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Research Report

Development of a Prototype Agent-based Microsimulation Model of the Asunción Metropolitan Area

Volume II: Technical Appendices

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EXECUTIVE SUMMARY

This is the second of two reports documenting the work and findings of a prototype Agent-Based Microsimulation (ABM) travel demand model system for Asunción. Volume I of the report series is the project final report. This Volume II report contains a set of technical appendices that provide detailed documentation of the data and network representations used in developing the model system, the model system itself and the example case studies to which the prototype model system has been applied to date.

The technical appendices included in this report are:

A. Base Data.
B. Base Road & Transit Networks & Assignment Model Calibration.
C. Example Case Study Networks.
D. Example Case Study Modelling Results.
E. Proposed Phase 2 Data Needs & Tasks.

VOLUME TABLE OF CONTENTS

APPENDIX A
BASE DATA

APPENDIX TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

A.1 INTRODUCTION

This appendix describes the base data that were assembled to construct the SATA prototype. It describes the zone systems used, population and employment data and the construction from these data sources of the conditional frequency distributions used to synthesize the base year population for the Asunción region. As discussed in Volume I of this report, data sources for this project were considerably scattered, ranging across different years, and coming from different sources. Thus, a considerable amount of time was allocated to data gathering. The UTTRI team received data on an on-going basis from the project start in May 2016, to as late as the end of November 2016 when digital network information was provided. This appendix contains the most relevant data sources from which SATA model was built.

A.2 ZONING SYSTEMS

The data obtained used three different spatial systems: 1998 zoning system, 2011 zoning system and census districts. The 1998 zoning system was provided to us in a non-geocoded PDF file. Several ArcGIS tools including Georeferencing and ArcScan were used to convert the map to a shapefile. Considering the data limitations, transferring data between different zoning systems was a key task, thus the need for digital information.

A.2.1 1998 Zone System

The 1998 PlanCETA zone system is defined in Tables A.1 and A.2 and Figure A.1 (Japan International Cooperation Agency, 1998).

UBICACIÓN	BARRIO
1	Santo Domingo
2	Mcal. López
3	Gral. José E. Díaz
4	Las Mercedes
5	San Roque
6	Mburicao
7	Villa Morra
8	Tembetary
9	La Encarnación
10	Los Laureles
11	Ciudad Nueva
12	San Cristóbal
13	Recoleta
14	Catedral
15	Manorá
16	Virgen Del Huerto
17	Cañada de Ybyray
18	Mcal. Estigarribia
19	Carmelitas
20	Silvio Pettirossi
21	Pinozá
22	Vista Alegre
23	Nazareth
24	Pirizal
25	Panambi Reta
26	Ycua Sati
27	San Antonio
28	Tacumbú
29	San Vicente
30	Bernardino Caballero
31	Carlos Antonio López
32	Madame Lynch
33	Dr. Gaspar R. de Francia
34	Hipódromo
35	Obrero
36	Santa Rosa
37	Santísima Trinidad
38	San Jorge
39	Itay
40	Luis A. De Herrera
41	Mburucuyá
42	Sajonia
43	Panambi Verá
44	Jara
45	Villa Aurelia
46	Ñú Guazú
47	San Pablo
48	Itá Pytá Punta
49	Loma Pyta
50	Virgen de la Asunción
51	Bella Vista
52	Gral. Andrés Rodríguez
53	Terminal
54	Santa Ana
55	Salvador del Mundo
56	Santa María
57	Republicano
58	Roberto L. Petit
59	Virgen de Fátima
60	Itá Enramada
61	De las Residentas
62	Zeballos Cué
63	Botánico
64	San Blas
65	Ricardo Brugada
66	Tablada Nueva
67	Bañado Tacumbú
68	San Rafael
69	San Felipe
70	Bañado
71	Banco San Miguel

Table A.1: List of 1998 Internal Zones. *Source: JICA (1998)*

Código	Nombre de la zona		Comprenden
72	Lambaré	norte	*Ver mapa de "LAMBARÉ".*
73	Lambaré	oeste	
74	Lambaré	este	
75	Fdo.de la Mora	sur	*Ver mapa de "Fdo.de la Mora".*
76	Fdo.de la Mora	norte	
77	Luque	norte	*Ver mapa de "Luque".*
78	Luque	central	
79	Luque	sur	
80	M.R.Alonso		
81	Villa Hayes		
82	Limpio		
83	San Lorenzo	norte	*Ver mapa de "San Lorenzo".*
84	San Lorenzo	central	
85	San Lorenzo	sur	
86	Ñemby		
87	San Antonio		
88	Villa Elisa		
89	Areguá		Areguá
90	Capiatá		Capiatá
91	Ypané		Ypané, Guarambaré, J.Augusto Salvadar
92	Ypacaraí		Ypacaraí , Itaguá
93	Itá		Itá
94	Villeta		Villeta, Nueva Italia
95	Chaco		Pozo Colorado, Filadelfia
96	Región Norte		Pedro Juan Caballero, Concepción
97	Región Oriental		Ciudad del Este, Cnel. Oviedo, BRASIL
98	Región Sur		Encarnación, ARGENTINA

Table A.2: List of 1998 External Zones. *Source: JICA (1998)*

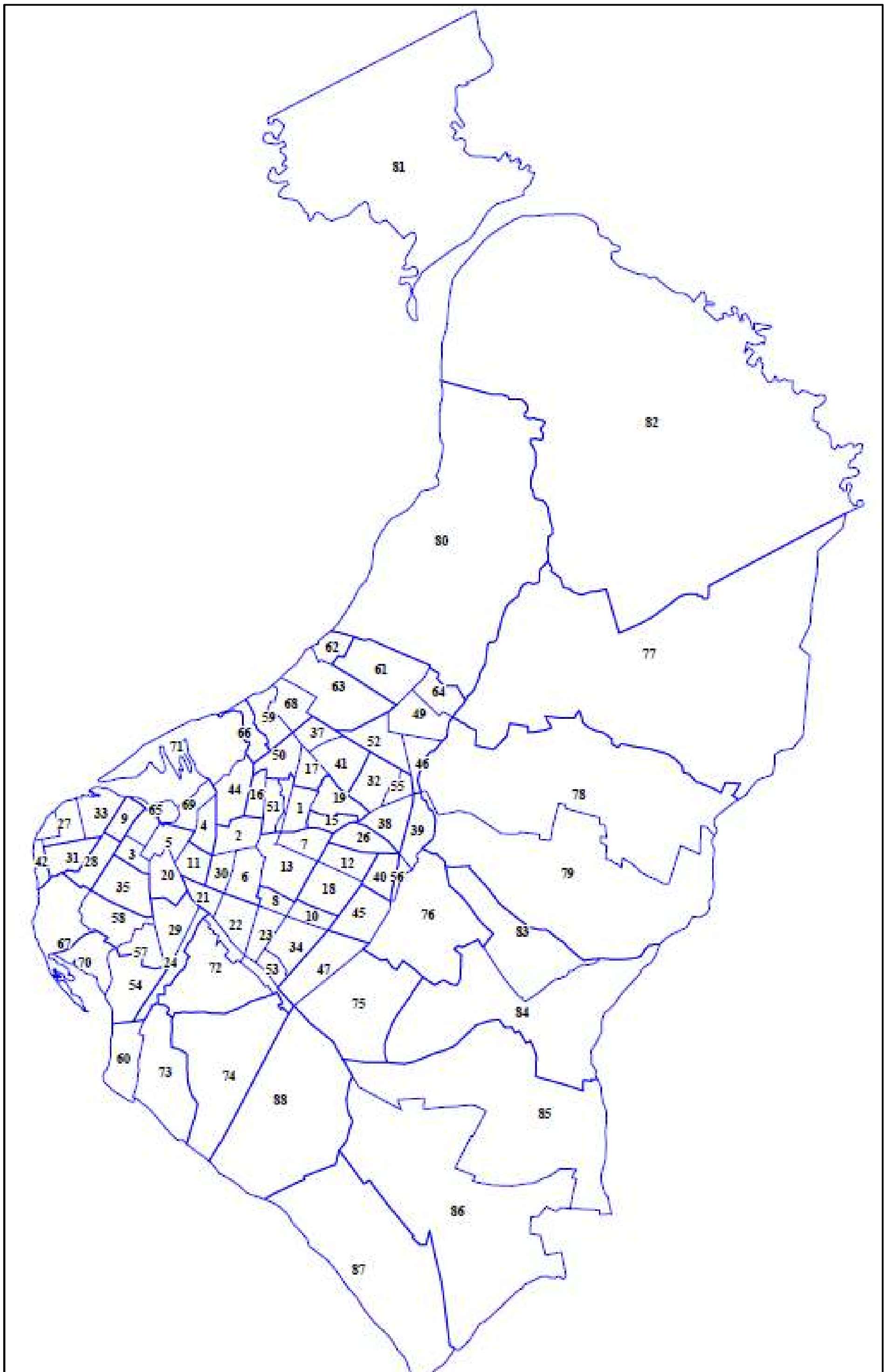

Figure A.1: 1998 Zone System. *Source: Japan International Cooperation Agency (1998)*

A.2.2 2011 Zone System

The second source of zoning information is the BRT Corridor Eusebio Ayala - Mariscal Estigarribia project (LOGIT, 2011). This zone system was provided in GIS format, which included the zone numbering as well as the EMME code for each zone. This was very useful considering that the network representation in EMME was provided by LOGIT, so mapping these two data sources was smoothly performed. Figure A.2 shows an ARCMap caption of the 282 zones that are part of the 2011 zoning system, where labels show the EMME codes for each zone.

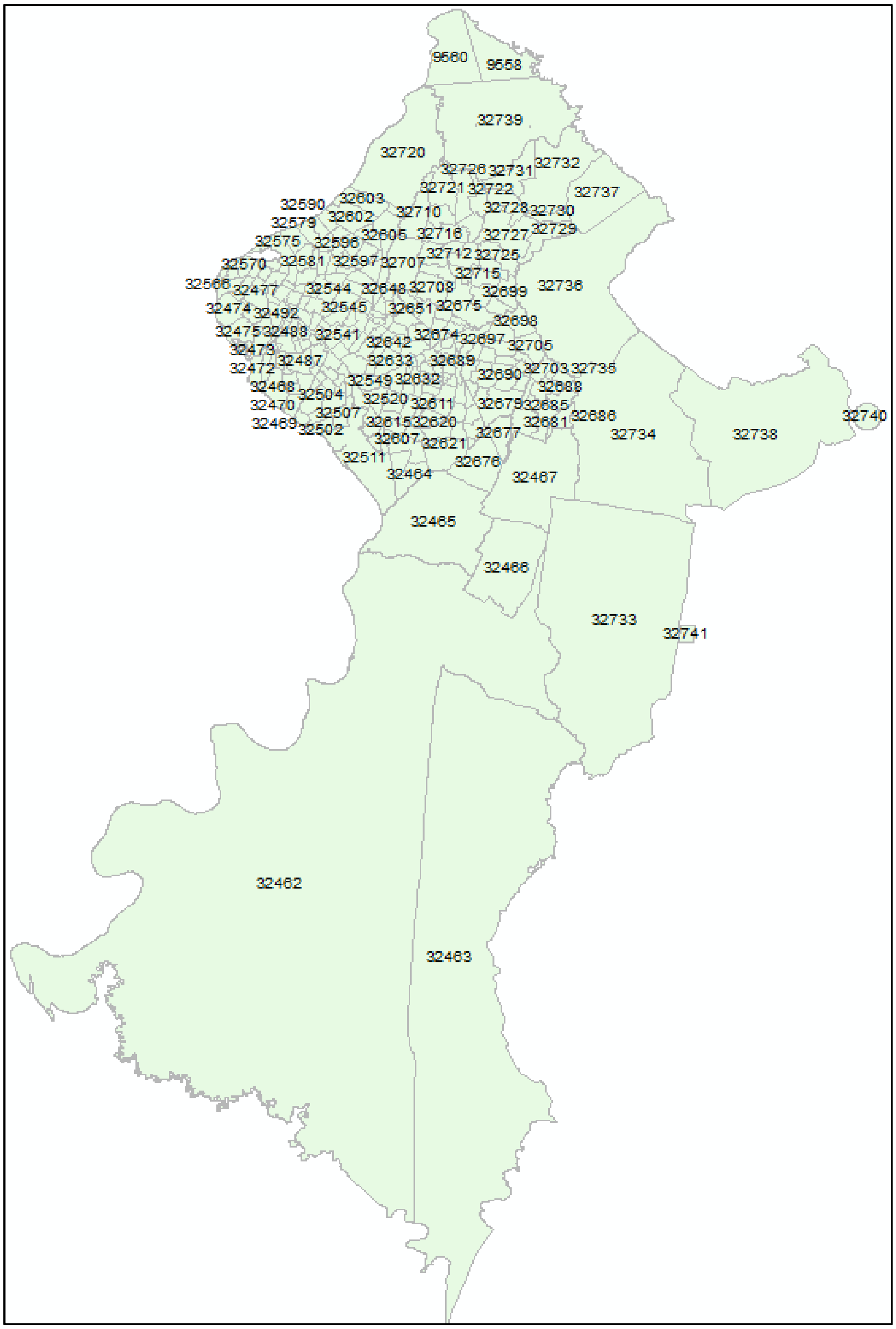

Figure A.2: 2011 Zone System. *Source: (LOGIT, 2011)*

A.2.3 Census Districts

Finally, the last zone system is provided by the census, consisting of 20 districts. This is mainly useful for population synthesis, which is described in the Section A.4. Figure A.3 shows the census districts and summarizes the three zoning systems at the same time.

