.196	0.244	0.066	2.065	0.017	0	0.778	0	0.294	0.360	0.333	0.442	0.601	5.396
Pom Prap Sattrupha	0.181	0.054	0	1.569	0	0	0.240	0.017	0	0	0.154	0.171	0.058	2.444
Prawet	0	13.125	11.399	0.921	0.814	0	0	38.497	0	0.579	0.024	0	0.117	65.476
Ratburana	0.387	10.048	2.129	0.993	0.546	0.464	0.279	30.235	0	0.083	0.248	0.187	1.126	46.725
Ratchathewi	0.495	1.375	0.466	1.467	0	0	2.605	0.167	0	0.140	0.453	0	0.057	7.225
Samphanthawong	0	0	0	1.033	0	0	0.055	0	0	0	0.026	0.123	0.172	1.409
Sathon	0.003	5.020	0	0.814	0.140	0.098	0.594	0.096	0	0.018	0.298	0.039	0.131	7.251
Suan Luang	0	9.272	4.201	0.492	0.025	0	0.017	6.090	0	0.121	0.247	0	0.276	20.741
Taling Chan	0	5.435	15.712	0	0	0	0.026	65.153	0	0	0.221	0.300	0.755	87.602
Thonburi	0.143	5.202	0.107	1.348	0.072	0.114	0.140	0.200	0	0	0.136	0.194	0.477	8.133
Yan Nawa	1.166	6.957	0.229	0.595	0.087	0.879	0.214	0.526	0	0.025	0.099	0.054	1.574	12.405
Total	21.333	269.203	135.426	39.670	11.267	4.466	47.741	1013.470	1.191	10.127	8.370	3.548	13.103	1578.915

Unit : km

Table 13.2 Sub-district Statistics Produced by GIS Data Manipulation (1)

District	Sub-District	Code	Area (km2)	Build Area (km2)	P_Density Gross (per Km2)	P_Density Net (per Km2)	Increase Rate (%)	Open Space (%)	Build-up Rate(%)	R_Density Gross (m/Ha)	R_Density Net (m/Ha)	Soi Density (m/ha)
Bang Kapi	Hua Mak	101203	15.70	8.27	7,575	14,376	5.92	37.22	52.70	95	181	88.87
	Khlong Chan	101201	12.41	8.52	10,061	14,645	4.94	31.30	68.70	116	168	93.23
	Wang Thong Lang	101202	16.97	13.26	8,523	10,905	6.00	21.65	78.15	118	151	89.23
Bang Khen	Anusawari	101401	15.68	13.99	6,300	7,065	9.55	10.83	89.17	101	113	87.25
	Khlong Thanon	101402	16.90	3.32	10,541	53,698	15.84	80.37	19.63	72	367	84.30
	O-ngoen	101405	13.62	0.82	480	7,953	9.97	93.97	6.03	24	401	68.59
	Sai Mai	101404	14.00	1.84	3,718	28,233	12.90	86.83	13.17	56	422	83.86
	Tha Raeng	101403	18.14	5.12	2,299	8,150	13.82	71.79	28.21	41	145	87.79
Bang Kho Laem	Bang Khlo	101503	4.71	4.02	14,941	17,506	2.15	2.89	85.35	66	77	68.67
	Bang Kho laem	101502	2.14	1.48	13,776	19,882	2.26	6.99	69.29	59	86	71.64
	Wat Praya Kri	101501	1.61	1.36	27,590	32,589	1.75	1.60	84.66	66	79	73.53
Bang Khun Thian	Bang Bon	101303	35.36	8.25	2,687	11,511	10.21	76.62	23.35	25	108	79.98
	Samae Dam	101301	45.93	11.39	2,357	9,502	10.56	74.99	24.81	35	141	80.93
	Tha Kham	101302	75.27	2.35	384	12,283	6.32	96.73	3.13	19	617	88.41
Bang Phlat	Bang O	101704	3.08	1.92	25,310	40,591	17.05	25.16	62.35	58	93	87.30
	Bang Pamru	101702	2.40	2.27	10,149	10,748	-1.45	5.57	94.43	91	96	86.51
	Bang Phlat	101701	3.33	2.59	13,175	16,902	-6.39	15.39	77.95	99	127	80.95
	Bang Yikhan	101703	3.04	2.67	33,111	37,736	19.22	0.00	87.74	73	84	76.65
Bang Rak	Bang Rak	101802	0.48	0.35	27,838	37,758	15.83	0.00	73.73	56	75	55.11
	Maha Phuttharam	101803	0.65	0.64	78,122	78,981	15.16	0.00	98.91	120	121	58.65
	Si Lom	101804	1.56	1.55	17,345	17,411	9.69	0.00	99.62	88	89	19.72
	Si Phraya	101801	0.76	0.76	80,568	80,568	21.45	0.00	100.00	96	96	53.21
	Surawong	101805	0.60	0.60	20,293	20,293	8.76	0.00	100.00	133	133	59.46
Bang Sue	Bang Sue	101601	13.09	11.28	25,883	30,030	2.35	9.26	86.19	100	117	81.17
Bangkok Noi	Arun Amarin	101005	2.94	2.73	24,073	25,926	0.00	1.43	92.85	63	68	83.36
	Ban chang Lo	101004	2.32	2.22	25,973	27,095	-2.21	2.89	95.86	84	87	60.98
	Bang Khun Non	101002	1.65	1.33	6,138	7,630	-12.62	14.11	80.45	53	66	77.88
	Bang Khun Si	101003	4.00	2.31	15,769	27,390	5.31	40.91	57.57	57	100	92.00
	Sirirat	101001	1.38	1.16	34,134	40,567	10.77	0.00	84.14	63	75	57.75
Bangkok Yai	Wat Arun	101102	0.86	0.76	31,834	35,869	4.86	0.00	88.75	79	89	68.98
	Wat Tha Phra	101101	5.39	4.64	14,248	16,539	0.52	0.00	86.15	75	87	81.04
Bung Kum	Khanna Yao	101902	21.31	6.93	2,266	6,971	5.53	59.35	32.51	53	163	88.66
	Khlong Kum	101901	24.85	14.00	6,089	10,810	6.91	43.67	56.33	95	169	93.94
	Saphan Sung	101903	16.96	7.13	3,046	7,249	7.37	57.98	42.02	65	154	87.79
Chatu Chak	Lat Yao	100401	32.48	29.06	7,011	7,835	2.04	2.25	89.49	113	126	86.07
Din Daeng	Din Daeng	103701	8.48	8.35	32,538	33,036	22.79	0.00	98.49	158	161	87.22
Don Muang	Si Kan	100603	20.69	11.20	4,757	8,791	8.22	45.88	54.12	79	145	89.01
	Talat Bang Khen	100602	21.24	16.18	4,133	5,426	7.30	23.82	76.18	60	79	74.54
	Thong Song Hong	100601	16.64	10.91	6,757	10,305	9.36	34.44	65.56	97	148	95.14
Dusit	Dusit	100701	2.36	1.96	20,156	24,196	3.59	0.00	83.30	74	89	40.71
	Si Yak Mahanak	100705	0.37	0.36	49,354	50,912	1.70	0.00	96.94	84	87	37.50
	Suan Chitlada	100704	1.88	0.55	14,530	49,553	-0.97	0.02	29.32	60	206	17.41
	Thanon Nakhon Chaisi	100702	5.57	5.12	32,298	35,162	2.13	0.00	91.85	86	93	60.54
	Wachira Phayabarn	100703	1.13	0.84	26,608	35,697	1.98	0.00	74.54	64	86	54.68
Huai Khwang	Bang Kapi	103603	6.13	3.15	1,101	2,139	-22.34	48.55	51.45	56	108	73.91
	Huai Khawang	103601	4.88	2.73	9,011	16,131	-13.75	44.14	55.86	82	146	83.49
	Samsen Nok	103604	5.34	4.55	5,281	6,207	-6.93	14.92	85.08	129	152	86.35
Jomtong	Bang Kho	100501	3.41	1.57	15,126	32,824	1.83	26.80	46.08	55	119	88.28
	Bang Khun Thian	100503	6.09	3.94	7,539	11,653	2.84	34.64	64.69	39	60	81.16
	Bang Mot	100504	8.55	4.69	5,074	9,579	6.66	44.93	52.97	28	53	60.15
	Chom Thong	100502	5.40	2.75	10,903	21,374	4.58	45.66	51.01	35	70	67.40
Khlong San	Bang Lam Phu Lang	100303	2.25	2.01	22,876	25,648	4.55	0.00	89.19	78	88	81.07
	Klong San	100301	1.08	0.94	29,996	34,236	4.80	0.00	87.62	63	72	52.40
	Klong Ton Sai	100302	1.74	1.61	19,992	21,705	0.90	0.00	92.11	84	91	51.19
	Somdet Chaophraya	100304	0.94	0.86	27,275	29,833	1.08	1.64	91.43	112	123	57.64
Khlong Toei	Klong Tan	100202	11.34	10.86	7,616	7,959	-2.55	4.03	95.69	129	135	83.93
	Klong Toei	100201	9.02	8.13	14,692	16,309	6.10	0.01	90.08	98	109	64.68
	Phra Khanong	100203	7.59	7.16	11,547	12,238	1.68	1.14	94.35	117	124	81.04
Lat Phrao	Chorakhe Bua	103102	14.47	7.14	4,629	9,372	5.72	50.61	49.39	106	215	87.65
	Lat Phrao	103101	14.08	10.28	6,899	9,443	6.24	26.94	73.06	118	162	90.45
Latkrabang	Khlong Sam Prawet	103004	17.44	0.84	457	9,474	12.03	95.18	4.82	36	741	82.04
	Khlong Song Tonnun	103003	16.17	1.63	2,210	21,977	16.91	89.95	10.05	42	417	92.09
	Khum Thong	103002	26.62	1.38	284	5,466	7.38	94.81	5.19	4	69	0.00
	Lam Prathiu	103006	33.28	2.69	558	6,901	9.71	91.91	8.09	31	383	72.09
	Lat Krabang	103001	10.73	3.74	3,593	10,292	5.68	65.09	34.91	70	200	84.30
	Thap Yao	103005	24.36	1.33	630	11,543	8.37	94.54	5.46	18	324	76.42
Minburi	Bang Chan	102604	22.60	3.53	1,677	10,735	14.76	84.38	15.62	47	302	74.37
	Minburi	102601	20.26	5.99	4,364	14,772	13.48	70.46	29.54	56	189	82.57
	Sai Kongdin	102602	13.19	0.35	453	17,122	11.48	97.35	2.65	25	929	75.83
	Sai Kongdin Tai	102603	16.17	0.87	610	11,324	8.67	94.61	5.39	42	777	82.56
	Samwa Tawanok	102606	40.08	0.57	274	19,240	8.31	98.57	1.43	21	1,474	85.15
	Samwa Tawantok	102605	28.72	0.77	233	8,631	8.14	97.30	2.70	20	758	80.79
	Sansaep	102607	36.24	1.29	717	20,130	10.87	96.41	3.56	31	864	77.10

Table 13.3 Sub-district Statistics Produced by GIS Data Manipulation (2)