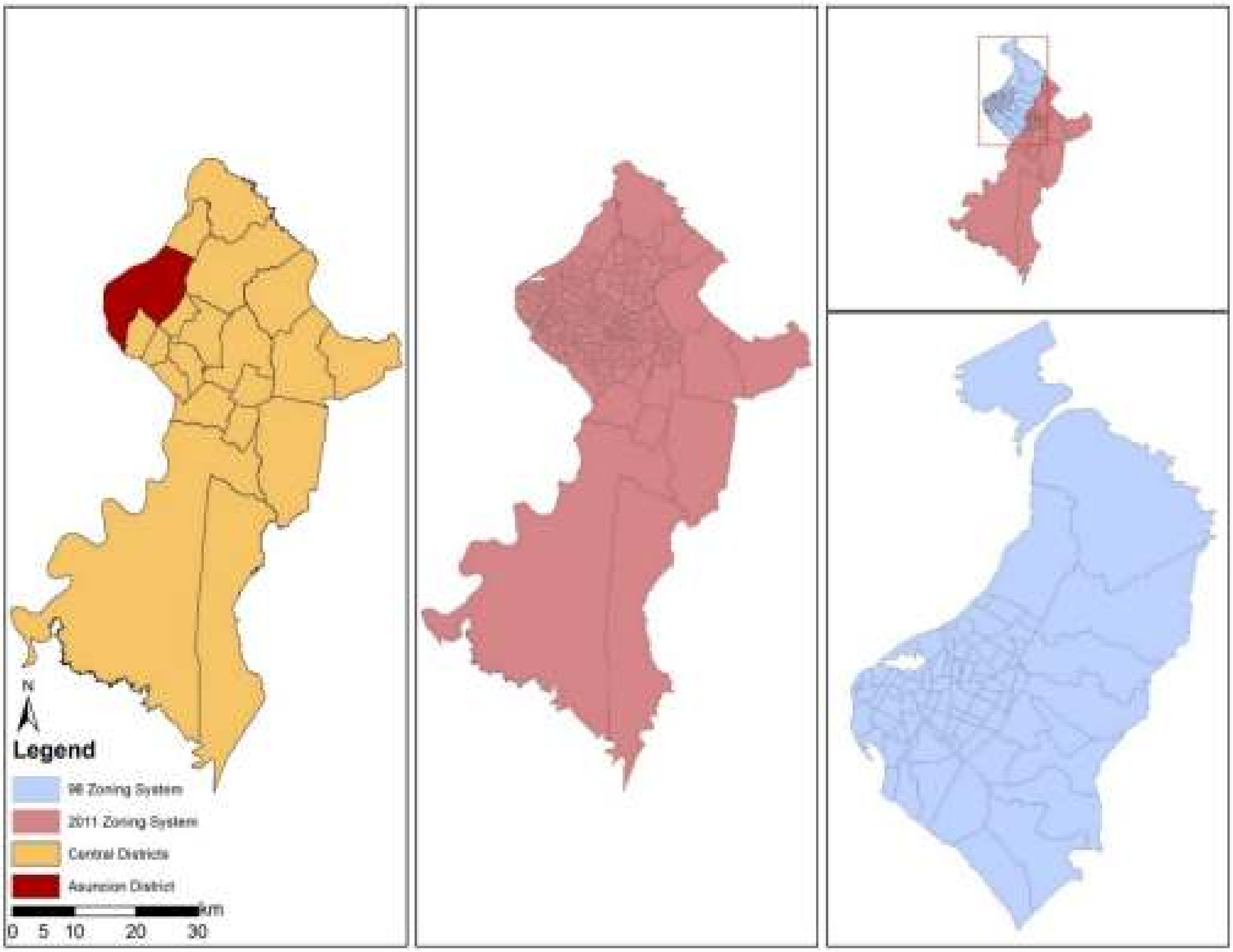

Figure A.3: Zoning Systems for Asunción and Central Area

A.3 ORIGIN-DESTINATION MATRICES

Origin-destination (OD) matrices are a critical data source for building a travel demand model since they provide the primary information on trip rates, origin-destination patterns, mode choice and trip purpose needed to calibrated the model. OD data for the Asunción region were obtained from the following sources:

- 1998 PlanCETA study.
- 2011 BRT Corridor Eusebio Ayala - Mariscal Estigarribia study.

A.3.1 1998 PlanCETA OD Matrices

The OD matrices obtained from PlanCETA (Japan International Cooperation Agency, 1998) are by far the most detailed information of mobility that could be obtained, given that they consider different combinations of purpose and mode for a 24-hour period. Namely, the modes considered are car and bus; and the purposes considered are: work, school, return-home, business, and "other". The caveat with this data source was that these matrices were provided in PDF format and also values were missing. However, raw data was also provided in FORTRAN code, thus aided by a reverse engineering procedure, the original data could be reconstructed and then manually transferred to Microsoft Excel format. A representative selection from the original OD matrices in PDF format is shown in Figures A.4 and A.5.

A.3.2 2011 BRT OD Matrices

The BRT Corridor Eusebio Ayala - Mariscal Estigarribia study (LOGIT, 2011) also collected OD matrix data, but only in a very limited way. Limitations of the 2011 data include:

- Trips are not disaggregated by trip purposes.
- It covers the AM peak period only.
- It deals with the bus mode only.
- Most critically, the study focused on the Mariscal Estigarribia corridor only, to the point that the study acknowledges that the OD matrices and the estimations performed are only relevant at the corridor level.

For sake of illustration, a subset of the 2011 OD matrix is shown in Figure A.6.

1998 Present Type: Bus Purpose: Go to School (page = 2 / 5)

ZONE	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	total
51)	3	4	4	22	3	4	2	3	0	0	0	0	0	0	0	0	0	0	123
52)	0	0	0	2	0	0	0	3	2	0	0	0	0	0	0	0	0	0	249
53)	2	0	0	14	2	24	1	45	3	3	0	0	0	0	0	0	0	0	1087
54)	3	4	4	25	4	4	2	4	0	0	0	0	0	0	0	0	0	0	418
55)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	114
56)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	251
57)	4	6	6	37	5	6	4	5	0	0	0	0	0	0	0	0	0	0	215
58)	8	11	11	69	9	12	6	9	0	0	0	0	0	0	0	0	0	0	1127
59)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	131
60)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	114
61)	6	5	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	477
62)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	82
63)	18	41	0	0	0	11	0	10	0	0	0	0	0	0	0	0	0	0	939
64)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	91
65)	4	5	5	30	4	5	3	4	0	0	0	0	0	0	0	0	0	0	159
66)	3	4	4	22	3	4	2	3	0	0	0	0	0	0	0	0	0	0	685
67)	3	4	4	20	3	4	2	3	0	0	0	0	0	0	0	0	0	0	116
68)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	143
69)	3	4	4	22	3	4	2	3	0	0	0	0	0	0	0	0	0	0	544
70)	2	2	2	14	2	3	1	2	0	0	0	0	0	0	0	0	0	0	85
71)	1	2	2	12	1	2	1	1	0	0	0	0	0	0	0	0	0	0	74
72)	0	0	0	12	5	1	0	21	0	0	0	0	0	0	0	0	0	0	926
73)	0	0	0	32	3	1	0	57	0	0	0	0	0	0	0	0	0	0	722
74)	0	0	0	19	4	2	0	64	0	0	0	0	0	0	0	0	0	0	738
75)	0	3	0	223	39	52	20	169	4	15	0	0	0	0	0	0	0	0	2078
76)	2	7	0	469	144	76	30	116	3	36	0	0	0	0	0	0	0	0	3870
77)	1	9	0	16	3	0	0	1	3	0	0	0	0	0	0	0	0	0	581
78)	3	31	0	59	10	0	0	5	9	1	0	0	0	0	0	0	0	0	2086
79)	1	14	0	27	5	0	0	2	4	0	0	0	0	0	0	0	0	0	972
80)	29	64	0	1	2	2	1	1	0	0	0	0	0	0	0	0	0	0	1305
81)	22	2	0	4	4	0	0	2	0	0	0	0	0	0	0	0	0	0	99
82)	4	279	0	6	0	0	0	1	0	0	0	0	0	0	0	0	0	0	582
83)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1156
84)	4	4	0	1375	280	57	4	87	6	61	0	0	0	0	0	0	0	0	4886
85)	4	0	0	279	163	13	0	19	0	8	0	0	0	0	0	0	0	0	1240
86)	0	0	0	56	16	224	52	61	0	0	0	0	0	0	0	0	0	0	1274
87)	0	2	0	2	0	51	200	14	0	0	0	0	0	0	0	0	0	0	626
88)	2	1	0	83	18	59	14	305	1	4	0	0	0	0	0	0	0	0	2398
89)	0	0	0	8	2	0	0	1	0	2	0	0	0	0	0	0	0	0	42
90)	0	0	0	62	6	0	0	4	0	2	0	0	0	0	0	0	0	0	271
91)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
92)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
93)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
94)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
95)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
96)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
97)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
98)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
total)	347	787	311	5055	1134	986	519	1510	40	154	0	0	0	0	0	0	0	0	64712

Figure A.4: Section from a PDF OD Matrix for the Bus Mode and School Purpose. *Source: JICA (1998)*

1998 Present Type: Cars Purpose: Go to Work (page = 2 / 4)

ZONE	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79
51)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	4	16	7
52)	0	26	67	0	0	0	0	0	0	0	0	62	0	0	0	0	9	33	15
53)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
55)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0	35	124	58
56)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36	128	59
57)	0	0	0	0	0	0	0	0	0	66	0	708	0	0	33	0	0	0	0
58)	70	0	0	0	0	0	0	0	0	0	0	0	0	0	62	0	0	0	0
59)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0	0	0	0
60)	0	0	0	0	0	0	0	0	0	0	0	193	26	0	0	0	0	0	0
61)	190	0	80	0	0	0	0	0	0	0	0	0	0	0	35	0	0	0	0
62)	0	23	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
63)	26	0	108	0	0	0	0	0	0	0	0	54	42	0	25	0	11	38	18
64)	0	0	0	0	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0
65)	0	0	0	29	28	0	0	0	0	0	0	33	0	0	0	0	0	0	0
66)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	19	9
67)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
68)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	164	0	0	0	0
69)	70	0	0	0	0	0	0	87	32	0	0	0	0	0	62	0	0	0	0
70)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
71)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
72)	0	0	0	0	0	0	0	0	0	0	0	1008	674	316	904	70	93	335	155
73)	0	0	42	0	0	0	0	0	0	0	0	599	128	119	86	0	0	0	0
74)	0	0	0	0	0	0	0	0	0	0	0	213	177	657	157	68	20	72	33
75)	0	0	0	0	0	0	0	0	0	0	0	408	57	157	1185	425	33	117	54
76)	0	0	0	0	0	0	0	0	0	0	0	36	0	33	870	0	35	124	58
77)	5	4	4	0	0	0	0	4	0	0	0	67	0	15	98	60	98	350	162
78)	19	15	13	0	0	0	0	16	0	0	0	240	0	53	352	213	350	1255	583
79)	9	7	6	0	0	0	0	7	0	0	0	112	0	25	163	99	162	583	270
80)	0	212	87	0	0	0	0	0	58	0	0	32	0	0	167	58	62	221	103
81)	0	0	6	0	0	0	6	0	0	0	0	155	6	0	6	0	21	74	34
82)	0	0	0	0	0	159	0	0	0	0	0	281	50	0	110	30	139	497	231
83)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	91	32	35	126	58
84)	0	0	0	0	0	0	0	0	0	33	0	415	29	0	2583	171	53	190	88
85)	0	0	0	0	0	0	0	0	0	0	0	67	0	0	495	367	14	50	23
86)	0	0	0	0	0	0	0	0	0	0	0	216	0	0	374	657	36	128	59
87)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
88)	0	0	0	0	0	0	0	0	0	0	0	433	159	64	61	348	9	34	16
89)	0	0	16	0	0	8	0	17	0	0	0	20	8	0	35	90	215	771	358
90)	0	9	25	0	0	0	0	15	0	0	0	16	0	12	1063	66	81	291	135
91)	0	0	0	0	0	0	0	0	0	8	0	20	9	71	32	48	10	36	17
92)	0	0	0	0	0	0	0	0	0	0	0	44	12	12	158	106	36	127	59
93)	0	0	0	0	0	0	0	0	0	0	0	0	9	9	26	44	20	72	34
94)	0	0	8	0	0	0	0	0	0	0	0	39	8	17	31	17	4	15	7
95)	0	0	10	0	0	0	0	0	0	0	0	19	0	5	6	23	8	27	13
96)	0	0	7	0	0	0	0	0	0	0	0	9	4	0	0	12	5	20	9
97)	0	0	17	0	0	0	0	0	0	0	0	12	15	0	103	76	39	138	64
98)	0	0	0	0	0	0	9	0	0	0	0	0	0	0	48	38	0	0	0
total)	614	321	727	84	433	482	15	265	462	107	63	10314	2337	2676	15083	3956	2336	8367	3880

Figure A.5: Section from a PDF OD Matrix for the Automobile Mode and Work Purpose. *Source: JICA (1998)*

O / D	32542	32543	32544	32545	32546	32547	32548	32549	32550	32551	32552	32553	32554	32555	32556	32557	32558
32462												8.7	17.4	8.7			
32463	7.856		11.86														
32464															1		
32465										18.8		26.28	8.759			9.401	
32466			8.7								9.537		8.759				
32467	8.289	8.406	8.281	8.759		8.7		9.766			28.48	69.35	53.25	17.52	52.44	28.34	
32468																7.564	
32469																	
32470															1		
32471															1		
32472																	
32473	1																
32474																	
32475																	
32476	11.14		11.11								9.916				10.39		
32477		1								19.83	19.43		19.75		30.78	21.03	
32478																	
32479																	
32480		11.9		1						7.564		1	10.39		2	7.458	
32481																	
32482																	
32483																	10.39
32484																	
32485																	
32486																	
32487				1													
32488		2															
32489										9.071	7.564						
32490		10.69								9.916					10.39	9.916	
32491																	
32492	21.37		1								9.916				9.574		
32493							9.518					20.01			10.01		

Figure A.6: Subset of the Metrobus Estimated OD Matrix. *Source: (LOGIT, 2011)*

Note that in order to construct the OD matrix shown in Figure A.6, LOGIT conducted a Frequency and Visual Occupancy (FOV) survey along with a boardings and alightings survey, and used them as inputs to finally estimate the OD Matrix. A subset from the FOV survey is shown in Table A.3. FOV survey data were used to help calibrate the Asunción transit network, as described in Appendix B.

ID	time	Line	Occupancy	Count station	Data	Day	% Big buses	# people	Max Capacity
0	5:00:00	45	D	1A	10112010	4 - Miercoles	100%	63	83
1	5:00:00	165	B	1A	10112010	4 - Miercoles	94%	20	80
2	5:00:00	21	B	1A	10112010	4 - Miercoles	100%	21	83
3	5:00:00	CABAÑAS	B	1A	10112010	4 - Miercoles	0%	12	37
4	5:00:00	59	B	1A	10112010	4 - Miercoles	81%	19	74
5	5:00:00	2	C	1A	10112010	4 - Miercoles	100%	42	83
6	5:00:00	165	B	1A	10112010	4 - Miercoles	94%	20	80
7	5:00:00	48	B	1A	10112010	4 - Miercoles	100%	21	83
8	5:00:00	111	B	1A	10112010	4 - Miercoles	100%	21	83
9	5:05:00	21	A	1A	10112010	4 - Miercoles	100%	0	83
10	5:05:00	27	D	1A	10112010	4 - Miercoles	100%	63	83
11	5:05:00	133	B	1A	10112010	4 - Miercoles	70%	18	69
12	5:05:00	11	B	1A	10112010	4 - Miercoles	59%	17	64
13	5:05:00	20	B	1A	10112010	4 - Miercoles	87%	20	77
14	5:05:00	59	C	1A	10112010	4 - Miercoles	81%	39	74
15	5:05:00	18.2	B	1A	10112010	4 - Miercoles	100%	21	83
16	5:10:00	20	B	1A	10112010	4 - Miercoles	87%	20	77
17	5:10:00	20	B	1A	10112010	4 - Miercoles	87%	20	77
18	5:10:00	29	D	1A	10112010	4 - Miercoles	97%	62	82
19	5:10:00	45	D	1A	10112010	4 - Miercoles	100%	63	83
20	5:10:00	18.2	C	1A	10112010	4 - Miercoles	100%	42	83
21	5:10:00	27	D	1A	10112010	4 - Miercoles	100%	63	83
22	5:10:00	30	A	1A	10112010	4 - Miercoles	100%	0	83
23	5:15:00	27	C	1A	10112010	4 - Miercoles	100%	42	83
24	5:15:00	28	B	1A	10112010	4 - Miercoles	100%	21	83
25	5:15:00	20	C	1A	10112010	4 - Miercoles	87%	40	77
26	5:15:00	18.2	C	1A	10112010	4 - Miercoles	100%	42	83
27	5:15:00	165	B	1A	10112010	4 - Miercoles	94%	20	80
28	5:15:00	27	C	1A	10112010	4 - Miercoles	100%	42	83
29	5:15:00	43	C	1A	10112010	4 - Miercoles	100%	42	83
30	5:20:00	21	B	1A	10112010	4 - Miercoles	100%	21	83
31	5:20:00	29	C	1A	10112010	4 - Miercoles	97%	41	82
32	5:20:00	11	D	1A	10112010	4 - Miercoles	59%	50	64
33	5:20:00	20	C	1A	10112010	4 - Miercoles	87%	40	77
34	5:20:00	111	B	1A	10112010	4 - Miercoles	100%	21	83
35	5:20:00	2	B	1A	10112010	4 - Miercoles	100%	21	83
36	5:20:00	133	B	1A	10112010	4 - Miercoles	70%	18	69
37	5:20:00	21	B	1A	10112010	4 - Miercoles	100%	21	83
38	5:20:00	15	C	1A	10112010	4 - Miercoles	100%	42	83
39	5:20:00	48	D	1A	10112010	4 - Miercoles	100%	63	83
40	5:20:00	59	C	1A	10112010	4 - Miercoles	81%	39	74
41	5:25:00	133	D	1A	10112010	4 - Miercoles	70%	53	69
42	5:25:00	11	D	1A	10112010	4 - Miercoles	59%	50	64
43	5:25:00	20	C	1A	10112010	4 - Miercoles	87%	40	77
44	5:25:00	11	C	1A	10112010	4 - Miercoles	59%	35	64
45	5:25:00	21	C	1A	10112010	4 - Miercoles	100%	42	83

Table A.3: Subset from the FOV Survey. *Source: (LOGIT, 2011)*

A.4 POPULATION

Population data are available in the General Direction of Statistics, Surveys, and Censuses of Paraguay (DGEEC) website for 2000-2025 at the district level. The main challenge related to these data is that it has to be mapped to different zoning systems depending on the purpose of the analysis. Moreover, while some zone boundaries' match among the different zoning systems, other zones have multiple overlapping areas. To address this problem, the following steps have been taken to generate the population for the 2011 zoning system, all performed in ArcMap 10.3:

1- For districts with a one-to-one mapping with its corresponding zones, population totals are directly assigned. This is the case for 9 districts located in the outskirts of the 1998 zoning system.

2- For the San Lorenzo district, which is located outside of the 1998 zoning system, population is assigned based on each zone's area. There are 58 zones that map into the San Lorenzo district.

3- The remaining 10 districts mostly coincide spatially with the 1998 zoning system. Note that the census data considers Asunción as a whole district, therefore population information for 2002 for these zones is retrieved from the LRT study (FEPASA, 2014) and is shown in Table A.4. The population share of each zone in 2002 is then multiplied by its corresponding total district population in 2011, to generate the population for the 1998 zoning system. Then the 1998 zoning system population (88 zones) is transferred to the 2011 zoning system (243 zones); whenever there is an overlap, the split is made according to the shares of overlapping area.

Zone		Population	Zone		Population
1	Santo Domingo	3,042	51	Bella Vista	5,040
2	Mcal. Lopez	6,779	52	Gral. Andres Rodriguez	7,089
3	Gral. Jose E. Diaz	7,423	53	Terminal	4,894
4	Las Mercedes	5,651	54	Santa Ana	6,448
5	San Roque	7,846	55	Salvador del Mundo	4,280
6	Mburicao	8,228	56	Santa Maria	5,155
7	Villa Morra	4,633	57	Republicano	12,175
8	Tembetary	3,748	58	Roberto L. Petit	28,330
9	La Encarnacion	5,149	59	Virgen de Fatima	6,394
10	Los Laureles	4,357	60	Ita Enramada	4,079
11	Ciudad Nueva	10,575	61	De las Residentas	14,248
12	San Cristobal	7,953	62	Zeballos Cue	2,285

13	Recoleta	11,448	63	Botanico	8,818
14	Catedral	4,530	64	San Blas	3,489
15	Manora	2,456	65	Ricardo Brugada	9,094
16	Virgen Del Huerto	5,792	66	Tablada Nueva	4,973
17	Canada de Ybyray	2,883	67	Banado Tacumbu	4,061
18	Mcal. Estigarribia	9,224	68	San Rafael	8,229
19	Carmelitas	6,343	69	San Felipe	4,953
20	Silvio Pettirossi	13,234	70	Banado Tacumbu	1,085
21	Pinoza	7,425	71	Banco San Miguel	10
22	Vista Alegre	13,921	72	Lambare north	53,266
23	Nazareth	8,091	73	Lambare west	18,566
24	Pirizal	5,050	74	Lambare east	67,216
25	Panambi Reta	3,189	75	Fdo.de la Mora south	52,797
26	Ycua Sati	7,953	76	Fdo.de la Mora north	77,416
27	San Antonio	11,702	77	Luque north	16,361
28	Tacumbu	13,934	78	Luque central	71,989
29	San Vicente	16,169	79	Luque south	75,261
30	Bernardino Caballero	7,657	80	M.R.Alonso	54,725
31	Carlos Antonio Lopez	14,982	81	Villa Hayes	33,505
32	Madame Lynch	9,315	82	Limpio	50,667
33	Dr. Gaspar R.de Francia	13,123	83	San Lorenzo north	43,867
34	Hipodromo	9,461	84	San Lorenzo central	83,217
35	Obrero	22,767	85	San Lorenzo south	79,478
36	Santa Roas	2,139	86	Nemby	54,193
37	Santisima Trinidad	5,107	87	San Antonio	21,328
38	San Jorge	5,186	88	Villa Elisa	41,358
39	Italy	3,026	89	Aregua	44,170
40	Luis A.De Herrera	6,260	90	Capiata	151,531
41	Mburucuya	9,471	91	Ypane	78,069
42	Sajonia	2,330	92	Ypacarai	77,724
43	Panambi Vera	3,194	93	Ita	49,495
44	Jara	14,864	94	Villeta	22,030
45	Villa Aurelia	10,936	95	Chaco	117,867
46	Nu Guazu	32	96	Region north	157,886
47	San Pablo	25,059	97	Region east	300,930
48	Ita Pyta Punta	3,490	98	Region south	91,835
49	Loma Pyta	5,676	-	-	-
50	Virgen de la Asuncion	11,147	Total		2,535,831

Table A.4: Population by Zone for 2002. *Source: (FEPASA,2014)*

A.5 JOBS & WORKERS

The 2002 census (DGEEC, 2002) contains the number of workers for each district in 4 categories: agricultural, industrial, commercials and services. Thus, it is possible to obtain the share of each category for every district. The census also provides the percentage of working population for individuals aged > 10. Therefore, the number of workers in a category in a zone for 2011 equals to the population in 2011 multiplied by the corresponding district share of people whose age is greater 10, by the district share of working population, and by the district share of the category.