District	Sub-District	Code	Area (km2)	Build Area (km2)	P_Density Gross (per Km2)	P_Density Net (per Km2)	Increase Rate (%)	Open Space (%)	Build-up Rate(%)	R_Density Gross (m/Ha)	R_Density Net (m/Ha)	Soi Rate (%)
Nong Chok	Khlong Sip	103502	30.70	0.29	274	29,322	9.13	99.06	0.94	10	1,069	51.56
	Khlong Sip Song	103503	41.31	1.08	193	7,379	9.39	97.39	2.61	7	279	0.00
	Khok Faet	103505	21.54	0.93	760	17,588	13.79	95.68	4.32	10	224	38.36
	Khu Fang Nua	103504	18.00	0.14	443	55,495	10.08	99.20	0.80	22	2,802	72.57
	Krathum Rai	103501	40.39	0.77	557	29,248	11.01	98.09	1.91	7	368	0.00
	Lam Phak Chi	103507	33.30	1.02	286	9,315	10.33	96.93	3.07	8	245	24.02
	Lam Toi Ting	103506	24.99	0.52	299	14,458	8.40	97.93	2.07	5	247	0.00
	Nong Chok	103508	30.82	1.36	422	9,572	9.54	95.59	4.41	9	198	0.00
Nong Khaem	Lak Song	103403	17.83	5.84	3,109	9,497	8.43	67.27	32.73	37	112	93.99
	Nong Khaem	103402	14.68	5.21	2,293	6,467	11.27	64.54	35.46	39	110	100.00
	Nong Khang Phlu	103401	14.44	5.29	3,809	10,396	14.74	63.36	36.64	57	155	89.59
Pathumwan	Pathumwan	102002	2.11	1.59	32,184	42,700	13.88	3.47	75.37	39	51	39.45
	Rong Muang	102003	1.25	1.21	68,873	71,072	12.23	0.00	96.91	104	108	37.22
	Suan Lumphini	102004	3.40	2.77	25,175	30,878	17.59	0.00	81.53	77	94	51.67
	Wang Mai	102001	1.33	1.11	38,952	46,647	12.63	0.00	83.50	128	153	60.11
Phasi Charoen	Bang Chak	102504	1.40	0.39	5,730	20,563	4.17	72.13	27.87	21	76	99.45
	Bang Duan	102507	4.25	1.19	8,964	31,974	2.51	71.97	28.03	40	143	82.67
	Bang Khae	102505	8.00	4.04	6,150	12,183	4.96	49.52	50.48	35	69	67.19
	Bang Khae Nua	102506	13.52	5.45	5,259	13,053	6.33	59.71	40.29	44	109	82.92
	Bang Phai	102508	15.96	5.14	2,125	6,606	5.91	67.81	32.17	44	136	69.75
	Bang Wa	102501	5.53	2.79	8,405	16,646	3.82	49.50	50.50	34	67	51.39
	Bang Waek	102509	2.90	1.20	7,859	18,983	4.48	56.03	41.40	50	121	72.69
	Khlong Kwang	102502	2.63	0.87	3,486	10,484	4.74	65.74	33.25	24	73	60.30
	Khuhasawan	102503	0.71	0.47	12,981	19,694	1.25	30.61	65.91	54	82	94.33
	Pak Khlong Pasicharoen	102510	1.72	1.62	15,585	16,550	-0.16	3.35	94.17	80	85	78.19
Phaya Thai	Samsen Nai	102301	9.07	8.87	27,997	28,644	2.94	0.00	97.74	107	109	74.80
Phra Khanong	Bang Chak	102401	15.19	14.54	8,751	9,139	6.28	1.45	95.76	132	138	80.92
	Bang Na	102402	18.75	14.74	6,680	8,501	5.04	18.75	78.58	112	143	78.08
Phra Nakhon	Ban Phan Thom	100106	0.41	0.39	32,382	33,535	-0.49	0.00	96.56	144	149	75.35
	Bang Khun Phrom	100105	0.45	0.44	20,438	20,837	0.59	0.00	98.09	74	76	57.13
	Bowon Niwet	100104	0.49	0.46	23,051	24,594	1.53	0.00	93.73	139	149	51.77
	Chana Songkhram	100102	0.35	0.28	14,025	17,529	-0.99	0.00	80.01	114	142	46.10
	Phra Borom Maha Ratchawang	100107	1.53	0.81	6,051	11,460	0.98	0.00	52.80	66	125	15.86
	Sam Ran Rat	100111	0.22	0.16	30,880	43,285	-0.90	0.00	71.34	81	114	38.72
	San Chao Phor Sua	100110	0.15	0.14	41,594	44,118	0.56	0.00	94.28	111	117	65.09
	Sao Chingcha	100112	0.16	0.13	33,898	41,710	0.32	0.00	81.27	130	160	59.16
	Talad Yot	100103	0.19	0.17	34,011	37,635	-0.12	0.00	90.37	122	135	79.19
	Wang Burapha Phirom	100108	0.70	0.57	29,946	37,008	1.51	0.00	80.92	135	166	24.20
	Wat Ratchabophit	100109	0.22	0.21	28,757	31,000	1.36	0.00	92.76	162	175	52.39
	Wat Sam Phraya	100101	0.52	0.38	11,756	16,028	-1.00	0.00	73.35	71	97	52.24
Pom Prap Sattruphai	Ban Baht	102204	0.40	0.38	79,786	84,544	19.87	0.00	94.37	111	118	13.61
	Klong Mahanark	102202	0.58	0.54	84,842	91,297	22.31	2.87	92.93	97	104	66.12
	Pomprab Satrupihe	102205	0.59	0.59	94,052	94,065	15.57	0.00	99.99	165	165	55.35
	Wat Debsirin	102203	0.43	0.43	77,014	77,146	21.41	0.00	99.83	168	168	61.67
	Wat Soammanut	102201	0.45	0.44	65,443	67,109	19.27	0.00	97.52	146	150	38.89
Prawet	Dok Mai	102102	14.95	4.67	1,400	4,483	12.41	68.78	31.22	65	207	85.17
	Nong Bon	102103	12.89	8.10	3,579	5,690	5.64	36.61	62.90	89	141	86.60
	Prawet	102101	37.64	13.51	2,558	7,128	7.01	62.43	35.89	66	184	92.25
Ratburana	Bang Mot	102904	11.41	3.30	4,778	16,511	10.65	70.17	28.94	26	91	61.74
	Bang Pakok	102903	8.04	4.59	11,771	20,613	5.81	36.20	57.15	37	64	66.18
	Ratburana	102901	5.61	4.02	15,583	21,780	-29.29	84.41	71.55	54	75	66.15
	Thung Khru	102902	21.65	3.37	2,219	14,267	10.30	84.44	15.55	8	52	67.38
Ratchathewi	Makkasan	102804	2.47	2.39	22,893	23,717	13.35	0.00	96.53	92	95	70.03
	Thanon Phaya Thai	102801	1.25	1.25	27,152	27,251	19.55	0.00	99.64	116	116	60.61
	Thanon Phetcha Buri	102802	0.99	0.85	49,346	57,013	13.26	9.91	86.55	79	91	61.58
	Thung Phaya Thai	102803	2.51	2.37	47,900	50,737	31.68	2.43	94.41	72	76	65.16
Samphanthawong	Chakkrawat	103202	0.51	0.44	42,914	50,164	11.29	0.00	85.55	124	145	54.20
	Sam Phanthawong	103203	0.49	0.44	39,792	43,808	11.94	0.00	90.83	130	143	44.30
	Talat Noi	103201	0.41	0.35	78,660	90,409	15.14	0.00	87.00	72	82	32.23
Sathon	Thung Mahamek	103302	2.91	2.91	10,582	10,582	1.56	0.00	100.00	107	107	74.63
	Thung Watdon	103303	2.52	2.42	25,501	26,511	1.55	3.81	96.19	75	78	55.74
	Yannawa	103301	1.83	1.68	23,015	25,055	-0.12	0.00	91.86	88	95	66.53
Suan Luang	Suan Luang	103801	20.74	14.25	7,806	11,358	7.45	29.36	68.72	88	128	87.66
Taling Chan	Bang Chuak Nang	100805	6.95	0.71	1,455	14,167	8.20	87.66	10.27	15	149	49.85
	Bang Phrom	100806	5.13	0.66	3,267	25,206	7.09	84.67	12.96	22	168	63.97
	Bang Ramat	100807	15.36	3.21	1,444	6,916	8.37	78.58	20.88	26	126	73.35
	Chim Phli	100802	15.49	6.00	2,631	6,795	10.77	60.60	38.72	46	119	63.35
	Khlong Chak Phra	100801	2.54	1.42	5,455	9,751	9.14	39.40	55.95	39	70	53.81
	Sala Thammasop	100808	19.53	3.94	1,146	5,681	14.91	79.83	20.18	30	149	67.58
	Taling Chan	100803	6.01	3.83	5,429	8,519	6.63	33.20	63.72	37	58	66.33
	Thawi Watthana	100804	16.60	1.92	787	6,801	9.12	88.42	11.58	25	216	67.91
Thonburi	Bang Yirua	100901	1.19	1.17	47,978	48,846	0.07	0.00	98.22	76	77	66.54
	Bukkhalo	100903	4.30	3.90	34,548	38,054	2.38	1.61	90.79	77	85	70.94
	Hirunruchi	100905	0.66	0.65	40,244	41,079	1.52	0.00	97.97	90	92	82.27
	Talat Phlu	100902	1.24	1.09	32,607	37,129	0.46	0.00	87.82	65	73	51.80
	Wat Kanlaya	100904	0.75	0.65	32,042	36,783	4.34	0.00	87.11	56	64	37.65
Yan Nawa	Bang Phong Pang	102702	4.96	3.74	12,220	16,229	6.73	7.59	75.30	57	76	62.07
	Chong Nonsi	102701	7.44	6.54	12,384	14,083	9.49	2.01	87.93	71	81	59.30
Grand Total	BMA		1,578.91	541.02								

13.3 Secondary Data Analysis

Geographic analysis allows users to study real-world processes by developing and applying models. Such models illustrate underlying trends in the geographic data and thus make new information available. A GIS enhances this process by providing tools which can be combined in meaningful sequences to develop new models. There are two kinds of analytical models, qualitative and quantitative, coupled with the GIS database. In stage of the secondary data analysis, the basis for the model calculation is a polygon overlay with a qualitative model for the urban development suitability and potentiality evaluation. The process of model consists of the following elements.

1) Select criteria;
2) Give different weights to the criteria selected (optional); and
3) Combine different criteria.

First, criteria were selected in terms of physical constraint, urban environment service, transportation service and living facilities service as shown on Table 13.4, and then the weight score was given to each item of thematic map manipulated by GIS.

Next step is to perform the spatial overlay of the plural maps according to the assigned score of each item, and sum up the total score value for four different evaluation maps. The results are shown in the relevant part of this report. The importance from the viewpoint of GIS is to assess the spatial distribution of problems and establish an objective before stating any analysis. To review the problem, the potential area for the urban development in future is being identified within an environmental regime. On this process, the score itself is merely estimated relative value for discriminating a specific site to meet with the planning requirements.

Table 13.4 Criteria and Weighted Score for Urban Development Potential Evaluation

Evaluation Condition		Score	-3	-2	-1	0
Physical Constraint	N1	Ground Subsidence	>1.5m	1.0 - 1.5m	0 - 1.0m	0m
	N2	Inundation by 1983 Flood	Yes			No
	N3	Inundation by 1995 Flood	Yes			No
	N4	Flood Protection Zone *1)	A zone	B zone	C zone	Others

Evaluation Condition		Score	1	0
Urban Environment Services	U1	Water Services	Yes	No
	U2	Sewerage Services	Yes	No

Evaluation Condition		Score	5	4	3	2	1
Transportation Services	T1	Accessibility to Trunk Roads	0.5km of R1/R2	1km of R1/R2	0.5km of R3	1km of R3	None
	T2	Accessibility to Railways	0.5km from STN	1km from STN	1.5km from STN	2km from STN	None
	T3	Accessibility to Bus Services	500m zone		1000m zone		None

Evaluation Condition		Score	5	4	3	2	1
Living Facilities Services	F1	Accessibility to Hospitals	<1km	1 - 2km zone	2 - 3km zone	3 - 5km zone	>5km
	F2	Accessibility to Commercial	<2km'	2 - 5km zone	5-10km zone	10-15km zone	>15km

*1) A : Eastern King's Dike
B : Inner Dike - King's Dike
C : Tonburi Lowlands

*2) R1 : Primary Road
R2 : Secondary Road
R3 : Trough Road

13.4 Tertiary Data Analysis

In this stage, simulation modeling analysis for the future urban potentiality in BMA is conducted. The objective of GIS is to provide the means to carry out the analysis which relate specially to the geographic component of the data. The analysis may be more complex and sophisticated. At the advanced level, GIS can allow statistical calculations of the relationship between data sets to be computed or distances between entities may be used to determine the route that must be followed to move as quickly as possible from one location to another. The most sophisticated analysis occurs when modeling is introduced. It is possible, for example, to use atmospheric modeling techniques to discover which area might be affected by pollution resulting from an explosion at a particular hazardous installation, given certain criteria. The traffic conditions were also restored by the simulation method according to the several alternative scenarios of transportation planning.

Finally, various indicators for the future urbanization were combined and analyzed through the mathematical model. Data manipulation capability of the BEIP-GIS is fully applied for the calculation and output mapping of the simulation modeling. The above digital procedures and simulation results are described in each section for land use plan, transportation plan and air pollution mitigation plan.

CHAPTER 14: RECOMMENDATIONS OF INFORMATION SYSTEM DEVELOPMENT

14.1 Development of Mapping System

Experts of BEIP study team have been working for more than one year and have conducted large volume of data collection through the counterpart staff of DPW of BMA. In the course of these efforts, study team have confronted many unseen difficulties such as availability of existing data, accuracy, date of data generation, accessibility to the new and original data, and institutional constraints for informatization etc.,. Those problems are mentioned in the following paragraphs.

(1) Necessity of Large Scale Topographical Map as a Base of Urban Planning

In BEIP study area, those base maps are available for urban planning works such as 1:4,000, 1:10,000, 1:20,000, 1:50,000. In these maps, 1:4,000 and 1:10,000 maps were prepared by JICA as a technical cooperation program in 1987. Royal Thai Survey Department (RTSD) is basically a responsible agency for national survey and mapping. This agency has been made an effort to the preparation and compilation for the national topographical mapping. 1:20,000 and 1:50,000 scale topographical maps are prepared by RTSD as a national base map in 1970's , 1980's, and early 1990's. As we recognize clearly that the urbanization and development activities are so fast in Bangkok that the basic data preparation for land use control or urban planning is totally late. The contents of those maps are now out of date already and updating works of these maps are relatively limited.

For the urban development and management planning of Bangkok as a modern and huge city, fast preparation of large scale topographical map is an essential investment. According to the result of BEIP study, built-up area of Bangkok in 1993 is calculated at 54,000 ha (540 square km), and land use changes are mainly taken place both in business district in the city and fringe area of Bangkok. Eastern agricultural area and south-western marsh land area of BMA are still less developed.