District	Jobs			Workers			
	Industrials	Commercials	Services	Farmers	Industrials	Commercials	Services
Areguá	1434	1810	1629	1800	6473	8382	5832
Asunción	39307	80417	121777	3170	41142	143604	54649
Capiatá	6624	8918	5770	2545	21665	31445	20928
Fernando de la Mora	7536	13907	12384	570	15047	35847	19587
Guarambare	557	905	902	1124	2753	3369	2694
Ita	1441	2483	1395	5710	6884	7641	5791
Itaugua	2564	3507	2724	3322	10031	11736	8016
J Saldivar	765	1985	1066	3463	4716	6419	6740
Lambare	4900	6946	8776	469	14958	35393	17579
Limpio	3493	3182	1902	1334	11689	14202	8061
Luque	7693	11780	9842	2352	24962	43149	22514
Nemby	1715	3243	2655	864	9413	16317	8235
Nueva Italia	286	325	143	73	1219	1854	1223
Roque Alonso	3126	4982	3336	12928	4832	6436	3265
San Antonio	1717	2019	1208	598	5830	8098	5174
San Lorenzo	9071	17169	12360	1559	25223	48312	29422
Villa Elisa	1942	3170	2229	293	5417	9751	6246
Villeta	2021	950	667	3121	3507	3651	1867
Ypacarai	1546	903	859	742	2559	3668	1895
Ypane	801	1297	886	1108	4130	5176	3654

Table A.5: Number of Workers and Jobs for Planning Districts Generated for 2011

The available information on jobs and businesses is limited. The 2011 National Economic Census (DGEEC, 2011) has jobs and businesses information for industrial, commercial and service categories at the district level, whereas agricultural data comes from a different source which is the 2008 agricultural census (Ministry of Agriculture and Livestock, 2008). The allocation procedure is the following:

1- Similar to the population section, for districts with one-to-one mapping to zones, the information is directly assigned to zones.
2- Using 2002 census point shapefiles of industrials, commercials, and service employment locations, the number of businesses in each zone for the 3 categories is calculated by

overlaying the points on zones. Using the shares calculated, the number of jobs per category obtained from 2011 National Econmoic Census for planning district is then distributed to the 2011 zoning system.

3- From the agricultural national census (Ministry of Agriculture and Livestock, 2008), it is found that about 90 percent of workers in the agricultural category reside where they work. Thus, in SATA's Place of Residence-Place of Work model (PoRPoW), farmers work locations are assumed to be the same as home locations.

A.6 CONDITIONAL DISTRIBUTIONS

In order to perform the population synthesis procedure, joint probability distributions are needed to estimate the different population attributes; these joint probability distributions are named "conditionals". The so-called conditionals are computed based on data from the 2002 census (DGEEC, 2002) and the Permanent Household Survey (EPH in Spanish) (DGEEC, 2015). It is worth mentioning that the UTTRI team obtained the microdata from the General Direction of Statistics, Surveys, and Censuses of Paraguay (DGEEC) by formal request. While these microdata includes several variables of interest that helped model population attributes, the sample size for any given year was small, thus data from years 2012, 2013, 2014, and 2015 were merged into a larger, more representative sample; this procedure was deemed adequate given that each year's sample size is small enough to rule out duplication.

The following attributes are considered at the district level from census data: Gender, and Age (13 categories: 0-4, 5-9, 10-14, …, 55-59, 60+) while employment, student status, vehicle ownership and household structure were obtained at the department level (Asunción and Central) from the EPH surveys from 2012-2015.

A.7 EMME NETWORK INFORMATION

Upon authorization from the Ministry of Public Works and Communications, the Brazilian company LOGIT provided the UTTRI team with a digital copy of the Asunción transportation network in EMME format. This network package was provided in Latitude/Longitude coordinates, requiring a re-projection using ArcGIS converting them into UTM coordinates. The new coordinates were then applied to the EMME network using the Python-based EMME shell. It is important to acknowledge that the spatial precision of the coded network was not perfect; in general, the network is shifted from its correct position but the distances between nodes were mostly not affected, so the network was deemed adequate. There were some areas of the network that were particularly inaccurate and were manually corrected. Additionally, since the studies carried by LOGIT were focused on transit only, the road network had only shape information, but no attributes of any kind were assigned to the links. For further detail on network coding see Appendix B.

A.8 Operational Designs for the BRT & LRT Projects

The last source of data that was fundamental for this project is the studies for the transit investment alternatives, and their operational design. These alternatives became the case studies analyzed with SATA. These two studies are the BRT Corridor Eusebio Ayala - Mariscal Estigarribia (LOGIT, 2011), and the Short Distance Passenger Train between Asunción and Ypacaraí Pre-Feasibility Study (FEPASA, 2014). Introductory details about these studies were presented in Chapter 5 of Volume I, while additional detail is presented in Appendix C.

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DGEEC (2002). General Direction of Statistics, Surveys, and Censuses. DGEEC: National Population Census. Retrieved from www.dgeec.gov.py

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APPENDIX B
BASE ROAD & TRANSIT NETWORKS & ASSIGNMENT MODEL CALIBRATION

APPENDIX TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

B.1 INTRODUCTION

The current EMME transportation network model was provided by LOGIT on July 26, 2016. However, this network has been heavily modified and updated in order to better reflect the current status of the transportation network in Asunción. Furthermore, the original network was not fit for the purposes of agent-based modelling.

The network given by LOGIT, as seen in Figure B.1, was made by them in order to complete a study on a proposed BRT in the Asunción and Central Regions. This BRT study was mainly focused along the Avenida Mariscal José Félix Estigarribia/Avenida Eusebio Ayala corridor until it got to the historic centre, where it then branched out throughout the historic centre. This BRT route was represented as parallel links in the network in order to capture their exclusive right of way status. These links have been maintained in the current network in order to model the BRT scenario using the Agent-Based Microsimulation model.

Since the original LOGIT model was mainly for the BRT use, it did have a mostly complete transit network along with a significant amount of transit information. This transit network included 529 transit lines along with observed surface speeds for the transit segments. The headway for the lines was also included, along with the dwell times at each node. Since the Asunción region has no formal bus stops, the EMME model then prescribes every node in the line to be a stop.

The road network in the LOGIT model was less developed, probably due to the fact that the study was focused on transit. Although the major structure of the model was correct, there was a significant amount of detail missing from the model. There was no road classification system present which meant that whether a road was dirt, gravel, or paved was unknown. Since the Asunción and Central regions have a significant amount of roads that are gravel and dirt, this is key information. Furthermore, the volume delay functions were not defined for the system meaning that no information regarding Asunción specific calibrated functions was known. The network also contained no information on road capacity (lane widths, the number of lanes, speed). These were all set to one default value. One way roads were also disregarded by the original model. While one-way roads in the system were not widespread, they were concentrated in high-traffic areas, including the historic centre as well as the centre of San Lorenzo, which made their effects on the system much larger.

After receiving the model from LOGIT, UTTRI staff then began to categorize what had been giving, as well as what needed to be done to the network to make it viable and accurate for the Asunción model to run on.

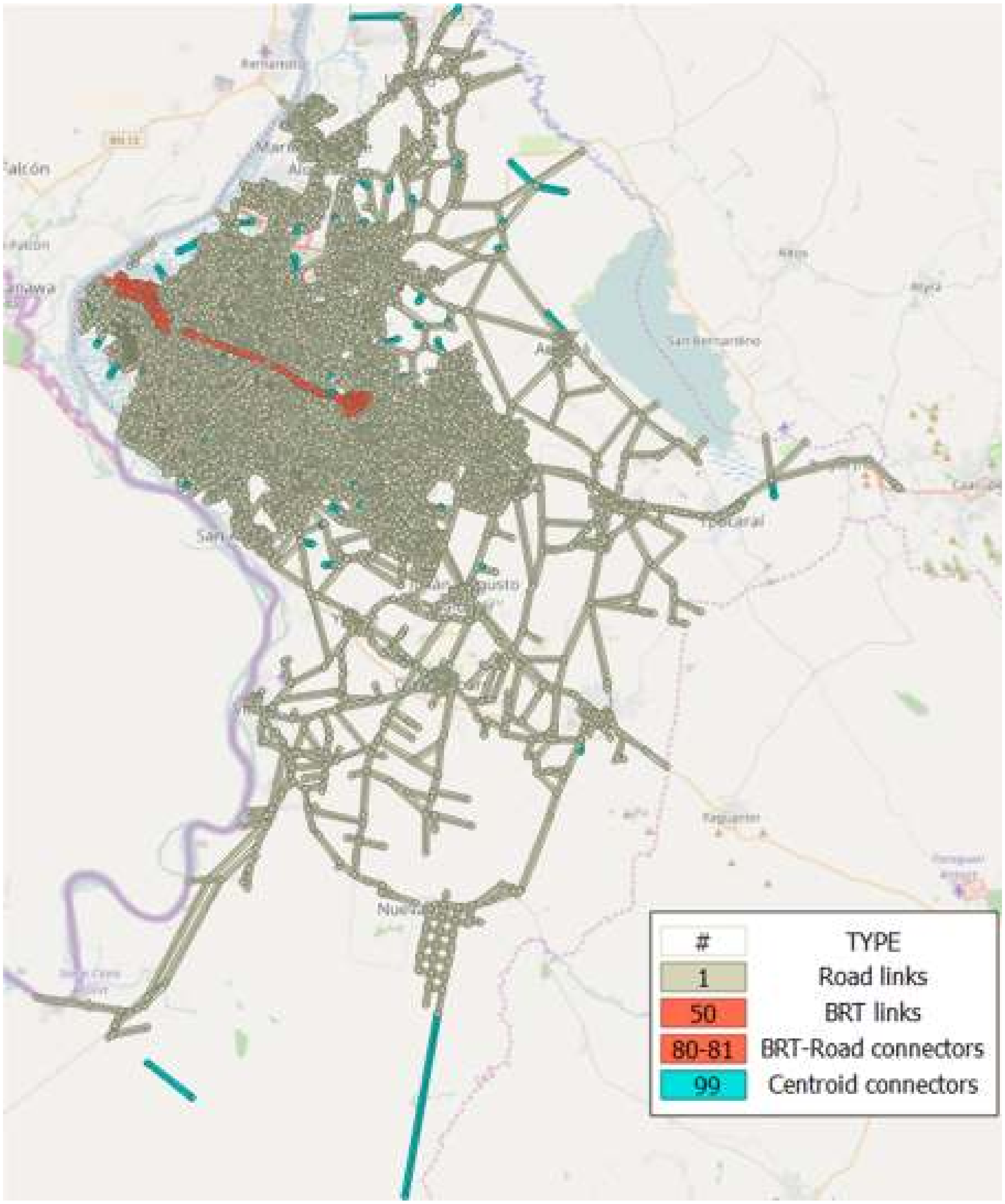

Figure B.1: Original Asunción Network

B.2 NETWORK ATTRIBUTE CODING

To begin with, the coordinate system needed to be converted for use in EMME. The coordinate system was originally in latitude and longitude and had to be converted to WGS 1984 UTM Zone 21S. In order to facilitate a more accurate network, the following attributes were changed. Attributes with the "@" symbol in front of them are attributes that were manually added to the network. The other attributes are default attributes of the network and are present in every network in the EMME program.

B.2.1 vdf – Volume Delay Function

The vdf (volume delay function) attribute is the key road attribute for EMME as it describes the ability of the road to handle traffic. Since EMME does macrosimulation, as opposed to microsimulation, and there are no traffic lights and intersections, it is the only measure of delay in the system. As stated above, when the network was given by LOGIT, all the links in the system had the default vdf of 1. Four categories of roads were then established in order to better categorize the network, each with their own vdf value and function. These were dirt roads, gravel roads, local paved roads, and arterial roads. Dirt roads were defined as roads that were mostly or completely dirt. In Asunción's case, since the natural ground is orange clay, these roads would be made mostly of clay and were given a vdf of 4. Gravel roads were defined as those roads that were made primarily of gravel and/or stones. Gravel roads were given a vdf of 3. Local paved roads were defined as paved roads that carried local traffic. They were given a vdf of 2. Arterial roads were designated as those who carried arterial traffic from one area of the region to the other and were given a vdf of 1.

As the data provided by Asunción authorities and LOGIT was incomplete, it was necessary to look at other sources to fill in the missing information. Google Maps was the main source of alternate information. Each link was looked at using Google Maps satellite view and evaluated. The state of the road (whether it was dirt, gravel or paved) was judged based on the satellite images. The dirt roads were identified by their orange clay colour, due to the natural clay in that region. Gravel was more difficult to assess but roads that appeared more grey/brown but not exactly paved were given this condition. Paved roads were easier to judge as these roads had a more distinct grey colour. Due to the inherent nature of working with satellite information, judgement calls had to be made in order to verify the condition of the road. Google Streetview was also absent in the region and it would have helped to give a much better idea of road condition. There were also instances where Google Maps had very blurry satellite imagery, particularly East and North of Asunción City, and in these cases, Bing Maps was used as a second reference in order to obtain a better representation of the road type. Google was used as the primary source in order to avoid conflicts between sources and because of the breadth of information that Google has.

The difference between paved local roads and arterials roads were also determined using judgement based on a road's length, location, capacity, and the type of traffic it would reasonably carry. Arterials were judged to generally carry traffic from one district of the region to another and had the greater capacity as compared to the local roads. The various road condition corresponds to the vdf function value assigned to them.

Due to time limitations placed upon this project, not every link was looked at with precision detail. Areas were looked over to determine the road condition, with individual links being glanced at rather than examined. Requests were made to the Asunción authorities for additional information regarding the roads, but it was not provided before the commencement of network editing with visual tools in September. However, in the November meeting, it was communicated that a shapefile with all the roads, as well as their condition (paved or unpaved), existed. This shapefile was made available after the meeting, however, the network had mostly been completed visually by that point and the shapefile only contained roads within the Asunción city limits. Using GIS tools, the network in EMME was compared to the shapefile and attributes were merged with the new information. Some cleaning up was done with regards to vdf to ensure that road condition was consistent. Although this method was not perfect due to differing networks, it did allow for a merged network that contained the information in the shapefile. This is shown in Figures B.2 and B.3.