For the economy of mapping cost and time, the new topographical map should be prepared in two scale. In those area where the urbanization is highly expected, 1:2,000 or 1:2,500 scale map should be prepared and rest of area where the development and urbanization is not so high, 1:4,000 to 1:10,000 scale would be acceptable. Administrative boundaries such as district, sub-district or related statistic unit etc., should be drawn clearly in these maps. In case of Japan as a reference, base map scale for urban planning area is regulated at 1:2,500, 1:5,000, and 1:1,0000. All of municipalities are prepared 1:500 or 1:1,000 scale topographical map for taxation and management of urban facilities or utilities in Japan.

(2) Urban Land Use Mapping

In addition to new topographical mapping, it is necessary to grasp the dynamics of urban land use correctly. For this purpose, existing urban land use mapping should be conducted based on the new base map. Preparation of the most updated data for urbanization is a basic responsibility of the urban planning agency, therefore, necessary budget and human resources should be invested in this sector. In this study, existing land use map which is compiled in 1995 by Mapping Division of City Planning Department, BMA is provided to the Study Team, however, the basic scale of this map is 1: 40000 and aerial photographs used for land use interpretation was taken in 1993. Therefore we are able to have only a macro level understanding on the land use pattern in BMA at 1993 from this map. Many buildings and sub-division development have been taking place in these three years, so the necessary updating of this map should be also conducted. New classification system and definition for urban land use mapping based on the large scale topographical map should be discussed so that the final land use map well shows the reality of existing urban conditions.

(3) Preparation of Aerial photograph in BMA

Preparation of the aerial photograph is also very significant to monitor the change of land use in BMA. In order to check the land use change efficiently in urbanized area, basic scale of aerial photograph should be set at 1:5,000 to 1:1,0000 and preferably, aerial photograph should be taken once a year or once every two years.

(4) Involvement of Private Sector for Mapping Service

It is not easy to mention something about the institutional system on mapping and surveying in this country, however, flexibility of various scale of map supply seems to be limited. Existing mapping service capability should be improved in short or middle term point of view. Because of the fast growing of the Thai economy, many kinds of infrastructures have been developed and started to operate. For the efficient operation and maintenance of urban facilities, quick supply of large scale map is an essential thing. Traditionally, survey and mapping functions are managed by military agency in general due to the requirement of national security. Aerial photograph can be taken under the permission of relevant military agency still in many countries, however, even in ASEAN countries like Philippines, Indonesia, or Malaysia,

14.2 Utilization of GIS for Administrative Purposes

(1) Problems for Introduction of GIS Technology

In BMA, many computer systems are installed and used for various data processing. GIS is not an exception. Many EWS or PC based mapping systems including GIS are using mainly in planning agencies. The largest and most critical constraints for the promotion of geographic database development is the supply of basic map data. In case of BLIS, due to the lack of most up-dated map data, old map which was compiled in 1985 had to be input into the most updated computer systems. Clear purpose and long term perspectives are the most necessary things for the development of the geographic database. The meaning of geographic information is to have the newest coordinate data (or geographic boundary data) and related attribute data at the same time. For the urban planning purposes, such data as existing urban land use, location of buildings, type of building use, land use zoning and so on, should be input beside the topographical data. In case of the development of tax assessment system, many factors for tax evaluation must be input together with land ownership data and also the systems for evaluation must be developed as a subsystem. It is very easy to purchase the most updated and sophisticated computer systems, but it is not easy to best use of the system efficiently without the plenty supply of the necessary data. Basic and accurate data preparation should be accelerated for the future informatization in BMA.

(2) Establishment of the System Information Center for BMA

In BMA, GIS has introduced and operated in several departments independently and package software on those systems are either ARC/INFO or MapInfo. Each system seems to be operated and maintained by a few engineers. Although GIS has installed in planning related agencies, application system development is still limited and the system is not fully utilized for planning works. Specific know-how such as urban/regional planning, transportation planning, urban facility management or tax assessment etc., should be well combined with the application of GIS technique. Without those know-how or methodology, so called GIS expert can only reproduce the input map again through the sophisticated computer systems. The most significant purpose to introduce and develop the geographic database is to conduct the spatial data analysis to support the various planning works or to support the various management works. In order to avoid the duplicated investment and to best use of the existing GIS equipment, data and human resources, establishment of the System Information Center based on GIS technique shall be one option. In this Center, systematic training for the GIS operation, application system development, necessary data generation and information production could be conducted as a basic service for the whole BMA. Necessary discussion on this matter shall be waited.

APPENDIX 1: THE BEIP TRANSPORT SIMULATION MODEL

1. Back Ground

1.1 Introduction

The simulation model used for BEIP has been developed for the whole of the Bangkok Metropolitan Region, BMA plus the five adjacent provinces of Nonthaburi, Samut Prakarn , Pathun Thani, Nakorn Pathom and Samut Sakorn .However the presentation of the results will concentrate on the BMA .

This appendix describes the development of the simulation model. The appendix is divided into an additional 6 sections. The overall model development structure is shown in Fig.AP-1.1.

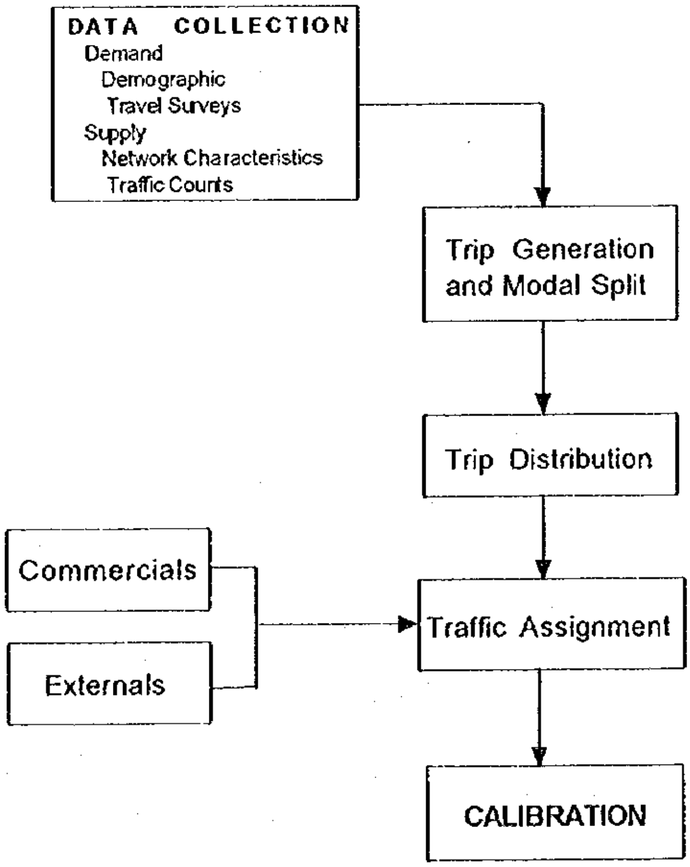

Fig. AP-1.1 Model Development Process

Section 2 describes the data collection procedure including the development of the traffic zone system, and the trip generation and attraction model including the initial production based modal split are detailed in Section 3.

The trip distribution for this model is discussed in Section 4. Section 5 describes the development of the commercial vehicle and external trip tables. The final model calibration / validation is given in Section 6.

In Section 7 the procedure for running the model to test different transport scenarios is documented for reference including the interface with GIS for presentation and environmental analysis. This section also describes the 10 cases analyzed in the development of the Transport Vision for BEIP. The final post distribution modal split for new network analysis is also described in this section .

2. Data Collection

2.1 Overview

The data collection for this study was jointly done with the Urban Transport Database Model (UTDM), a national government project being undertaken for OCMRT. In the past, transport studies in Bangkok have developed their own databases and zoning systems. Now for the first time a common approach is being used by two different major studies. Although some details are different the models developed in each project use a common database.

The UTDM project is designed to develop a model that will form the basis of transport modeling in Bangkok for some time, the BEIP simulation model is developed to evaluate overall transport strategies in Bangkok, rather than at the individual project level. In many respects the BEIP simulation model can be considered a sub model of UTDM.

2.2 Traffic Zoning System

For the first time in Bangkok ,the zone boundary is developed directly from the census boundaries. Each traffic zone was designed to consist as an aggregation of Census Enumeration Districts. The BMA is divided into over 4,000 enumeration districts each with approximately 500 households.

In the case of the BMA, it was divided into 332 zones with an average of 6,000 households per traffic zone. The whole BMR is divided into 505 zones. There are further 15 zones which are the external stations representing the locations where the major roads cross the study area boundary for the transport simulation model. The roads represented by the external stations are given in Table AP-1.1.

Table AP-1.1 External Stations

External Zones	Road Location	
506	Highway Route #	35
507	Highway Route #	4
508	Highway Route #	346
509	Highway Route #	321
510	Highway Route #	340
511	Highway Route #	3111
512	Highway Route #	3309
513	Highway Route #	1
514	Highway Route #	32
515	Highway Route #	3261
516	Highway Route #	305
517	Highway Route #	3312
518	Highway Route #	304
519	Highway Route #	34
520	Highway Route #	3

In the development of the zone boundaries within the BMR, three principles were adhered to namely:

- a zone boundary does not cross a district or sub-district boundary ;
- a zone is designated to be homogeneous in nature; and

- a zone is designated to represent a transport catchment area .

However overall the guiding control was that a zone is an amalgamation of census enumeration districts.

2.3 Home Interview Survey

The major data collection exercise for the transport model was the home interview survey. This was a joint survey with UTDM. UTDM undertook the first 4,000 surveys followed by an additional 4,000 by BEIP. The same survey staff was used in both sets of data together with a consistent technique for survey sample development. The survey sample expansion factors were developed for a combined sample. The sample selected from each province is given in Table AP-1.2

Table AP-1.2 Sample Distribution

Province	Sample	Total Households (x1000)
Bangkok	3,971	2,037
Samut Prakarn	1,459	242
Nonthaburi	1,022	163
Pathun Thani	723	147
Nakhon Pathon	225	172
Samut Sakhon	479	94
TOTAL	7,879	2,857

On the completion of the zoning system a zone to enumeration district equivalence table was prepared for use by NSO . NSO then reprocessed the census data and summarized selected census data on the basis of the 505 internal traffic zones for the BMR.

Other survey data collected by the UTDM project used in BEIP included:

- Roadside Interview Surveys
- Midblock Traffic Counts
- Turning Movement Counts
- Public Transport Passenger Interview Surveys
- Travel Time Delay Surveys
- Taxi Surveys

2.4 Demographic Data

The base year demographic data for 1995 was developed jointly with UTDM and has been thoroughly documented by that project data. The home interview data provided an additional check on the consistency of the base year. A summary of the planning data is given in TableAP-1.3 for the base year 1995 and the trend forecast year of 2011. The districts boundaries are shown in Fig. AP-1.2

Table AP-1.3 Summary of Demographic Data

District	Population		HH size		Avg. HH Income		Employment		Student	
	1995	2011	1995	2011	1995	2011	1995	2011	1995	2011
Phra Nakhon	106,334	107,190	4.49	4.02	27,580	44,048	158,370	301,928	69,542	71,075
Pom Prap Sattrupha	198,739	181,747	4.54	4.17	17,248	27,620	99,345	143,291	30,872	28,215
Samphanthawong	73,479	67,422	4.60	4.11	36,783	58,834	52,092	83,236	16,610	15,241
Bangkok Noi	251,535	308,989	4.22	3.90	15,497	24,819	41,509	59,973	50,816	60,519
Bang Phlat	247,004	301,047	4.18	3.81	19,902	31,448	77,430	125,852	39,977	49,097
Khlong San	144,402	167,473	4.61	4.12	18,591	29,736	77,766	105,743	15,749	18,254
Thonburi	296,430	343,068	4.42	3.95	15,074	24,114	85,862	115,151	48,637	56,143
Bangkok Yai	103,961	127,170	4.27	3.85	17,725	28,353	46,686	66,209	44,657	54,631
Dusit	283,042	282,910	3.99	3.67	22,671	36,260	84,911	124,549	115,323	115,296
Bang Rak	164,413	150,669	4.09	3.79	14,985	23,955	296,236	451,530	50,219	46,028
Bang Kho Leam	144,223	168,481	4.28	3.84	13,215	21,134	84,683	116,020	11,246	13,052
Bang Sue	338,730	404,365	3.93	3.58	23,138	37,222	85,456	109,689	40,195	50,403
Pathumwan	290,939	266,851	4.48	4.02	16,389	26,214	163,612	259,048	91,673	83,849
Phaya Thai	254,027	307,974	3.77	3.57	18,561	30,019	73,320	127,026	33,577	42,367
Yan Nawa	152,804	180,088	4.08	3.76	14,636	23,324	118,295	175,901	23,445	27,472
Ratchathewi	259,641	241,399	3.77	3.65	17,935	28,591	249,932	454,861	80,120	74,479
Sathon	136,963	161,532	4.12	3.72	17,351	27,764	113,728	206,506	57,427	67,280
Klong Toei	306,564	338,142	3.94	3.68	17,122	27,457	394,509	522,341	101,313	111,377
Chatu Chak	227,700	269,669	3.78	3.67	31,188	49,156	129,891	175,990	126,719	148,518
Don Muang	298,654	520,213	3.61	3.47	22,681	37,330	137,784	217,654	77,796	131,643
Bang Kapi	388,381	538,462	3.44	3.39	24,141	36,444	220,334	221,074	132,524	154,555
Bang Khen	377,261	420,802	3.58	3.42	24,217	37,406	70,325	68,640	58,269	64,553
Bung Kum	251,249	488,993	3.62	3.51	23,000	35,230	80,863	122,623	27,197	57,972
Phra Khanong	258,079	310,499	3.86	3.52	35,226	55,468	152,774	154,317	57,285	66,766
Suan Luang	161,910	282,459	3.86	3.55	26,416	45,022	62,365	80,631	22,036	44,631
Prawet	163,345	340,256	4.40	3.91	23,528	38,732	64,788	88,409	21,416	34,126
Huai Khwang	93,576	156,008	3.50	2.20	16,382	25,908	150,046	228,307	33,165	66,659
Lat Phrao	164,073	297,852	3.82	3.57	23,624	35,170	42,007	52,968	12,706	29,715
Din Daeng	261,227	242,888	3.65	3.57	16,546	26,607	123,923	116,320	72,077	66,973
Minburi	185,830	268,491	4.12	3.70	25,349	43,920	74,282	61,498	30,085	45,325
Latkrabang	123,696	160,370	3.96	3.76	14,690	23,638	83,922	42,813	34,061	42,149
Nong Chok	93,244	95,465	4.57	4.10	12,667	20,262	32,739	16,156	13,342	13,652
Chom Thong	199,282	306,122	4.21	3.80	15,502	24,739	69,117	81,862	22,082	35,963
Taling Chan	171,706	282,862	4.03	3.71	28,703	48,352	44,541	33,524	19,648	39,696
Bang Khun Thian	229,975	477,459	4.03	3.75	21,219	32,167	123,789	111,165	34,861	72,670
Phasi Charoen	314,860	438,888	4.15	3.76	12,607	19,697	173,720	199,421	77,663	128,752
Ratburana	264,724	325,158	4.32	3.95	24,738	40,327	75,270	53,839	40,968	48,866
Nong Khaem	144,123	166,520	3.92	3.65	28,041	44,872	122,102	91,834	36,160	41,408
BMA TOTAL	8,126,125	10,495,953	3.99	3.66	21,032	33,802	4,338,325	5,767,895	1,871,458	2,319,369
OTHER PROVICES										
Samut Prakarn	982,794	1,258,387	4.05	3.72	15,232	23,151	661,040	932,209	61,355	106,162
Nonthaburi	668,926	1,007,608	4.09	3.71	27,093	43,788	278,857	341,686	103,033	122,661
Pathun Thani	584,283	919,464	3.97	3.69	17,733	32,949	363,844	302,407	123,879	164,451
Nakhon Pathon	721,917	1,071,249	4.19	3.77	15,098	23,722	411,093	555,506	153,107	266,344
Samut Sakhon	367,689	473,211	3.92	3.64	12,997	21,323	296,559	430,049	42,793	30,374
GRAND TOTAL	11,451,734	15,225,872	4.01	3.67	20,094	32,452	6,349,718	8,329,752	2,355,625	3,009,360

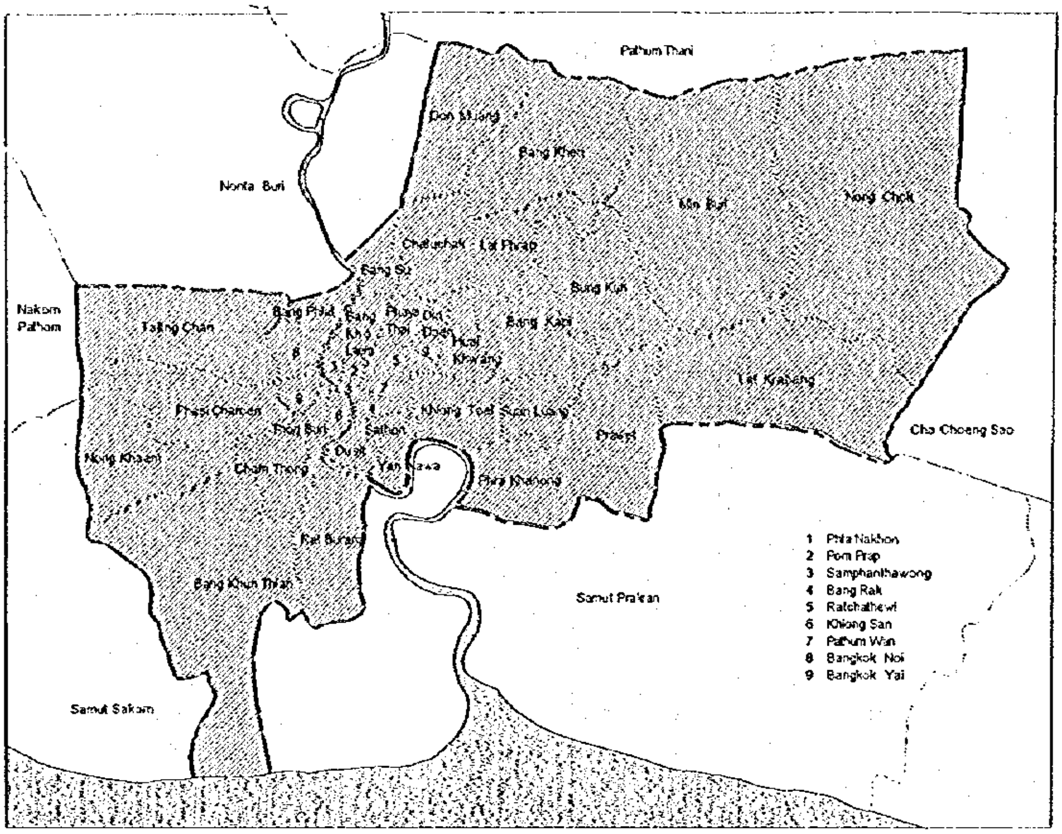

Fig. AP-1.2 Districts within the BMA

2.5 Network Development

The road network is a computerized simulation of the road system located within the study area. The network consists of numerous links (road segments) and nodes (intersection points), with each link being embedded with a unique set of indexes describing its operating capabilities. Two of the most important measures in this regard are speed and capacity.

There does not, at present, exist a manual in Thailand which quantitatively describes the relationship between speed, volume and capacity and road inventory under local conditions. In the past, these relationships have been developed in an ad hoc manner.

To adopt a scientific approach ,sources external to Bangkok and Thailand must therefore be employed for this purpose. It is the opinion of this project that link speed and capacity can adequately be developed based on recent findings of investigations conducted by UTDM and Indonesian Highway Capacity Manual.

It is judged that the application of these findings in a Bangkok context is more appropriate than the more traditional highway capacity manuals prepared for use in American , Japanese or Australian highway capacity techniques.

The use of a Thailand highway capacity manual is, of course, preferred once such a document is available and adopted on a uniform national scale. Since on the master inventory file there are data about road inventory such as locality, number of lanes and side friction new relationships derived in Thailand can readily be used in the future. This inventory to date has been based on the records of the BMA.

The study area road system, including all national, province, district roads and major through sois, a total of some 1,700 kilometers within the BMA. The level of detail with which the zone structure and highway network are built must be in balance; thus, not all existing roads need be included. Indeed, to provide linkage between all zones, a highway network embracing all nationally-owned, and principal BMA- and DOH-owned roads, is adequate.

The base-year (1995) network was therefore built via three steps:

- Digitization of the network, using the capabilities of ARC/INFO software, zone boundaries and relevant road network elements depicted on maps developed by Royal Thai Survey. Within the study area, base map scales varied between 1:20,000 for BMA and 1:50,000 for outside BMA.;
- Integration of field surveys and inventory data available via previous studies and our field survey conducted within the study area. This included a review of all inventory data held at the BMA within the Department of Public Works.; and
- Calculation of link parameters , the link parameters were calculated via a series of linked spreadsheets. (In retrospect if this procedure is used again it is strongly recommended that this procedure be redeveloped in a database framework.)

For the purpose of the development of a transport model ,the transport modeling software in this case, TRANPLAN[1] , highway network simulation programs require following parameters for each link:nodes, link distance,link capacity,and an assignment group code (capacity index in some software).

The A and B nodes are numeric values that identify the "from" and "to" ends of a link. Node locations are defined by their X and Y coordinates, which are derived from the digitizing process, and thus permit displays of network content, performance and operation via a graphical network editor in this case , NIS.

The Link distance defining the length of a link in kilometers ,this is measured directly from the GIS software.

Free flow speed, which is defined as the safe speed at which a vehicle would travel on a link in the absence of other traffic. The average free flow speeds are calculated based on equations used in the Indonesian Highway Capacity Manual, augmented by speed studies conducted throughout the study area.

Link capacity is defined in terms of practical capacity and assignment capacity. Practical capacity represents an absolute limit regarding the number of vehicles (pcu's) which can be accommodated on a given road section under realistic operational and terrain conditions.

Assignment capacity represents a trip-making threshold for modeling purposes at which alternative route choices (as possible) are likely. This is generally adopted as being synonymous with a Level of Service C/D[2] and uninterrupted flow condition[3].

[1] TRANPLAN (Transport Planning) and NIS (Network Information Systems)is an integrated set of computer programs offering , witin a single package , comprehensive planning and forecasting capabilities for both highway and transit systems. TRANPLAN/NIS is proprietary software distributed by the Urban Analysis Group , Danville , California ,USA and licensed for use by Pacific Consultants International.

[2] Lecel of Service as defined by the Highway Capacity Manual , Spedial Report 209 Transportation Research Board , USA 1985 (with subsequent updates)

Assignment capacity, free flow speed and traffic loadings are integrated via speed-decay curves which dynamically decrease link attractiveness (speed) as the volume to capacity ratio (V/C) increases.

Practical capacity is calculated in terms of hourly pcu's per lane or section, assignment capacity (about 80 percent of practical capacity) is generally expressed as daily link pcu's based on a specified percent peak hour factor.

Assignment group (ASG) code is used to identify links to which a common capacity restraint function is to be applied, that is, link speed is reduced by a pre-determined function as the link volume to capacity ratio increases.

Speed decay functions mirror the IHCM speed-flow relationships and depict speed decreasing from free-flow status as the V/C ratio increases. The change is particularly pronounced for narrow roads due to numerous avoidance maneuvers between directional traffic streams, as well as between traffic streams and roadside activities

Link type groupings are developed in accordance with relationship with the database and represent inventory items such as the agency ownership of the road.

3. TRIP GENERATION

3.1 Overview

Two concepts require definition when describing the structure of trip generation models. The first is the concept of trip productions and trip attractions; the second is trip stratification.

In this model also the initial modal split is applied at the generation stage. This stage focuses on predicting the absolute number of daily person trips generated by each of the study area's 505 zones by purpose by mode .

3.2 Definitions

(1) Trip Production / Attraction

In modeling terms there are two types of trip ends - productions and attractions. Trip productions are located at the trip maker's home (the majority of all urban trips begin or end at home). Trip ends 'produced' by the home are linked with the characteristics of the household producing the trips - the number of persons, workers and students in the household, the household income and the number and type of private vehicles available to household members.

Trip attractions on the other hand are trip ends located away from the trip maker's home and are estimated as a function of variables that 'attract' trips (persons) to that location (for example, the availability of jobs or educational places).

The 1995 household survey yields information describing the socioeconomic characteristics of potential tripmakers in a given zone. This information (household income, number of persons, workers and students in the household and the availability of private vehicles) is related to the number of trips produced by members of individual households.

Trip productions therefore are estimated as a function of a zone's residential development. The attraction, or non-home, end of trips is estimated as a function of the socioeconomic variables that tend to "attract" trips. Variables used for this purpose include employment (number of jobs) and school enrollment.

It is generally accepted that trip productions are estimated with more accuracy than trip attractions. Therefore, total trip productions are used to define a control total for aggregate travel in the study area. As the final step in the trip generation modeling procedure, trip attractions are therefore factored to equal trip productions.

(2) Trip Stratification

Trip makers travel to satisfy different objectives. In the study of travel behavior it has been found that it is possible to more accurately estimate the different kinds of trips separately than in total. In addition, the purpose for which a trip is made is often related to differences in several characteristics of the trip (the time of day, the mode of travel and the distance one is willing to travel to satisfy one's travel objective).

Trip characteristics, particularly vehicle ownership patterns, are strongly correlated with household income. Therefore, stratifying total trips by trip purpose, levels of income as well as vehicle ownership improves the accuracy of model components addressing these trip characteristics.

In the BEIP models four major trip purposes are used:

- Home-based Work (HBW) - Trips between residence and primary work location.
- Home-based Educational (HBE) - Trips between residence and school location.
- Home-based Other (HBO) - Trips between residence and all other locations (shopping, recreational, religious and personal business locations).
- Non-home-based (NHB) - Trips with neither end at home (for example, a trip between work place and restaurant).