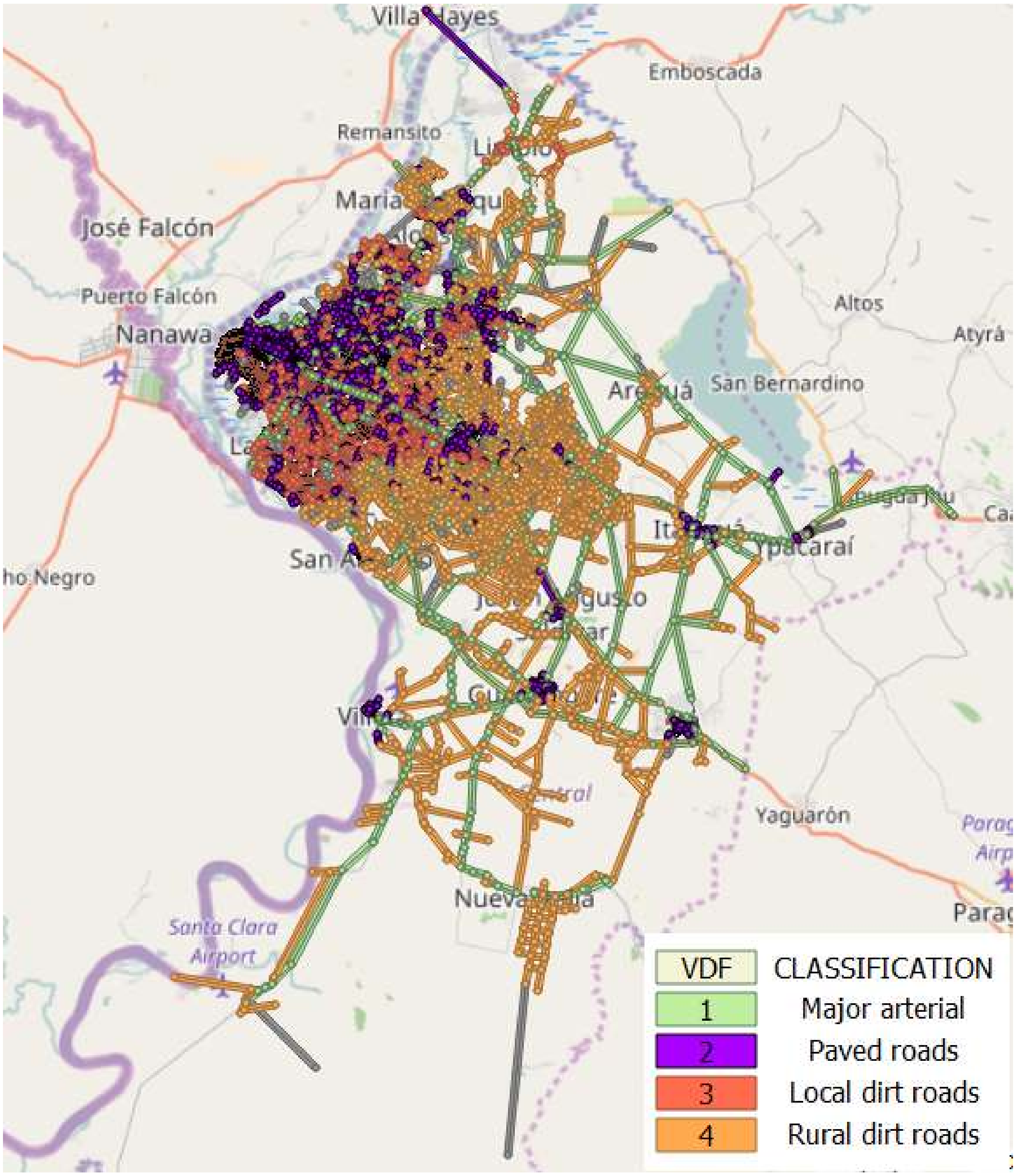

Figure B.2: Full Network by Road Condition

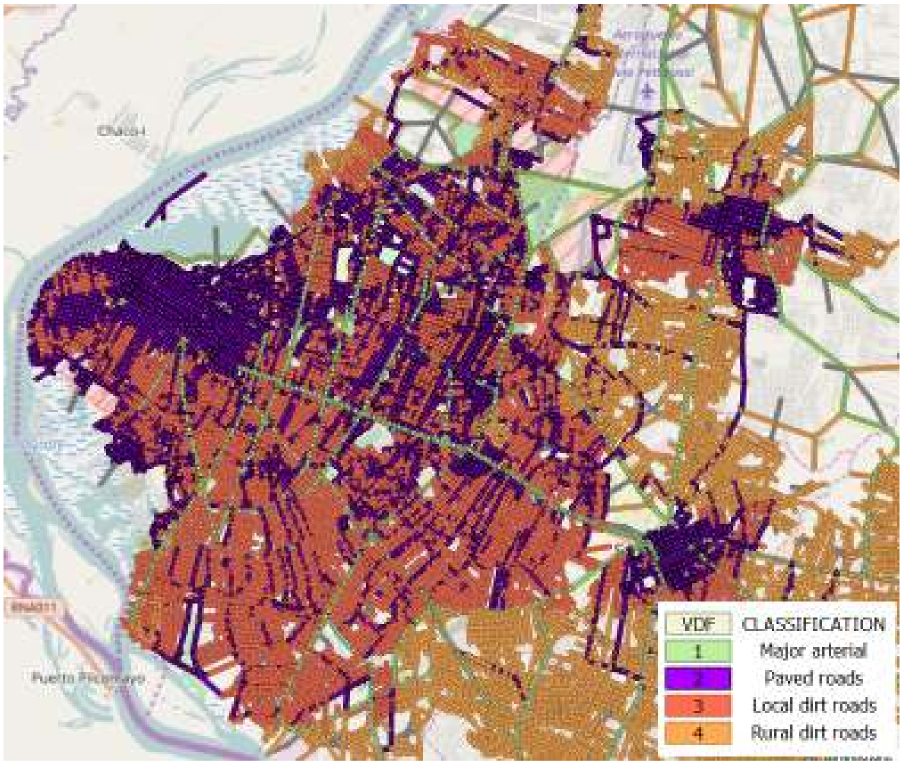

Figure B.3: Zoomed in Section of Asunción Region Displaying the Condition of the Road

B.2.2 Lanes

The number of lanes in each link (single direction) is stored in the lanes attribute in EMME. This lanes attribute was not provided in the original network and therefore had to be modified in order to account for road capacity as the vdf functions had a lane variable. The capacity of the network was also established in veh/hour/lane, therefore number of lanes for the links was essential to determine.

Google Maps was also used here to determine the number of lanes, although it had inherent flaws due to the static nature of the satellite images. There was no difference between parked cars and cars in another lane. The measurement tool was used to determine the width of roads, followed by judgment to find the number of lanes in each direction. Arterials were generally the only roads that had multiple lanes of traffic in each direction, with very few roads that were judged to be local having multiple lanes, and these were mostly concentrated near the historic centre.

The lanes attribute is also crucial when dealing with one-way roads. Since EMME has two links for each road, one in each direction, the lanes attribute for the link in the in the opposite direction of the road would be set to 0. Therefore, that link would not be able to handle any automobile traffic while still allowing for pedestrian traffic in both directions. Google Maps was also used with regards to the determination of these one-way roads. These links were mainly near the historic centre of Asunción and in the centre of San Lorenzo. Google provides directions for one way links for the roads but it has conflicting directions when compared to Bing Maps or Open Street Maps. Google was again taken as the primary source for these links to avoid any conflicts. Not every link in the entire network was looked at for details as it was found to be too time intensive. The focus was on links in the historic centre and downtown San Lorenzo as these were places where due to the anticipated traffic, one-way links would have the greatest effect.

B.2.3 @cuo

@cuo is essentially a location attribute and would represent where in the network a link is. The network was divided into three areas, Centuro (Centre), Urbano (Urban), and Otros (Other). Centuro represented the historic centre of Asunción. This had limits of Humaita in the South, Don Juan Melchor Bosco in the west, Brasil in the East, and Florencio Villamayor in the north. Urbano mostly described the Asunción city limits but deviated slightly. In the north, instead of Soldado Robustiano Quintana being the boundary, it was extended slightly to Avenida Eusebio Ayala. In the south, the Urbano boundary follows Avenida Cacique Lambare rather than turning inwards. This was done to provide better location-based road condition assumptions as well as easier to make changes to one location at a time in terms of network parameters. Open Street Maps was used here to determine where the link is quickly and easily as EMME allows for it to be inserted in the background of the network. This is seen in Figure B.4.

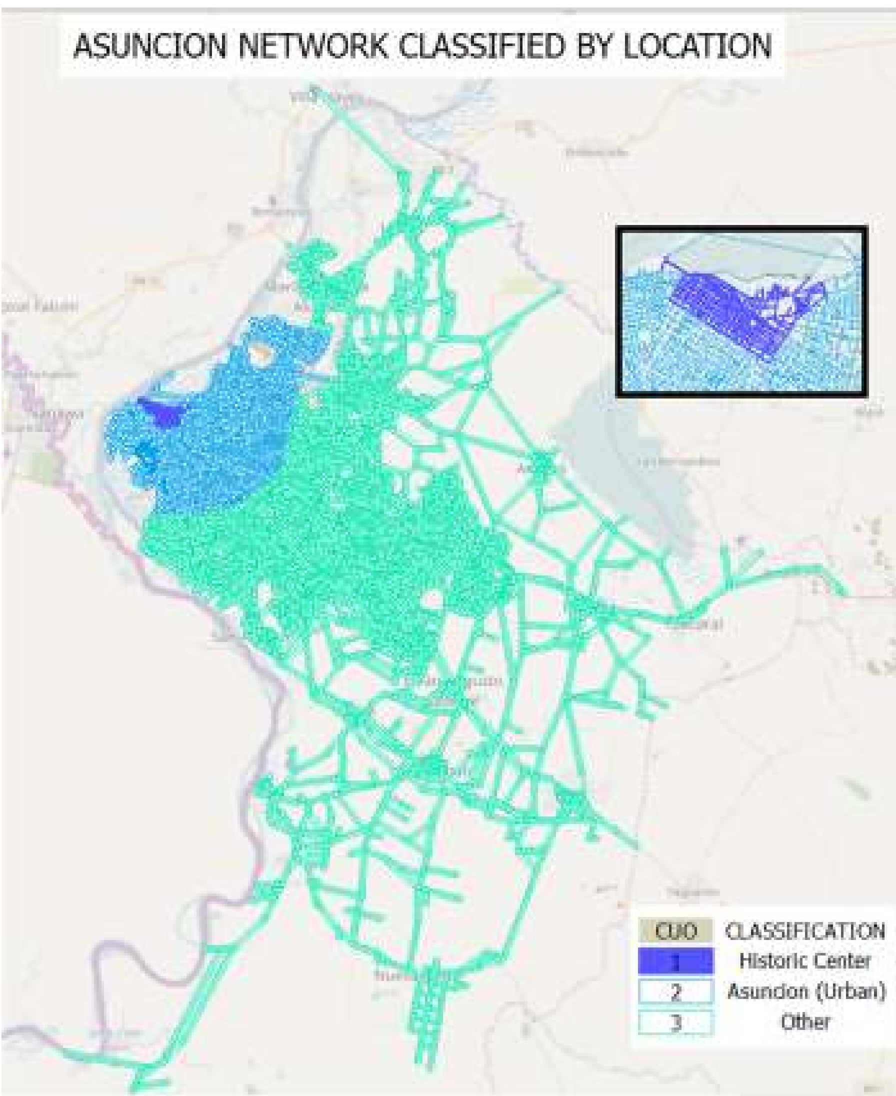

Figure B.4: Network Classified by Location

B.2.4 @dirt
The @dirt parameter was there to describe whether a road was a dirt road (meaning gravel or dirt) or whether it was paved. This was a simple 0 or 1 value, with 0 being paved and 1 being unpaved. This parameter was inherently related to the vdf attribute and it could be seen as simply any road that is vdf 3 or 4. Google Maps was again used to determine the condition of the road.

B.2.5 ul1, ul2 and ul3
These three are the user defined link data attributes that the EMME model has by default. When the network was provided there were values inside ul1 and ul2, but it was not known what those values represented. Following the standards established in TMG's Network Coding Standards 2011, ul2 was established as the free flow speed for the link and ul3 was established as the capacity/lane of the link. The values of the free flow speed and capacity were adjusted as will be described in the network calibration section below. The old 'ul2' values were kept in a new attribute '@oldul2' in order to preserve the data in case it is needed.

B.3 General Network Modifications

As stated above, although the major structure of the network was accurate, as compared to the Open Street Maps background layer, there was significant deviation of the network when examined closely. Most importantly, due to the conversion of the network from latitude and longitude to WGS 1984 UTM Zone 21S, there exists a shift in the network. Roads are not exactly where the base Open Street Map layer expects them to be and this shift is inconsistent throughout the map. This would mean that the lengths of links would be incorrect, however, the degree of the shift is not that high that it would have an impact on the results. Due to time constraints, the shift was left in place as it was judged not to impact results and the network was still largely accurate.

Other errors in the network, when found, were rectified. Unconnected links and nodes were found using a minimum spanning tree algorithm in EMME notebook. These unconnected links were then either connected to the network or deleted from the network depending on the link. The network also consisted of roads that had with missing connector links which had to be connected in order to ensure a complete network. A number of roads were not modelled at all in the original network. These ranged from smaller streets (which were left unmodelled) as well as larger arterial type roads (which were added in). The smaller streets were left unmodelled due to the density of the network as it is. The number of centroids as compared to the density of the network would mean that the smaller roads are superfluous to the results of the assignment. In this network, the number of zones is too low as compared to the detail in the network that it already ascribes. The larger roads that were missing included Avenida Jose Asunción Flores Costenera, which was built after the network had been built. This was added as it is a major arterial road that provides an alternate way to approach the historic centre. Other roads that were not included were a large section of Accesso Sur near Ypane and Guarambre. Lastly, in the north of the Bahia de Asunción was an area of populated land that was recently flooded. This naturally means that the roads in that area are no longer functional and this area has been unconnected from the network. The network there has been preserved, so if the roads and area become functional, it can be easily connected.

While the majority of the network had distinguishable roads, there was a section of the network that had to be rebuilt entirely due to the original network not matching the Open Street Maps baselayer. This area was the De La Residenta neighbourhood. The links and nodes were deleted and rebuilt in order to provide for a better network.

The original LOGIT network had coded in a 487 zone system. This zoning system is largely based on the 2011 BRT study with 282 zones as the 487 zones system subdivided the zones along the Avenida Jose Felix Estigarribia corridor. The original network had id number ranges for the centroids in the 32462-33492 range along with 9558 and 9560. Based on a shapefile provided of the 282 zoning system, it was also coded into the network using a similar range as the 487 zone system. As the 1998 zoning system with 98 zones was not coded into any of the scenarios given by LOGIT, it also had to be coded into the network in order to import the Origin-Destination (OD) demand matrices from the study into the network. However, the only 1998 zoning system file provided was an image file which had to be converted into a shapefile and then imported into the network in order to define the zones. These coded centroids numbers were put into the 32500-32598 range. It was decided that model would be based on 282 zone system but the 98 zone system would also be required for calibration purposes.

B.4 NETWORK CALIBRATION

In order to be sure that the modelled network was an accurate representation of the network in Asunción, it was necessary to calibrate it. This was done by assigning OD Automobile Demand matrix from the 1998 Study by JICA to verify the auto network. The transit network was verified by assigning the 2011 BRT OD Transit matrix. After assigning these matrices, the values obtained from EMME were compared to the traffic counts (or visual occupancy counts for transit) provided by the Asunción authorities. In order to assign the matrices, it was necessary to adapt OD matrices to the correct zoning system. Furthermore, the 1998 Automobile Demand matrix was given for a full day, instead of an AM period or even hourly matrix. A number of ways were looked at to extract the AM peak hour while maintaining directionality in the network, but none of them were feasible. Therefore, a simple multiplication of the matrix by 8.5% was done. The 8.5% number was obtained from the range provided in the 1998 Study. This factored the matrix into the peak AM hour but did not preserve directionality, meaning that the direction of traffic would not be towards the historic centre in the AM. The 2011 transit demand matrix was given for the peak AM hour and thus did not require factoring.

B.4.1 Traffic Calibration

Before assigning automobile traffic, it was necessary to obtain capacity and free flow speeds for the links. These values were mostly based on the 1998 JICA Study which looked the complete transportation network. With the help of the vdf and @cuo variable, the values shown in Table B.1 were assigned.

Table B.1: Road Capacities and Free Flow Speed by Type of Road

Type of Road	Location(s)[1]	Free Flow Speed (km/hr)	Capacity (PCU/hr/lane)[2]
Arterial	Outer	80	1200
Arterial	Urban and Historic Centre	60	1000
Local Paved	Outer	50	800
Local Paved	Urban	40	500
Local Paved	Historic Centre	35	500
Gravel	All Locations	20	125
Dirt	All Locations	20	125

1. The location is based on the @cuo parameter described above.
2. PCU is passenger car equivalents.

A number of other values were also assigned in order to try to match the results to the counts. However, these values were kept as the final ones as they were judged to be the most reasonable and still gave valid results.

The vdf values in the links also had to have corresponding functions in the EMME database. As this data was not known for the Asunción Region, functions from GTA Model v4 model were used. Defining these functions for compatibility with the local infrastructure would be an area of future study after data collection is done.

The original network also had link lengths in meters, but since EMME requires them to be in kilometers, it was necessary to change them over. These were changed with a simple mass change throughout the network. With these solved, XTMF (eXtensible Travel Modelling Framework) was used to assign the OD Automobile Demand matrix to the network. The results were first run with much higher capacity and free flow speed values, which gave almost no congestion in the network, even in the historic centre, which is not observed in reality. However, in order to be sure that the values are actually reasonable and the network accurate, it was necessary to compare it to the traffic counts conducted in 1998.

The traffic counts were conducted in 1998 at a number of locations across the Asunción region. Screenline counts, section counts, cordon counts, and intersection counts were all done to support the 1998 Study. However, the intersection counts were not provided and were not integrated with this study. The screenline, section, and cordon counts were combined into a third normalized database for easy information extraction. The AM period was defined as 6 AM-9 AM based on discussions with the Asunción authorities and the previous studies. The combined count for the AM period was multiplied by 0.43, which was based on the GTA peak period factor to find the peak hour volume. This is shown in Table B.2.

Table B.2: Combined Volumes of All the Counts for Each Start Time, AM Peak Period

Start Time	Sum of All Counts
600	4044
615	5957
630	8600
645	11226
700	11714
715	11181
730	11121
745	10830
800	10869
815	10315
830	9816
845	9275
Total	**114948**
Total*0.43	**49427.64**

In order to compare, an extra attribute, @stn1, was coded in to the links that had a count associated with them with the id of the count. During the assignment, XTMF was used to extract the volumes at these locations and was then compared the volume at the count. Due to the lack of directionality in the demand matrix, it was anticipated that the volumes for both directions would not match. Furthermore, the counts were conducted in 1998, while the network has been updated for the current day. It is assumed that the network has been upgraded and improved in the interim and therefore, the number of routes and the 'supply' of roads in the system has increased. This would mean that the numbers in the counts would be expected to be higher than the volumes seen in the EMME network. In order to reflect this, the total volume in the counts and the total volume of the links with counts has been compared on an aggregate basis. This is shown in Table B.3 below.

Table B.3: Volume of Cars at Each Count Location

Count ID	Volume	Count ID	Volume	Count ID	Volume	Count ID	Volume
10011	1468	**10101**	399	**20051**	126	**20213**	362
10013	1459	**10103**	0	**20063**	551	**20221**	1791
10021	445	**10111**	2866	**20071**	551	**20223**	1722
10023	453	**10113**	2849	**20083**	356	**20231**	2150
10031	324	**10121**	1620	**20091**	530	**20233**	2057
10033	416	**10123**	1581	**20103**	374	**30020**	0
10041	497	**10130**	164	**20111**	374	**30022**	0
10043	513	**10132**	218	**20121**	1814	**30030**	0
10051	2323	**10140**	240	**20123**	1755	**30032**	0

10053	2229	**10142**	298	**20133**	174	**30041**	9
10061	394	**10150**	1666	**20141**	225	**30043**	9
10063	420	**10152**	1649	**20153**	192	**30051**	7
10071	0	**10160**	176	**20161**	139	**30053**	8
10073	254	**10162**	175	**20173**	154	**30060**	0
10081	333	**20011**	600	**20181**	814	**30062**	0
10083	209	**20023**	417	**20183**	894	**30070**	0
10091	0	**20033**	489	**20193**	388	**30072**	0
10093	301	**20043**	410	**20201**	430	**Total**	**45811**

It can be seen that the total volume on the links with count stations is lower than the observed volume on the counts. However, this number was judged be within reasonable limits of calibration and thus ensured that the auto network is a reasonable representation of the network in the Asunción Region.

B.4.2 Transit Calibration

Transit calibration was done in a manner similar to the traffic calibration above. The demand matrix (taken from the 2011 BRT Study) was given only for the peak hour. However, when looking through the study behind the matrix, the study stated that the focus was on Jose Felix Corridor and therefore the demand would not be accurate for the whole network.

XTMF was again used to assign the transit demand to the network. The transit functions were imported from the GTAv4 model as there was no local function definition for the Asunción Region. A multiclass non-fare based uncongested transit assignment module was used. This module has been developed by TMG for use in EMME and is available as part of the TMG Toolbox. This module applies an extended transit assignment for each class using a non-fare based approach. Since the fare information was not clear for the Asunción Region, a non-fare based approach was used, with boarding time penalties being the main parameter. Transit line speeds were updated based on the weighted speed of the segments within the line.

After the transit assignment was conducted, the numbers were compared to the counts from the visual occupancy survey provided. However, the assignment produced volumes that were much lower than these counts. Even when the transit assignment was conducted with a range of boarding time penalties from 2-9 minutes, it did not appear to make a difference. Furthermore, journey levels were modified such that walk all way to the destination was no longer allowed and thus forced every user to use the transit system in order to access the system. Figure B.5 shows the comparison of the assignment volumes and the volumes at each count.

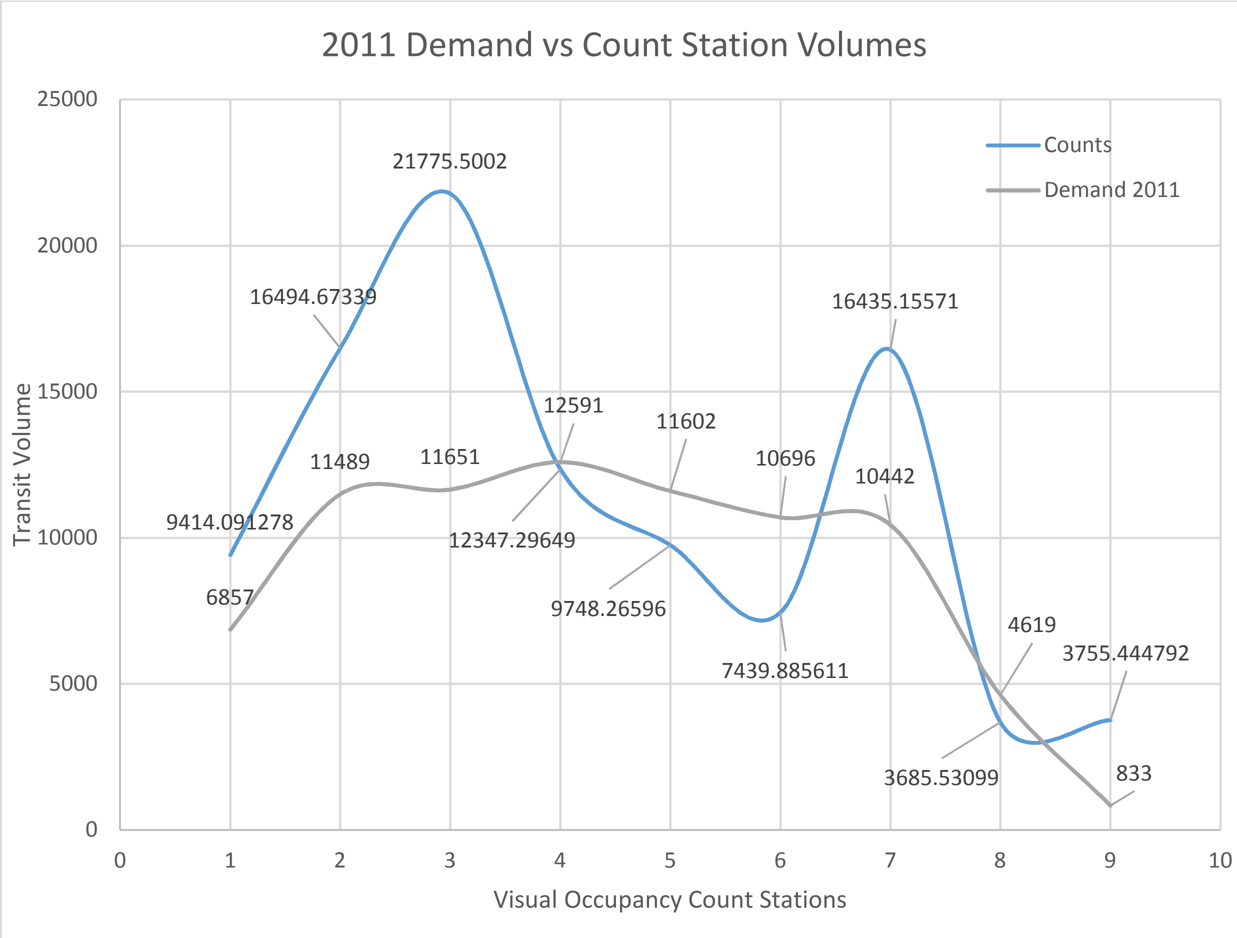

Figure B.5: Assigned Demand & Visual Occupancy Count at Each Station

It was then judged that due to the lack of clarity in the 2011 Transit demand matrix, and in the absence of more information, the transit system would be considered to be an accurate representation of the system in Asunción. However, later on during network coding for the BRT and LRT lines, it was revealed that the transit network that was given to us was a combination of very different scenarios revolving around the BRT. Transit lines in the network included the combination of lines that are operating today and lines that will be modified when the BRT starts running. This resulted in an artificially increased capacity in the original network. Transit lines were then organized into the following subsets

1. Current Scenario. This subset has all the lines unmodified in their current locations.
2. Modified state for BRT. This subset has some transit lines modified to complement the BRT network, some lines deleted due to redundancy, and other lines left alone.