In addition to these major trip purposes, two important characteristics of the tripmaker have been used to further stratify trip purpose; namely, vehicle ownership patterns and household income. Review of the 1995 home interview survey data found that trips made by different vehicle availability groups had different characteristics of trip length and mode choice.

To represent these differences in the model (and improve the accuracy of the forecasts) A total of sixteen purpose/vehicle availability group designations are used to represent these differences in the model (and improve the accuracy of the forecasts). These sixteen different categories of trips are processed separately by the trip generation and (later) trip distribution model components. For each of the four trip purposes listed above, four different levels of vehicle ownership are adopted; namely, households which own:

- Group 1: No vehicles;
- Group 2: At least one motorcycle (but no cars);
- Group 3: At least one car (and possibly a motorcycle); and
- Group 4: Two or more cars (and possibly a motorcycle).

As discussed in the following paragraph, household income is the single most important determinant of vehicle ownership. Results of the home interview survey yield typical household incomes; these were combined into four major groupings, with each grouping containing roughly one-fourth of study area households. These four groupings represent households with low, medium-low, medium-high and high incomes (Table AP-1.4)

Table AP-1.4 1995 Household Income Distribution: BEIP STUDY AREA

Income Group Number	Income Group Name	Income Range (Baht/Month)	Number of Households	Percent In Range	Percent In Group
1	Low	Less than 5,000	125,786	4.4	26.5
		5,000 - 9,999	631,787	22.1	
2	Low-Medium	10,000 - 14,999	754,714	26.4	26.4
3	Medium-High	15,000 - 19,999	431,674	15.1	22.7
		20,000 - 24,999	217,266	7.6	
4	High	25,000 - 29,999	214,407	7.5	24.4
		30,000 - 39,999	174,385	6.1	
		40,000 - 49,999	117,209	4.1	
		50,000 - 99,999	160,091	5.6	
		100,000 and up	31,446	1.1	
	Total		2,858,766	100.0	100.0

Source: 1995 BEIP Household Survey

3.3 Generation Model Development

Further review of home interview survey results confirmed, in addition to the previously defined stratification's, that considerable differences in vehicle ownership and trip making propensity exist between residents of the Bangkok Metropolitan Area (BMA) and persons residing outside of the BMA but within the Bangkok Metropolitan Region (BMR).

In terms of monthly household income (year 1995 Baht), differences are not overly pronounced. The BMA average is, for example, 20,600 Baht, and outside of BMA, 18,500 Baht . However, a BMA resident is more likely to own a vehicle than a person residing outside of Bangkok if incomes are reasonably similar. For example, some 60 percent of BMA households with an income of between 10,000 and 15,000 Baht are likely to own no vehicles, and slightly over 10 percent own a car (Fig. AP-1.3). In the case of households outside of the BMA with similar incomes, only some 40 percent own no vehicles and about 25 percent own one car (Fig. AP-1.4).

Thus , one additional stratification hierarchy by geographic entity (BMA, outside of BMA) was maintained throughout the production modeling process.

Two different mathematical techniques are used to construct the trip production and attraction models. The trip production models cross-classify households by income and vehicle availability category. Within each income/vehicle availability group an average rate of trip making for each of the household cross classifications is derived from the findings of the home interview survey .

These averages are then plotted and smooth curves are fitted to the individual points. The trip rate curves represent trips per worker for homebased work trips, trips per student for homebased school trips and trips per person for homebased other and non homebased trips. In some cases, aggregations in vehicle ownership categories proved possible due to similarities in trip making patterns. The adopted trip rates confirm that (Table AP-1.5):

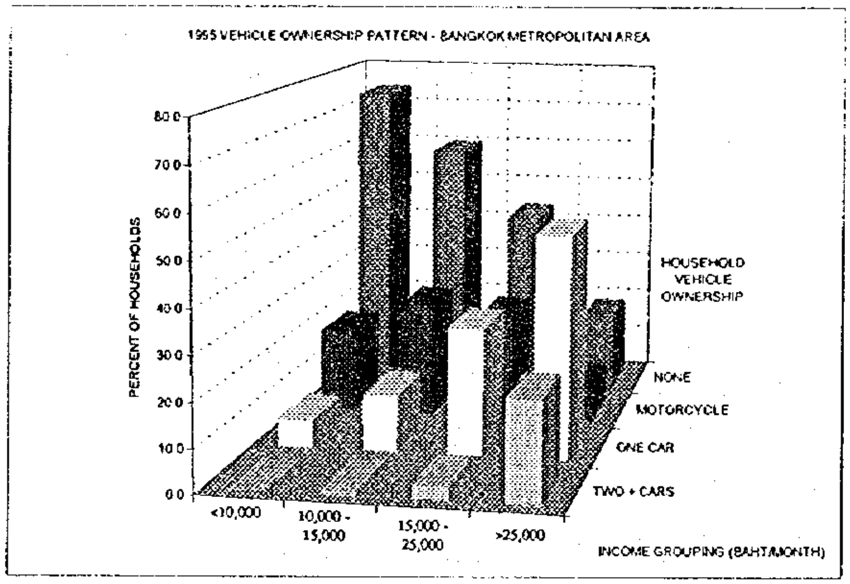

Fig. AP-1.3 Vehicle Ownership within BMA

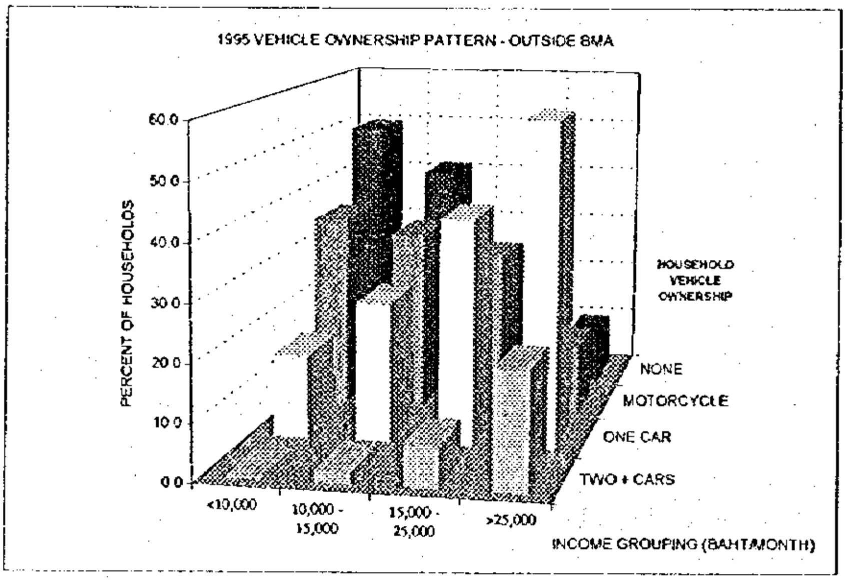

Fig. AP-1.4 Vehicle Ownership within BMR ,but outside BMA

- The unit trip production rate of BMA residents is higher for all trip purposes than the rate exhibited by persons residing outside of the BMA. These data confirm that urban study area residents travel away from the home more often than their rural compatriots.
- Trip production rates are, in the case of HBE trips, largely insensitive to income or vehicle ownership levels. The same pattern, although to a less pronounced degree, is observed for HBW trip productions by BMA residents. This suggests that non-discretionary trips (work, school) are accomplished regardless of the household's social strata.

- HBO and NHB trip production rates, two categories which can be viewed as being more discretionary in nature, exhibit marked increases (particularly so for persons residing outside of the BMA) as household income and/or relative levels of vehicle ownership increases . From the original home interview surveys there was a significant level of underreporting in these two categories . These trip rates were adjusted by cross checking against the larger sample frame of the SIMR home interview survey.

Table AP-1.5 Person Trip Rates

WITHIN BANGKOK METROPOLITAN AREA												
INCOME GROUP	TRIP PURP	VEH O'SHIP	TRIPS PER WORKR	TRIP PURP	VEH O'SHIP	TRIPS PER STUDNT	TRIP PURP	VEH O'SHIP	TRIPS PER PERSON	TRIP PURP	VEH O'SHIP	TRIPS PER PERSON
1	HBW	1,2	1.70	HBE	2	2.15	HBO	1	0.20	NHB	1	0.06
		3,4	1.50		1,3,4	2.06		2	0.33		2	0.15
								3,4	0.44		3,4	0.26
2	HBW	1,2	1.80	HBE	2	2.20	HBO	1	0.21	NHB	1	0.07
		3,4	1.5		1,3,4	2.09		2	0.35		2	0.17
								3,4	0.45		3,4	0.27
3	HBW	1,2	1.80	HBE	2	2.20	HBO	1	0.22	NHB	1	0.08
		3,4	1.60		1,3,4	2.09		2	0.37		2	0.18
								3,4	0.46		3,4	0.29
4	HBW	1,2	1.80	HBE	2	2.20	HBO	1	0.22	NHB	1	0.10
		3,4	1.63		1,3,4	2.09		2	0.37		2	0.18
								3,4	0.46		3,4	0.33

OUTSIDE BANGKOK METROPOLITAN AREA (BMR LESS BMA)												
INCOME GROUP	TRIP PURP	VEH O'SHIP	TRIPS PER WORKR	TRIP PURP	VEH O'SHIP	TRIPS PER STUDNT	TRIP PURP	VEH O'SHIP	TRIPS PER PERSON	TRIP PURP	VEH O'SHIP	TRIPS PER PERSON
1	HBW	1,2	1.30	HBE	1,2,3,4	1.67	HBO	1	0.07	NHB	1	0.02
		3,4	0.85					2	0.15		2	0.05
								3,4	0.25		3,4	0.17
2	HBW	1,2	1.37	HBE	1,2,3,4	1.70	HBO	1	0.09	NHB	1	0.03
		3,4	1.00					2	0.16		2	0.06
								3,4	0.27		3,4	0.19
3	HBW	1,2	1.43	HBE	1,2,3,4	1.70	HBO	1	0.10	NHB	1	0.04
		3,4	1.1					2	0.18		2	0.09
								3,4	0.27		3,4	0.20
4	HBW	1,2	1.49	HBE	1,2,3,4	1.70	HBO	1	0.12	NHB	1	0.05
		3,4	1.43					2	0.18		2	0.10
								3,4	0.28		3,4	0.22

Notes: (1) Income group definitions(all Baht/month/household)
1-less than10,000
2-10,000-15,000
3-15,000-25,000
4 -more than 25,000
(2) Vehicle Ownership definitions
1-households with no vehicles
2 - households owning at least one motorcycle
3-households owning at least one car
4-household own at least two cars

3.4 Trip Attraction Model Development

The trip attraction models employ linear regression analysis to calibrate the coefficients as shown in the following equation:

$$A_j = a_1 + b_1x_1 + b_2x_2 + b_nx_n$$

where:

A_j = Trip attractions in zone j;

X_{1-n} = Socioeconomic variables describing zone j (employment, school enrollment, etc.); and,

$a_1 b_{1-n}$ = Constants and coefficients determined through calibration.

Results are presented in graphical form for homebased work trips (Fig. AP-1.5) and homebased educational trips (Fig. AP-1.6). In each plot, a comparison of observed and modeled attractions on a zonal basis is presented, as is the equation form and correlation coefficient (r^2). It is noted that all r^2 values are extremely high thus confirming (as expected) the strong correlation between HBW trips and employment, as well as between HBE trips and student places.

However, the regression analyses for homebased other trips and nonhomebased trips proved more problematic. These type of trip attractions are typically related to landuses such as commercial activity, retail development and religious institutions. Regretfully, zonal information which quantifies these data (such as square meters of retail/commercial activity, number of restaurant seats, number of theater seats, size of religious institutions) are not available from governmental sources, nor do the resource and temporal constraints of the current study permit development of such a database.

In light of this limitation, a series of regression runs were undertaken to evaluate the statistical relationship of available zonal variables with HBO and NHB trips. It was found that tertiary employment is the most appropriate surrogate indicator; unfortunately, the correlation coefficient is less than hoped for (Fig. AP-1.7 and AP-1.8).

To partially compensate for this shortcoming, the generation process was structured to maintain sensitivity toward both observed and empirical levels of demand. In other words, the application of base (1995) and future zonal socioeconomic variables resulted in the calculation of a relative rate of growth vis-à-vis observed conditions; that is,

$$T_F = T_B * \frac{T_{RF}}{T_{RB}}$$

where, for each zone,

T_F = Estimated future - year trips
T_B = Base - year trips
T_{RF} = Regression trip estimate derived from future socioeconomic variables
T_{RB} = Regression trip estimate derived from base - year socioeconomic variables

The final calculated attractions are, as indicated previously, balanced to calculated productions for the BMA and areas outside of the BMA.