Further information regarding these lines are given in Appendix C.

B.5 Final Network Modifications

In order to clean up the network and make it easier to use and analyse, a final network edit was made to change the node id's. All node id's were increased by 1000 in order to create a range from 0-1000 exclusive to centroids. The centroids were then inputted into that range and were mapped based on zone data information from other sources provided by the Asunción authorities. This was done to integrate the information coming from the different areas of the model and provide comprehensive and easy to understand results. Finally, 2 external zones were deleted from the network as they had no demand, and another 3 zones were combined together in order to form 1 zone and align the network with the census areas. The network in its present state now contains a total of 278 zones that conform to both EMME network model as well as the EPH/Census zoning system.

B.6 CONCLUSIONS

The original network by LOGIT was not fit for the task of agent-based modelling so a number of steps were taken to improve the network and make it more representative of the actual network in Asunción. This improvement updated the condition of the road, the number of lanes in each link, the capacity, the free flow speed as well as many other smaller things. The network also saw a number of changes that help to control variables and allow for better results. These changes were validated for traffic portion using the demand from the 1998 Asunción Study and it was found to be within tolerable limits, meaning a valid network. The transit side was harder to calibrate due to the lack of good information to work it, but it was also judged to be a reasonable network. Lack of data for the network did hinder efforts to improve the network further, and this should be studied in the future to ensure a more thorough network. Nonetheless, this process has led to the completed network that is fit for use as part of the Agent Based Microsimulation Model.

APPENDIX C
CASE STUDY NETWORKS

APPENDIX TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

C.1 INTRODUCTION

Having SATA's model system specified and its corresponding inputs such as a synthesized population, estimated mode choice parameters, an adequate representation of the network, among others, the last stage of this study is the application of SATA to model different scenarios related to transportation infrastructure projects.

In Asunción and the Central Region, the two major projects that are currently proposed are the *BRT Corridor Eusebio Ayala - Mariscal Estigarribia* (LOGIT, 2011), and the Short Distance Passenger Train between Asunción and Ypacaraí Pre-Feasibility Study (FEPASA, 2014). These are the first massive transit infrastructure projects to be implemented in the region, making them the obvious choice for case studies. Therefore, four scenarios are presented below: the base case, the BRT scenario, and the LRT scenario.

Since all scenarios are related to public transit alternatives, it is noteworthy that the differences between scenarios consist of "turning on and off" different transit lines/transit services. In essence: the EMME database contains all possible lines and services, then each scenario is represented by a Comma Separated Values (csv) master file specifying the lines to be considered, these master files become inputs to the Full Network Set Generator tool from XTMF, and ultimately, SATA generates results for each scenario.

C.2 THE BASE CASE

The base case (oftentimes translates as the "do nothing" approach) consists of running the calibrated model according to the current conditions of the study area. This scenario establishes an initial reference which works as a comparison point with respect to the proposed infrastructure investment projects.

Appendix B covered the representation of the road network and touched upon the representation of the public transit network. A more detailed description of the transit network is presented in Table C.1, which contains the 278 bus lines that are currently operating in the system. This information is retrieved from the Metrobus studies and from the Brazilian firm LOGIT (LOGIT, 2011) & (LOGIT, 2015). Figure C.1 presents a plot of these lines.

Table C.1: Base Case Transit Lines

Code	Description	Code	Description	Code	Description
L1.1B	L1.1 B	L111C	L111 C	L13.2	L13.2C B
L1.1C	L1.1 C	L119B	L119 B	L13.2B	Tacumbu B
L1.2B	L1.2 B	L119C	L119 C	L13.2C	Tacumbu C
L1.2C	L1.2 C	L11B	L11 B	L13AB	L13A B
L10IB	L10 Interno B	L11C	L11 C	L13AC	L13A C
L10IC	Interno C	L12-2B	L12-2 B	L13B	L13 B
L110B	L110 B	L12-2C	L12-2 C	L13C	L13 C
L110C	L110 C	L128B	L128 B	L13ROB	L13 Rojo B
L111B	L111 B	L128C	L128 C	L13ROC	L13 Rojo C

Code	Description	Code	Description	Code	Description
L14.2B	L14.2 B	L23C	L23 C	L35C	L35 C
L14.2C	L14.2 C	L26MLB	Mlopez B	L36B	L36 B
L14B	L14 B	L26MLC	Mlopez C	L36C	L36 C
L14C	L14 C	L26PIB	Pitinatuta B	L37.1B	L37.1 B
L159B	L159 B	L26PIC	Pitinatuta C	L37.1C	L37.1 C
L159C	L159 C	L28B	L28 B	L37.2B	L37.2 B
L15CAB	Caaguazu B	L28C	L28 C	L37.2C	L37.2 C
L15CAC	Caaguazu C	L29ANB	L29 Anahi B	L37.3B	L37.3 B
L15PEB	Petropar B	L29ANC	L29 Anahi C	L37.3C	L37.3 C
L15PEC	Petropar C	L29THB	L29 Thompson B	L37ARB	Artigas B
L15SLB	Salinas B	L29THC	L29 Thompson C	L37ARC	Artigas C
L15SLC	Salinas C	L2B	L2 B	L37ESB	España B
L15STB	Santonio B	L2C	L2 C	L37ESC	España C
L15STC	Santonio C	L2LIB	Limpio B	L38B	L38 B
L15VCB	Veracruz B	L2LIC	Limpio C	L38C	L38 C
L15VCC	Veracruz C	L2SLB	Santa Librada B	L38GIB	Gical B
L165B	L165 B	L2SLC	Santa Librada C	L38GIC	Gical C
L165C	L165 C	L2SMB	SMTC B	L39.2B	L39.2 B
L16B	L16 B	L2SMC	SMTC C	L39.2C	L39.2 C
L16C	L16 C	L2UNB	Universo B	L39B	L39 B
L18.2B	L18.2 B	L2UNC	Universo C	L39C	L39 C
L18.2C	L18.2 C	L30AMB	L30 Amarillo B	L3IB	L3 Interno B
L187B	L187 B	L30AMC	L30 Amarillo C	L3IC	L3 Interno C
L187C	L187 C	L30APB	L30 AeropuertoB	L40B	L40 B
L18B	L18 B	L30APC	L30 AeropuertoC	L40C	L40 C
L18C	L18 C	L30AZB	L30 Azul B	L41.2B	L41.2 B
L1IB	L1 Interno B	L30AZC	L30 Azul C	L41.2C	L41.2 C
L1IC	L1 Interno C	L30ROB	L30 Rojo B	L41.3B	L41.3 BC
L203CB	L203 CB	L30ROC	L30 Rojo C	L41BC	L41 BC
L20LUB	Luque B	L30VEB	L30 Verde B	L42B	L42 B
L20LUC	Luque C	L30VEC	L30 Verde C	L42C	L42 C
L20THB	L20 Thompson B	L31.4B	L31.4 B	L43B	L43 B
L20THC	L20 Thompson C	L31.4C	L31.4 C	L43C	L43 C
L22IPB	Ipvu B	L31B	L31 B	L43TOB	Toledo B
L22IPC	Ipvu C	L31C	L31 C	L43TOC	Toledo C
L232RB	L232 Ruta1B	L32B	L32 B	L44.2B	L44.2 B
L232RC	L232 Ruta1C	L32C	L32 C	L44.2C	L44.2 C
L232SB	L232 Sur B	L34B	L34 B	L44B	L44 B
L232SC	L232 Sur C	L34C	L34 C	L44C	L44 C
L23B	L23 B	L35B	L35 B	L454B	L454 B

Code	Description	Code	Description	Code	Description
L454C	L454 C	L60IC	L60 Interno C	R19PBC	Piribebuy C
L47B	L47 B	L6IB	L6 Interno B	R1ACB	Acahay B
L47C	L47 C	L6IC	L6 Interno C	R1ACC	Acahay C
L48B	L48 B	L6SAB	L6 Santonio B	R20QUB	Quiindy B
L48C	L48 C	L6SAC	L6 Santonio C	R20QUC	Quiindy C
L49B	L49 B	L7B	L7 B	R21SBB	San Bernardino B
L49C	L49 C	L7C	L7 C	R21SBC	San Bernardino C
L4IB	L4 Interno B	L82B	L82 B	R22SEB	Santa Elena B
L4IC	L4 Interno C	L82C	L82 C	R22SEC	Santa Elena C
L50B	L50 B	L85B	L85 B	R23TOB	Tobati B
L50C	L50 C	L85C	L85 C	R23TOC	Tobati C
L51B	L51 B	L8B	L8 B	R24VAB	Valenzuela B
L51C	L51 C	L8C	L8 C	R24VAC	Valenzuela C
L52.1B	L52.1 B	L9.2B	L9.2 B	R25YAB	Yaguaron B
L52.1C	L52.1 C	L9.2C	L9.2 C	R25YAC	Yaguaron C
L52.2B	L52.2 B	L9.3B	L9.3 B	R26YBB	Ybicui B
L52.2C	L52.2 C	L9.3C	L9.3 C	R26YBC	Ybicui C
L53B	L53 B	L96B	L96 B	R27YUB	Yuti B
L53C	L53 C	L96C	L96 C	R27YUC	Yuti C
L53TOB	Toledo B	L9B	L9 B	R28LOB	Lomagrande B
L53TOC	Toledo C	L9C	L9 C	R28LOC	Lomagrande C
L54B	L54 B	R10CEB	Ciudad del EsteB	R29CAB	Cabañas B
L54C	L54 C	R10CEC	Ciudad del EsteC	R29CAC	Cabañas C
L55B	L55 B	R11EAB	Eusebio Ayala B	R2ALB	Altos B
L55C	L55 C	R11EAC	Eusebio Ayala C	R2ALC	Altos C
L56B	L56 B	R12VRB	Villarrica B	R30GUB	Guarambare B
L56C	L56 C	R12VRC	Villarrica C	R30GUC	Guarambare C
L58B	L58 B	R13MBB	Mbocayaty B	R31CUB	Curuguaty B
L58C	L58 C	R13MBC	Mbocayaty C	R31CUC	Curuguaty C
L59B	L59 B	R14MIB	Misiones B	R32OLB	Oleary B
L59C	L59 C	R14MIC	Misiones C	R32OLC	Oleary C
L59LPB	Laspedras B	R15NEB	Ñemby B	R331MB	1o de Marzo B
L59LPC	Laspedras C	R15NEC	Ñemby C	R331MC	1o de Marzo C
L59TOB	Toledo B	R16NSB	Nsa B	R342JB	20 de Julio B
L59TOC	Toledo C	R16NSC	Nsa C	R342JC	20 de Julio C
L5IB	L5 Interno B	R17PAB	Paraguari B	R35SAB	Santa Ana B
L5IC	L5 Interno C	R17PAC	Paraguari C	R35SAC	Santa Ana C
L6.1IB	L6.1 Interno B	R18PIB	Pirayu B	R3AEB	Arroyos EsterosB
L6.1IC	L6.1 Interno C	R18PIC	Pirayu C	R3AEC	Arroyos EsterosC
L60IB	L60 Interno B	R19PBB	Piribebuy B	R4ATB	Atyra B

Code	Description
R4ATC	Atyra C
R5CPB	Caacupe B
R5CPC	Caacupe C
R6CGB	Caaguazu B
R6CGC	Caaguazu C
R7CZB	Caazapa B
R7CZC	Caazapa C
R8CTB	Caraguatay B
R8CTC	Caraguatay C
R9CRB	Carapegua B
R9CRC	Carapegua C