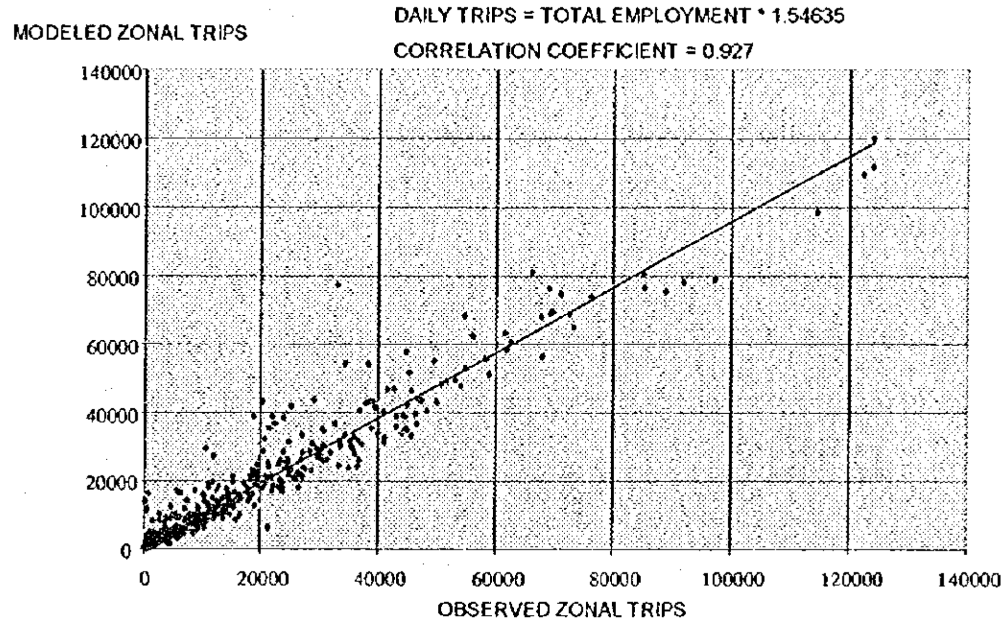

Fig. AP-1.5 Regression for Home Based Work (HBW)

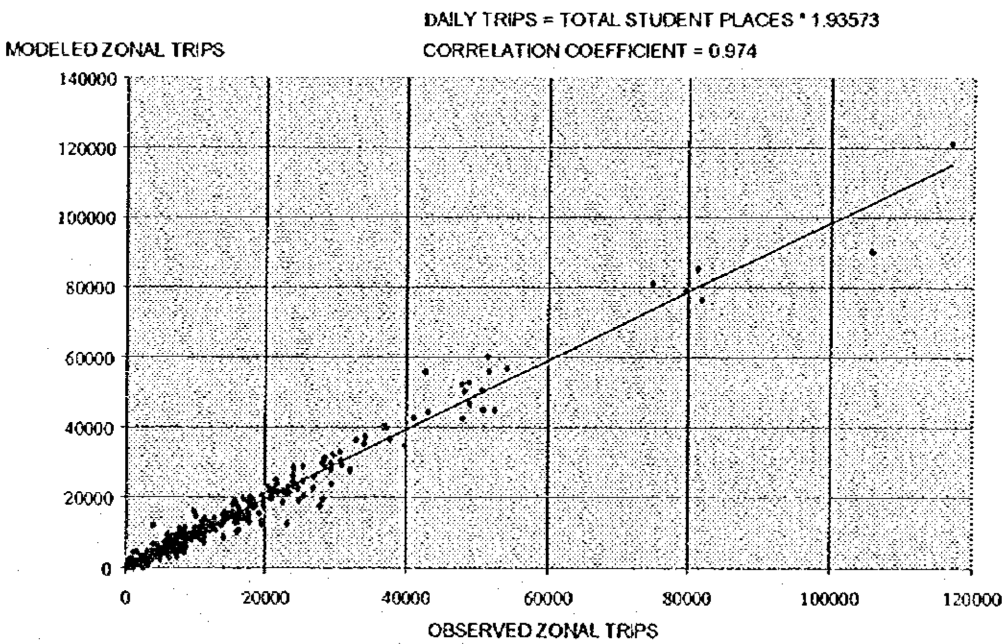

Fig. AP-1.6 Regression for Home Based Education (HBE)

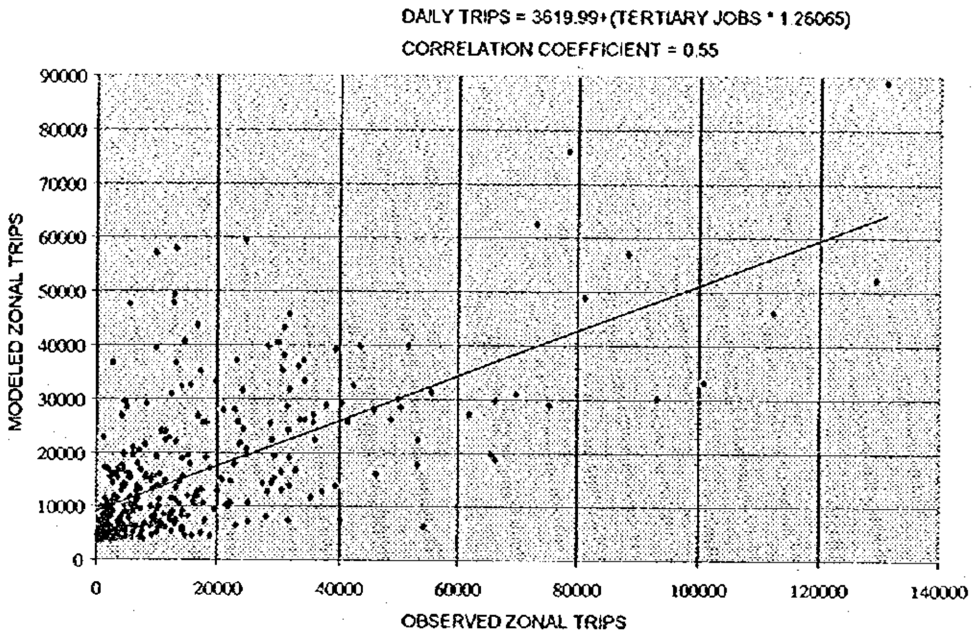

Fig. AP-1.7 Regression for Home Based Others (HBO)

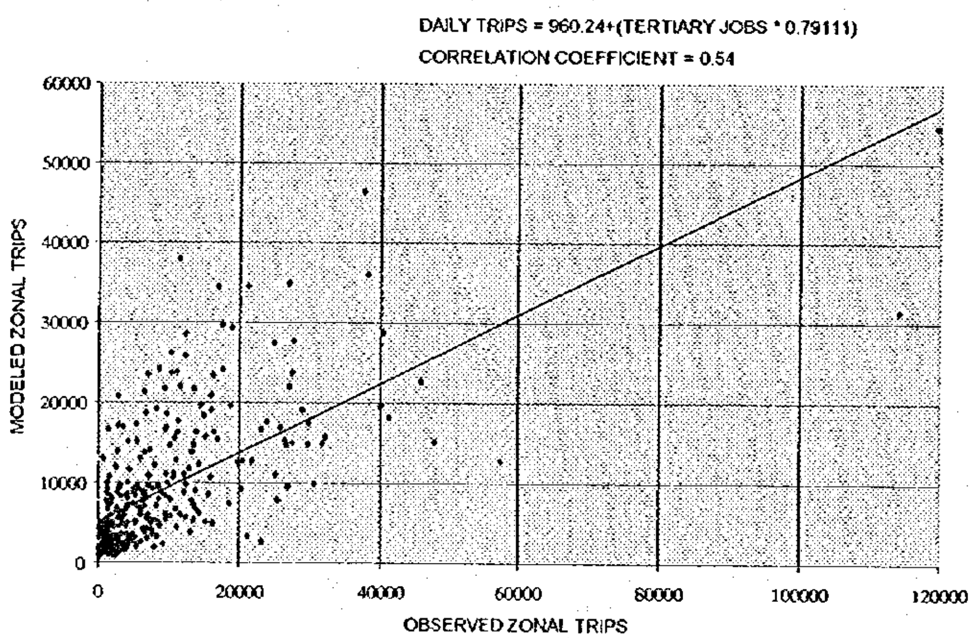

Fig. Ap-1.8 Regression for Non Home Based (NHB)

3.5 Pre Distribution Modal Split

A pre distribution modal split approach was adopted in this study for the base year analysis . In future years this was complimented with the modal split diversion curves derived during the SIMR study .(This is discussed further in Section 7 .) The modal split proportion factors were derived for each trip purpose and each vehicle ownership group from the 1995 home interview survey . These proportions are shown in Tables AP-1.6-AP-1.9 for each trip purpose .

Table AP-1.6 Modal Proportions for Home Based Work

Classification	Area	Income Group	Walk	M/C	Car	Public
HBW - 0 Veh	BMA	1	17.7%	8.0%	0.9%	73.5%
		2	17.5%	7.5%	1.3%	73.6%
		3	15.5%	5.2%	0.8%	78.4%
		4	7.0%	3.2%	3.3%	86.5%
	BMR	1	10.6%	7.8%	2.2%	79.4%
		2	8.4%	8.3%	0.5%	82.8%
		3	14.0%	8.8%	0.5%	76.7%
		4	6.5%	1.8%	3.9%	87.8%
HBW - M/C	BMA	1	8.0%	82.5%	0.3%	9.3%
		2	13.1%	67.8%	1.1%	18.0%
		3	9.1%	54.9%	0.6%	35.3%
		4	7.6%	42.7%	1.6%	48.1%
	BMR	1	4.0%	88.2%	0.9%	6.9%
		2	7.8%	77.6%	2.1%	12.5%
		3	6.5%	55.8%	3.6%	34.1%
		4	5.3%	57.9%	0.3%	36.4%
HBW - CAR	BMA	1	6.2%	12.1%	61.6%	20.1%
		2	4.1%	3.8%	74.8%	17.2%
		3	5.2%	5.6%	66.4%	22.8%
		4	3.1%	6.6%	62.2%	28.1%
	BMR	1	0.2%	11.4%	81.2%	7.2%
		2	3.7%	15.1%	69.4%	11.7%
		3	5.4%	12.8%	63.3%	18.6%
		4	3.7%	12.3%	68.6%	15.5%
HBW - CAR 2 +	BMA	1	1.4%	2.1%	83.5%	12.9%
		2	1.4%	2.1%	83.5%	12.9%
		3	1.4%	2.1%	83.5%	12.9%
		4	1.4%	2.1%	83.5%	12.9%
	BMR	1	5.0%	4.2%	78.2%	12.5%
		2	5.0%	4.2%	78.2%	12.5%
		3	5.0%	4.2%	78.2%	12.5%
		4	5.0%	4.2%	78.2%	12.5%

Table AP-1.7 Modal Proportions for Home Based Education

Classification	Area	Income Group	Walk	M/C	Car	Public
HBE - 0 Veh	BMA	1	33.3%	5.8%	0.8%	60.2%
		2	28.5%	3.4%	0.2%	67.8%
		3	21.9%	1.9%	2.0%	74.2%
		4	14.4%	5.9%	1.8%	78.0%
	BMR	1	29.7%	5.3%	2.0%	63.0%
		2	28.5%	5.9%	4.5%	61.1%
		3	15.7%	1.1%	8.3%	74.9%
		4	15.7%	1.1%	8.3%	74.9%
HBE - M/C	BMA	1	24.6%	21.6%	0.7%	53.1%
		2	24.6%	21.6%	0.7%	53.1%
		3	29.2%	19.6%	0.8%	50.5%
		4	29.2%	19.6%	0.8%	50.5%
	BMR	1	14.6%	36.5%	1.5%	47.4%
		2	23.2%	23.7%	4.0%	49.1%
		3	22.2%	22.8%	0.9%	54.1%
		4	22.2%	22.8%	0.9%	54.1%
HBE - CAR	BMA	1	10.4%	15.8%	30.0%	43.8%
		2	21.8%	10.9%	7.4%	59.9%
		3	15.7%	7.9%	17.8%	58.7%
		4	9.2%	4.4%	20.2%	66.2%
	BMR	1	20.2%	3.9%	15.4%	60.5%
		2	13.5%	16.1%	19.4%	51.0%
		3	18.3%	4.9%	13.9%	62.9%
		4	12.5%	16.3%	15.6%	55.6%
HBE - CAR 2 +	BMA	1	6.7%	2.4%	45.5%	45.4%
		2	6.7%	2.4%	45.5%	45.4%
		3	6.7%	2.4%	45.5%	45.4%
		4	6.7%	2.4%	45.5%	45.4%
	BMR	1	2.5%	3.0%	72.4%	22.2%
		2	2.5%	3.0%	72.4%	22.2%
		3	13.1%	6.9%	27.0%	53.0%
		4	9.2%	3.3%	42.0%	45.6%

Table AP-1.8 Modal Proportions for Home Based Other

Classification	Area	Income Group	Walk	M/C	Car	Public
HBO - 0 Veh	BMA	1	34.0%	5.0%	1.0%	60.0%
		2	34.0%	5.0%	1.0%	60.0%
		3	34.0%	5.0%	1.0%	60.0%
		4	15.4%	6.5%	14.8%	63.3%
	BMR	1	34.0%	5.0%	1.0%	60.0%
		2	34.0%	5.0%	1.0%	60.0%
		3	34.0%	5.0%	1.0%	60.0%
		4	15.5%	4.5%	8.9%	71.1%
HBO - M/C	BMA	1	29.0%	50.0%	1.0%	20.0%
		2	29.0%	50.0%	1.0%	20.0%
		3	29.0%	50.0%	1.0%	20.0%
		4	29.0%	50.0%	1.0%	20.0%
	BMR	1	29.0%	50.0%	1.0%	20.0%
		2	29.0%	50.0%	1.0%	20.0%
		3	29.0%	50.0%	1.0%	20.0%
		4	29.0%	50.0%	1.0%	20.0%
HBO - CAR	BMA	1	35.0%	15.0%	30.0%	20.0%
		2	35.0%	15.0%	30.0%	20.0%
		3	35.0%	15.0%	30.0%	20.0%
		4	35.0%	15.0%	30.0%	20.0%
	BMR	1	35.0%	15.0%	30.0%	20.0%
		2	35.0%	15.0%	30.0%	20.0%
		3	35.0%	15.0%	30.0%	20.0%
		4	35.0%	15.0%	30.0%	20.0%
HBO - CAR 2 +	BMA	1	30.0%	10.0%	50.0%	10.0%
		2	30.0%	10.0%	50.0%	10.0%
		3	30.0%	10.0%	50.0%	10.0%
		4	30.0%	10.0%	50.0%	10.0%
	BMR	1	30.0%	10.0%	50.0%	10.0%
		2	30.0%	10.0%	50.0%	10.0%
		3	30.0%	10.0%	50.0%	10.0%
		4	30.0%	10.0%	50.0%	10.0%

Table AP-1.9 Modal Proportions for Non Home Based

Classification	Area	Income Group	Walk	M/C	Car	Public
NHB - 0 Veh	BMA	1	18.4%	9.3%	24.4%	47.9%
		2	31.0%	15.8%	11.4%	41.8%
		3	23.2%	39.6%	5.6%	31.6%
		4	12.7%	4.5%	22.9%	59.9%
	BMR	1	6.9%	66.3%	7.7%	19.1%
		2	48.2%	5.9%	11.7%	34.2%
		3	40.0%	10.0%	10.0%	40.0%
		4	40.0%	10.0%	10.0%	40.0%
NHB - M/C	BMA	1	30.0%	20.0%	10.0%	40.0%
		2	30.0%	20.0%	10.0%	40.0%
		3	30.0%	20.0%	10.0%	40.0%
		4	30.0%	20.0%	10.0%	40.0%
	BMR	1	30.0%	20.0%	10.0%	40.0%
		2	30.0%	20.0%	10.0%	40.0%
		3	30.0%	20.0%	10.0%	40.0%
		4	30.0%	20.0%	10.0%	40.0%
NHB - CAR	BMA	1	20.0%	10.0%	50.0%	20.0%
		2	20.0%	10.0%	50.0%	20.0%
		3	20.0%	10.0%	50.0%	20.0%
		4	20.0%	10.0%	50.0%	20.0%
	BMR	1	20.0%	10.0%	50.0%	20.0%
		2	20.0%	10.0%	50.0%	20.0%
		3	20.0%	10.0%	50.0%	20.0%
		4	20.0%	10.0%	50.0%	20.0%
NHB - CAR 2 +	BMA	1	20.0%	10.0%	60.0%	10.0%
		2	20.0%	10.0%	60.0%	10.0%
		3	20.0%	10.0%	60.0%	10.0%
		4	20.0%	10.0%	60.0%	10.0%
	BMR	1	20.0%	10.0%	60.0%	10.0%
		2	20.0%	10.0%	60.0%	10.0%
		3	20.0%	10.0%	60.0%	10.0%
		4	20.0%	10.0%	60.0%	10.0%

3.6 Adjustment for Under Reporting

In all home interview surveys there is a general tendency to under report non regular trips, trips that are made on the day of the survey but are trips that the interviewee does not normally make on that day. These trips are most likely to be non work or non educational trips. The trips that are typically under reported are therefore Homebased Other and Non Homebased trips. The home interview survey , can thus be biased towards work and educational trips from the home .

However in this project roadside interviews were also conducted at fourteen sites within the study area. These surveys which resulted in a random sample of vehicles being stopped are unlikely to be biased towards any trip purpose. The difference in the different percentage distribution of the four trip purpose was used to estimate purpose expansion factors. The purpose expansion factors were developed for Homebased Other and Nonhome Based. These factors were used in the trip generation analysis and appended to the home interview survey files. The values derived in this way are 2.8 and 3.2 for Homebased Other and Nonhome Based respectively. (Trip Rates presented in Table 5 includes these factors)

4. Trip Distribution

The trip distribution models take zonal productions and attractions produced in earlier phases of the model, and link them to form a trip matrix of zone-to-zone movements. A total of 16 models were built; 12 for private vehicle modes (four purposes by three vehicle availability groups) and four for public transport modes (four purposes).

The public transport distribution has basically been developed in detail as part of the UTDM process and is documented in their Interim Report (Sept. ,1996) and is not discudssed in detail further. The basic reason for this is the detail development of the public transport network was undertaken by UTDM whilst the major development of the road network was prepared by BEIP.

4.1 Overview

A gravity model is used to achieve the trip distribution and is expressed as:

$$T_{(i,j)} = \frac{P_i \; A_j \; F_{t(i,j)} K_{(i,j)}}{\sum_{x=1}^{n} A_x \; F_{t_{(i,x)}} \; K_{(i,x)}}$$

Where $T_{(i,j)}$ = trips produced in zone i and attracted to zone j

P_i = trips produced in zone i

A_j = trips attracted to zone j

$t_{(i,j)}$ = travel time between zone i and zone j

$F_{t_{(i,j)}}$ = empirically derived travel time factor that expresses the average area-wide effect of spatial separation on trip interchange between zones that are t(i,j) apart

$K_{(i,j)}$ = specific zone-to-zone adjustment factor to allow for the incorporation of spatial/geographic influences upon travel patterns

Distribution functions for each zone pair are prepared using as input public and private vehicle generalized cost skims and the calibrated distribution function. Subsequently, these distribution function values and an observed modal split matrix are applied to zonal trip productions and trip attractions to generate private and public person trip matrices. These two steps are conducted separately for each of the four trip purposes - home-based work, home-based school, home-based other and non-home-based.

4.2 Details of the Model

For private vehicle trips, generalized cost is calculated using the following equation:

$$GC = t_{ij} + \left[(R \times d_{ij}) / V\right] + (C / V)$$

Where GC	=	Generalized cost expressed in minutes
t_{ij}	=	access/trip time for movement from zone i to zone j
R	=	cost per kilometer, taken as 0.72 Baht
d_{ij}	=	distance from zone i to zone j
V	=	value of time, which is different for each mode of public transport , related to the average income of the user by mode. It is taken as 57 Baht/hour for the private person trip by private vehicle.
C	=	out-of-pocket trip cost (parking, tolls)

For public transport trips, generalized cost is calculated as:

$$GC = t_{ij} + (F_{ij} / V)$$

Where,

GC	=	Generalized cost expressed in minutes
$t_{i,j}$	=	Access/wait/trip time for movement from zone I to zone j
F_{ij}	=	fare for movement from zone I to zone j
V	=	Value of time, taken as 28 Baht/hour (Average over all public transport modes)

For both private and public transport trips, intrazonal generalized costs were estimated by taking half the value of the cost to the nearest three zones. For private transport trips, terminal times were also added at each and of the trip. The terminal times estimated for the base year are five minutes for CBD zones, two minutes for all other zones.

The criteria used in defining the distribution function is that, when applied, it should return a trip length distribution (TLD) as close as possible to the observed TLD. The TLD gives for each cost increment the percentage of trips occurring at that cost. The observed TLD was created by taking the observed trip matrix, together with the associated generalized cost, and tabulating the number of trips, and thus the percentage, for each cell with a given cost.

Typically, a TLD rises quickly from zero to a peak and then drips off gradually, finally becoming ragged as observations become sparse. All trips with both trip-ends within the study area (zones 1-505) were included in the observed trip matrix (and trip length distribution). The resultant TLD is then input to the gravity model calibration program together with an initial estimate of the distribution function. TRANPLAN uses an iterative technique to adjust the input distribution function in an effort to match the observed TLD; this is generally achieved after about five or ten iterations.

The iterative procedure uses a weighting factor of the percentage of trips for each interval thereby ensuring that the curves are fitted closest for the intervals which contain the greatest number of trips. The use of such an approval yields trip distribution functions which are reasonably free from irregularities caused by sampling errors and other errors inherent in survey data.

Models were calibrated for private vehicle trips by purpose (HBW, HBE, HBO, NHB) by vehicle availability group (none, motorcycle, car); for public transport trips, models were calibrated for each purpose. Resultant frequency curves (F - factors) for the Hone Based Work private person trip are depicted in Table AP-1.10 as an example.

Average trip lengths vary, as expected, with longest trips typically increased by public transport trips, and shortest trips being those mode by households not owning a vehicle.(see Table AP-1.11)

As a final check , person trip matrixes derived by the distribution model were converted to vehicle trips, assigned to the road network, and compared to observed traffic counts for private person trips . At this stage a set of K factors or geographical refinement factors were also developed to fine tune the trip tables and to correctly replicate the travel patterns as a result of geographical barriers such as the river .(This is discussed furher in model calibration.)

Table AP-1.10 F Factors for Home Base Work

TIME (1) (MINUTES)	PRIVATE TRIPS (2) BY VEHICLE OWNERSHIP GROUP NONE	M'CYCLE	CAR	TIME (1) (MINUTES)	PRIVATE TRIPS (2) BY VEHICLE OWNERSHIP GROUP NONE	M'CYCLE	CAR
1	640116	1454017	130553	61	331	3205	3629
3	393620	1092557	112962	63	304	2794	3297
5	247221	826629	97935	65	280	2444	2998
7	158507	629667	85072	67	260	2143	2730
9	103689	482822	74041	69	242	1884	2489
11	69168	372633	64563	71	226	1661	2271
13	47025	289426	56403	73	211	1468	2076
15	32567	226202	49367	75	198	1300	1899
17	22962	177869	43287	77	187	1153	1739
19	16474	140699	38024	79	176	1025	1594
21	12020	111947	33461	81	166	913	1463
23	8915	89579	29496	83	156	815	1344
25	6717	72080	26047	85	147	728	1236
27	5139	58315	23040	87	138	652	1137
29	3989	47429	20415	89	130	584	1048
31	3141	38774	18118	91	122	524	966
33	2507	31859	16106	93	114	471	892
35	2028	26305	14341	95	106	423	824
37	1661	21824	12789	97	99	381	762
39	1377	18189	11423	99	92	343	705
41	1154	15229	10219	101	84	309	653
43	978	12806	9155	103	77	278	605
45	838	10814	8215	105	70	251	561
47	725	9169	7381	107	64	226	521
49	633	7806	6642	109	57	204	484
51	557	6670	5985	111	51	184	450
53	495	5721	5401	113	45	165	418
55	443	4925	4880	115	40	149	389
57	399	4254	4416	117	35	134	363
59	363	3686	4001	119	30	121	338
60	346	3436	3810	120	28	114	326

(1) Includes costs associated with trip time, trip distance and out-of-pocket costs converted to equivalent minutes.

(2) Trips made by private means of mechanized transport (car, motorcycle). Vehicle ownership group relates to household characteristics . Maxmum trip lengths by household ownership grouping: None - 146 minutes; Motorcycle -177 Minutes ; Car - 218 minutes.

Table AP-1.11 Average Trip Length Distribution

TRIP PURPOSE	HOUSEHOLD VEHICLE OWNERSHIP	Average Trip Length (Equivalent Minutes)
		PRIVATE
HBW	None	29.6
	Motorcycle	31.5
	Car	43.9
HBE	None	40.5
	Motorcycle	42.3
	Car	38.8
HBO	None	27.8
	Motorcycle	25.0
	Car	37.7
NHB	None	26.7
	Motorcycle	30.5
	Car	41.6

The final calibration process is discussed in Section 6 .

5 . Non-Person Trips

In any city there are other types of trips being made at any one time besides internal person trips . In particular there are two major categories namely external trips and commercial vehicle trips . The development of the trip tables for these two categories of trips is presented in this section.

5.1 External Trip Table

The major home interview surveys undertaken during this project does not record trips being made by people from outside the study area to inside the study area or those trips that pass through the study area . This is termed the external cordon and the crossing points or external station locations are described in Section 2.

This external trip table was developed in three stages :

- Development of External-Internal Trip Table ;
- Development of External-Internal Trip Table ; and
- Allocation of Buses (Bus Passengers were not interviewed at the Cordons).

A flowchart depicting the process is given in Fig. AP-1.9

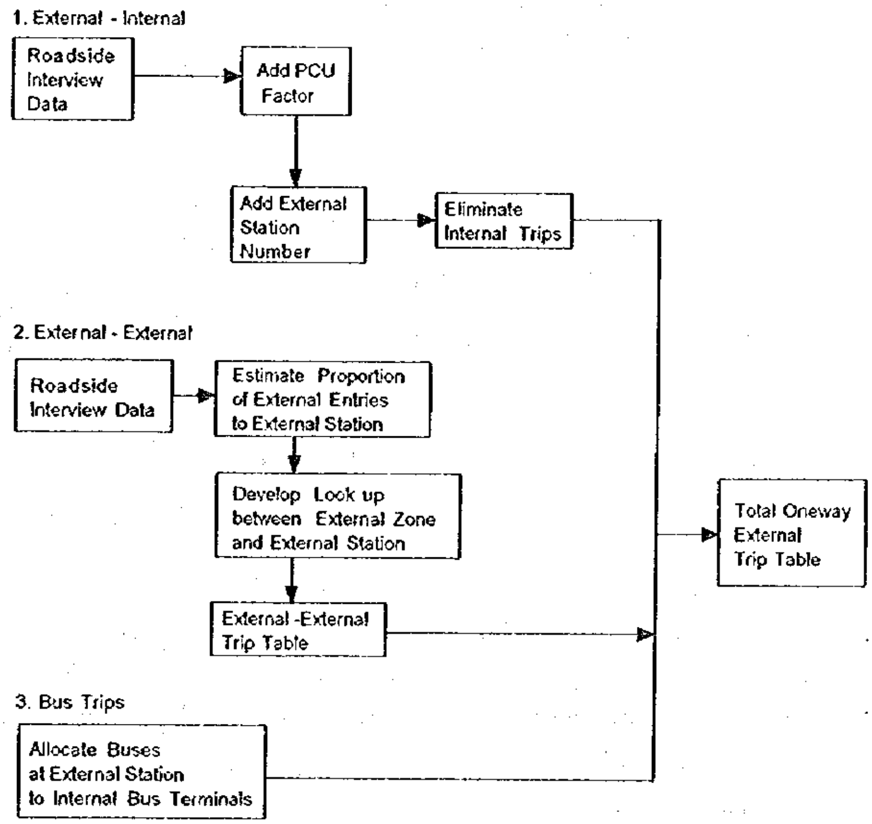

Fig. AP-1.9 External Trip Table Development

The development of the External to Internal Table is relatively simple . It is the observed external station (506-520) to the internal zone (1-505).

The external to external trip table involves linking the external zones (up to 812) as defined for the roadside interview . The procedure was as follows :

- Build the full trip table from the roadside surveys (zones 1 - 812).
- Allocate each combination of External Station to External Zone to have a temporary destination zone i.e. matrix expansion procedure.
- These temporary destination zones are then associated with an external station.
- The matrix is then squeezed back to a 520 X 520 matrix .

The buses was then allocated to the three intercity bus terminals.

This external matrix was developed from the beginning as an all day pcu matrix .

5.2 Commercial Vehicles

The commercial vehicle model for the study area was developed for truck movements within the BMR . The external matrix discussed above includes the external truck movements. There is little data available on commercial vehicle movements in Bangkok . The best source of data is from traffic count information. For that reason a matrix estimation technique was used in the development of the commercial vehicle matrix . Fig. AP-1.10 depicts this in a flowchart .

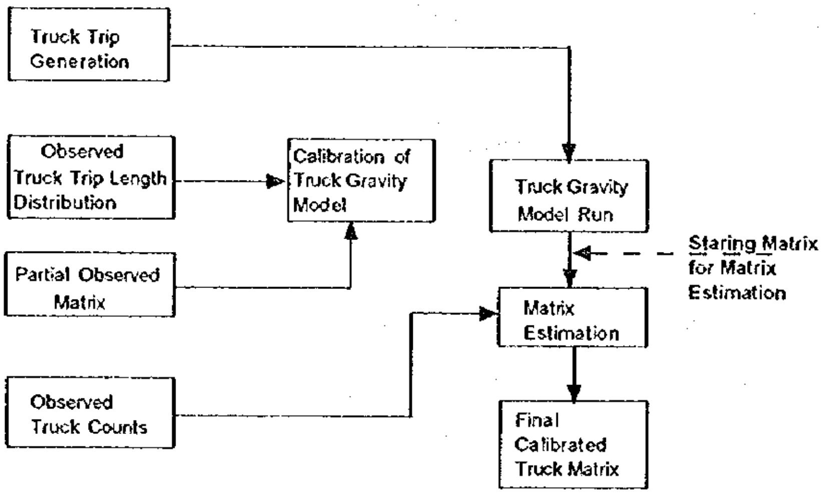

Fig. AP-1.10 Commercial Vehicle Trip Table

The goods vehicle (commercial) matrix was developed in three steps namely :

- Trip Generation
- Trip Distribution
- Trip calibration , Matrix Estimation.

It is important to note that the generation and distribution used in the development are really used simply to improve the starting matrix for the matrix estimation procedure .The truck trip generation equations have been adopted from the earlier SPURT study namely:

Truck Trip Generation in a zone

= (0.009*Zonal Employment) + (0.01*Zonal Households)

The gravity model for trip distribution is calibrated against the observed truck trip length distribution from the internal roadside interview locations . In this case the F factors derived from the gravity model take the form of a Gamma function as described below :

F(Cij)=Cij^X1*exp(X2*Cij)

where

F(Cij) is the F factor curve

Cij is the generalized cost of travel

X1 and X2 are calibration constants with the value of

X1=-1.5

X2=0.00163

This results gives good correspondence between the observed and the estimated mean trip length of 176.8 for the observed and 180.1 for the estimated .These F Factors are the used in a full run of the gravity with the trip generations discussed above to produce a starting matrix for matrix estimation .

The matrix estimation uses as input traffic count data from over 150 sites to produce the best estimate of a goods vehicle matrix.

6. Traffic Assignment and Calibration

6.1 Overview

Prior to the assignment of the trip tables to the network it is necessary to develop the peak hour pcu trip table from the total daily person trip tables and from the external trip table and the commercial vehicle trip table. This will then able the assignment of the vehicle peak hour trip table to the road network.

6.2 Development of Peak Hour Private Trip Table

The person trip tables as output from the gravity models are not in a suitable format for traffic assignment . These tables need to be converted to a peak hour origin destination matrix from the production / attraction format as output from the gravity model .The following formula is used in the first step :

$$ODij = a*PAij + b*TR\{PAij\}$$

where ODij is the matrix in origin destination format

PAij is the matrix in production attraction format

TR{} is the mathematical matrix transpose function

a,b are constants used to develop the morning peak hour

(see Table AP-1.12)

Table 12 Peak Hour Factors

Factor	Trip Purpose			
	HBW	HBE	HBO	NHB
a	0.15	0.15	0.04	0.02
b	0.01	0.01	0.04	0.02

This is still in the form of a person trip table , these are then converted to vehicle format with two sets of factors namely :

- Passenger Car Unit (pcu) factor
- Vehicle Occupancy Factor

These are presented in Table AP--1.13. The peak factors for goods vehicles and external vehicles are also presented in this table .

Table AP-1.13 Vehicle Occupancy and PCU factor

Vehicle Type	Peak Hour Factor	PCU Factor	Trip Purpose Occupancy Factor			
			HBW	HBE	HBO	NHB
Car	-	1	1.73	2.32	2.08	1.97
Motorcycle	-	0.25	1.38	1.6	1.22	1.47
Goods Vehicle	0.03	2.3	-	-	-	-
External Vehicle	0.05	-	-	-	-	-

The peak hour trip table for traffic assignment is the addition of the three pcu tables namely person , external and commercial trip tables.

6.3 Traffic Assignment

The purpose of the trip assignment process is to replicate the amount of traffic on the road system. Thus, the content of trip matrixes (peak hour trips) is "loaded" onto the roadway network where trip origin-destination patterns are permitted to interact with embedded network parameters (distance, time, speed, capacity and other user-specified criteria such as road toll).

Since route choice, travel time and congestion impacts are important considerations, an equilibrium assignment algorithm is considered appropriate. Equilibrium, in the context of transportation assignments, occurs when no trip can be made by an alternative path without increasing the total travel time of all trips in the network. Equilibrium assignment consists of an iterative series of all-or-nothing traffic assignments with an adjustment of link capacity/speed reflecting congestion encountered in each associated iteration.

The load from each assignment after the first iteration is combined with the previous load in such a way as to minimize the impedance of each trip and thus reducing the number of iterations to find the equilibrium loads. Equilibrium assignment is multipath because the final loads are a linear combination of the all-or-nothing loads of each iteration. These loads may be assigned to different paths because of the time adjustments after each iteration.

For the BEIP project these assignment paths are bases on a generalized cost derived in equivalent minutes for the path between each zone pair and takes the form of:

$$GCij = a^*Tij + b^*Dij + c^* Aij$$

where GCij is defined as generalized cost in equivalent minutes

Tij is the travel time

Dij is the distance

Aij is the additional cost such as expressway tolls in units of 10 Baht

a,b,c are constants defined as: a = 1.0 , b = 0.76 and c = 6.58

The other parameters input into the road traffic assignment include the preload volumes developed in the bus passenger assignments which as discussed in previous sections are not discussed in this technical appendix .

6.4 Calibration / Validation

When the traffic assignment procedure is complete , the results are then compared with the on ground counts . If there is a good comparison then there is no need to do any review of the parameters . This is not usually the case . Indeed this is now considered an important step in model development , the calibration or validation procedure .(See Fig. AP-1.11)

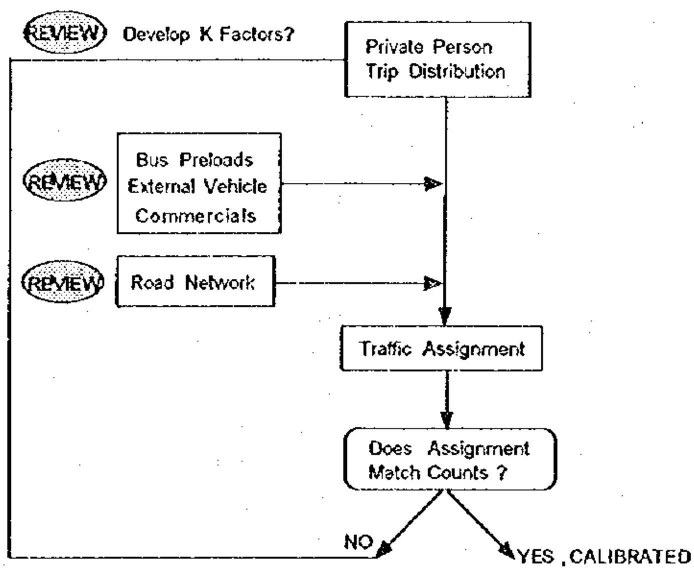

Fig. AP-1.11 Model Validation Procedure

Indeed during the BEIP to calibrate the model it was necessary to both make modification to the network , change the initial speed coded on links or in some cases make network corrections as well as develop K Factors or geographical calibration factors . The relationship of these factors to the gravity model is presented in Section 4.

The model was considered calibration in the final validation against screenlines (see Table 14) and in detail along the river screenline for the morning peak hour in Table AP-1.15.

Table AP-1.14 Screenline Calibration

SCREENLINE	NUMBER OF STATIONS	DAILY PRIVATE TRIPS		Ratio
		Observed	Estimated	
Railway	19	965,233	995,573	1.03
River Bridges	12	735,391	774,722	1.05
CBD	25	1,584,664	1,725,085	1.09
East	17	611,826	549,296	0.90
North	10	251,758	249,659	0.99
West	9	171,108	194,390	1.14
Total	92	4,319,980	4,488,725	1.04

Table AP-1.15 River Screenline Morning Peak PCU Comparison

Link	Location Name	Direction	COUNT	ASSIGNMENT
R1	PATHUMTHANI BRIDGE	EB	1,513	1,147
R2	NONTHABURI BRIDGE	EB	1,643	1,069
R3	PHRA NANG KLAO BRIDGE	EB	2,629	1,017
R4	RAMA VII BRIDGE	NB	2,967	2,260
R5	KRUNG THON BRTIDGE	EB	2,759	4,592
R6	PHRA PIN KLAO BRIDGE	EB	6,492	5,328
R7	MEMORIAL BRIDGE	NB	2,937	2,829
R8	PHRA POK KLAO BRIDGE(New Memorial)	NB	3,556	4,505
R9	TAKSIN BRIDGE	EB	4,512	6,325
R10	KRUNGTHEP BRIDGE	EB	2,522	3,226
R11	RAMA IX BRIDGE	EB	2,058	3,120
R12	POO CHAO SAMING PRAI FERRY	EB	430	
	TOTAL		34,018	35,418
			% Difference =	4.1%
R1	PATHUMTHANI BRIDGE	WB	1,549	1,588
R2	NONTHABURI BRIDGE	WB	1,500	866
R3	PHRA NANG KLAO BRIDGE	WB	2,397	1,305
R4	RAMA VII BRIDGE	SB	3,111	2,443
R5	KRUNG THON BRIDGE	WB	1,506	1,677
R6	PSRA PIN KLAO BRIDGE	WB	3,015	2,204
R7	MEMORIAL BRIDGE	SB	280	1,721
R8	PHRA POK KLAO BRIDGE	SB	2,601	3,180
R9	TAKSIN BRIDGE	WB	2,185	2,715
R10	KRUNGTHEP BRIDGE	WB	1,831	941
R11	RAMA IX BRIDGE	WB	2,610	1,178
R12	POO CHAO SAMING PRAI FERRY	WB	279	
	TOTAL		22,864	19,818
			% Difference =	-13.3%
	GRAND TOTAL		**56,882**	**55,236**
			% Difference =	**-2.9%**