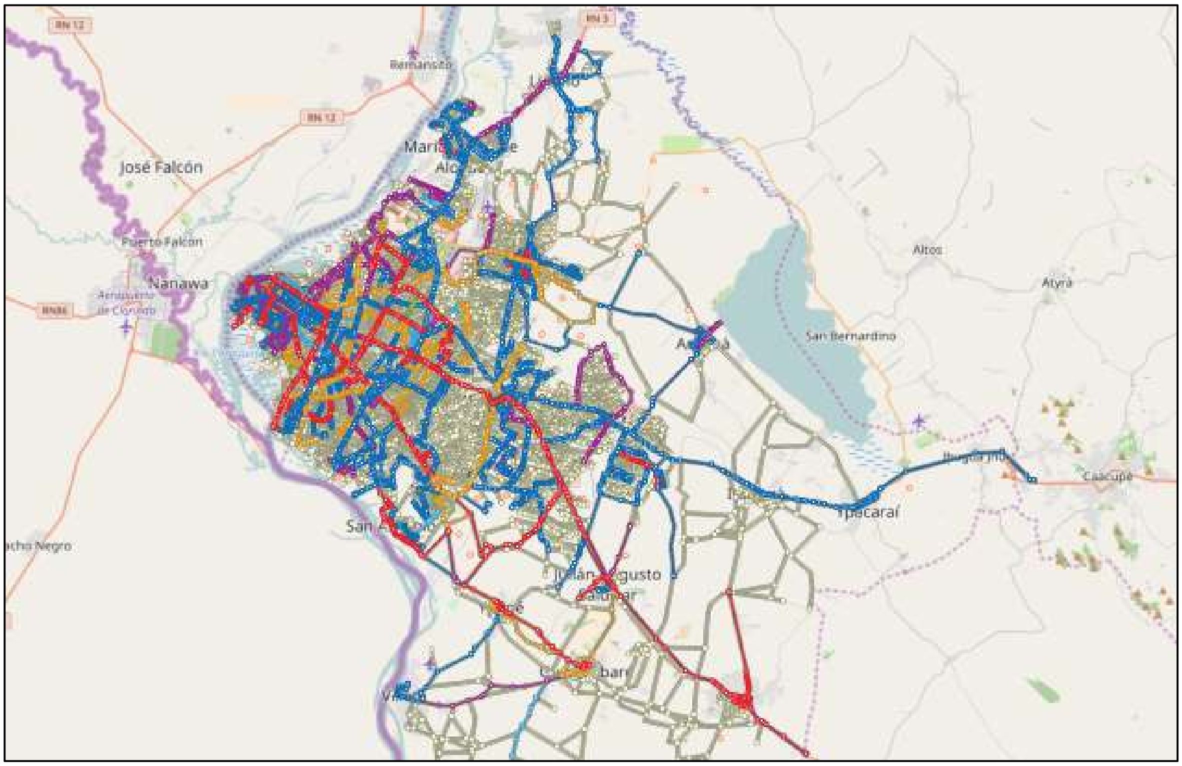

Figure C.1: Base Case Transit Lines

C.3 BRT SCENARIO (THE METROBUS PROJECT)

The implementation and operational design of the BRT system, as recommended by LOGIT proposed four lines with different operational regimes. Information about these lines was retrieved from the operational design section of the LOGIT study. Namely, number of lines, alignments, speeds, headways, and stops. In specific, the four proposed lines are:

- An all-stop line (T01), with terminals at the Asunción Historic Center and San Lorenzo. The line headway is 2.94 minutes, and its operating speed is 18 kph. The line stops are shown in Figure C.2.
- An express line (T11), with terminals at the Asunción Historic Center and Capiatá. The line headway is 1.92 minutes, and its operating speed is 20 kph. The stops are shown in Figure C.3.
- A semi-express line (T12), with terminals at Brasil Avenue (the fringe of the Asunción Historic Center) and San Lorenzo. The line has a headway of 2.44 minutes, and an operating speed of 20 kph. The stops of this line are shown in Figure C.4.
- A second semi-express line (T13), with terminals at Brasil Avenue and San Lorenzo. The line headway is 2.19 minutes, and its operating speed is 21 kph. The stops are shown in Figure C.5.

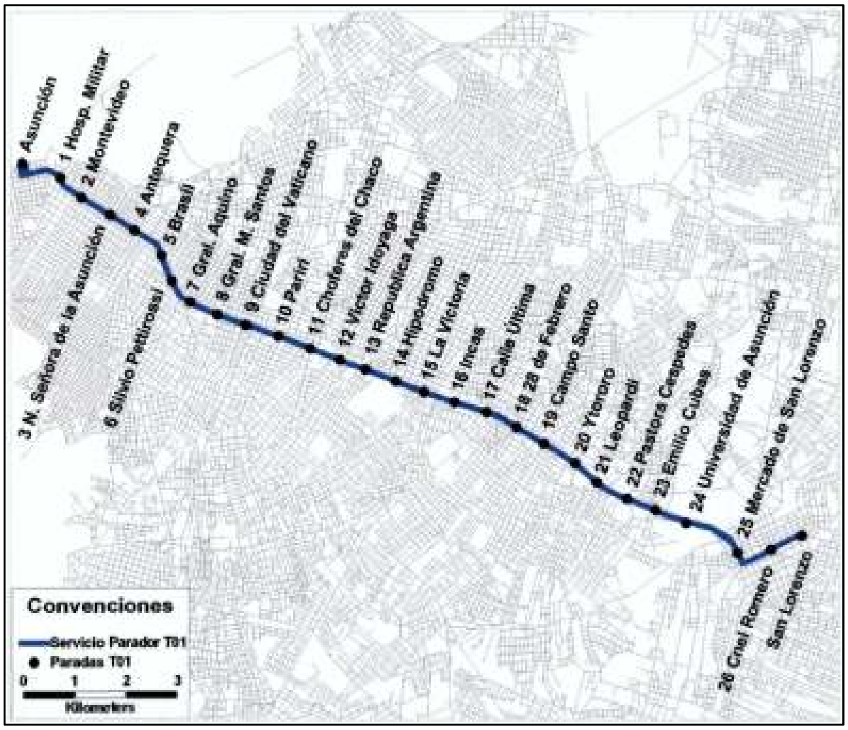

Figure C.2: BRT system: all-stop line T01. Source: BRT Corredor Eusebio Ayala - Mcal. Estigarribia (2011)

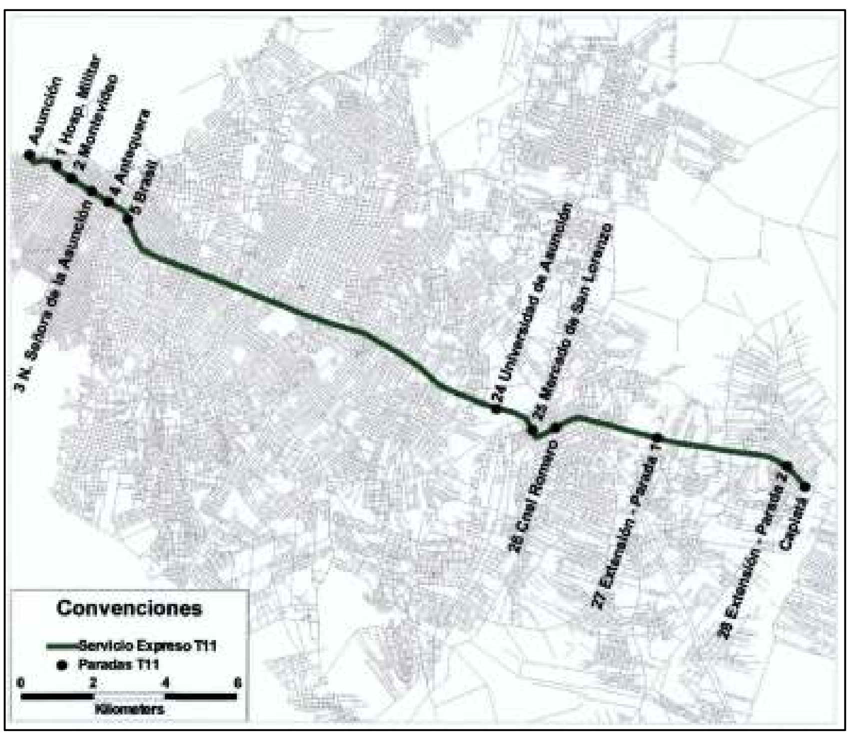

Figure C.3: BRT system: express line T11. Source: BRT Corredor Eusebio Ayala - Mcal. Estigarribia (2011)

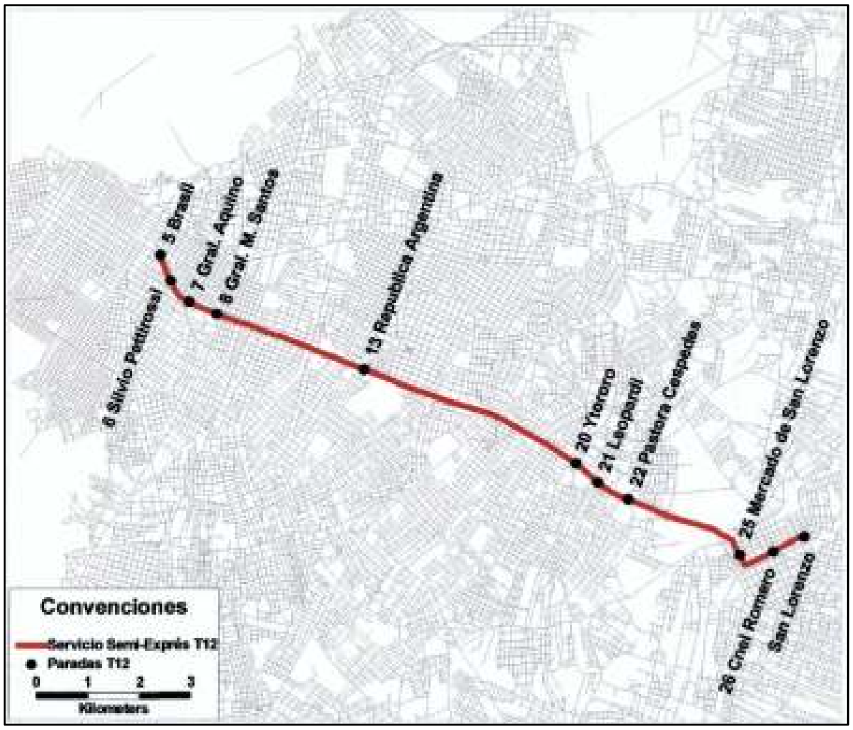

Figure C.4: BRT system: semi-express line T12. Source: BRT Corredor Eusebio Ayala - Mcal. Estigarribia (2011)

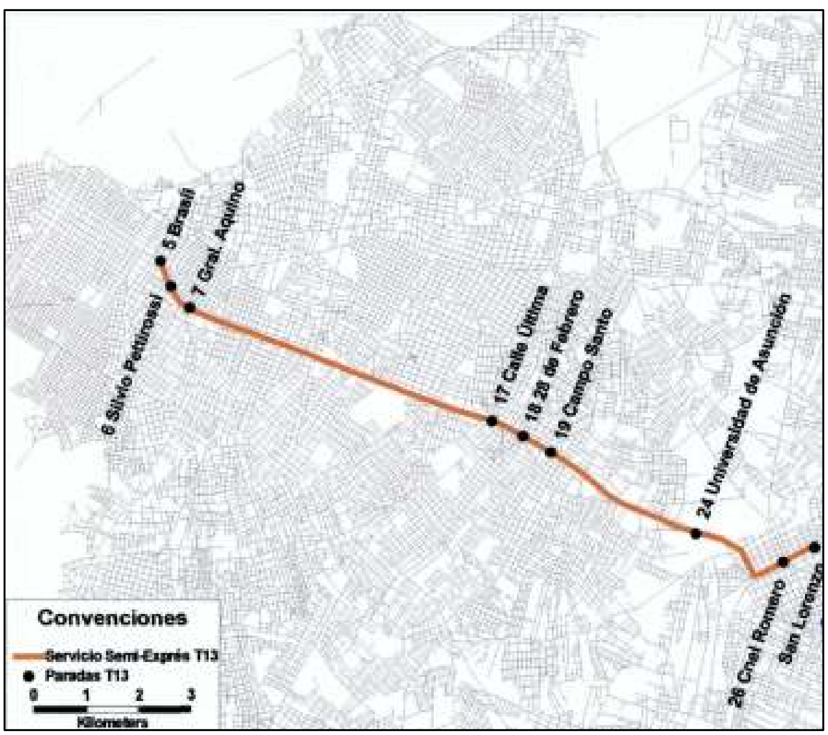

Figure C.5: BRT system: semi-express line T13. Source: BRT Corredor Eusebio Ayala - Mcal. Estigarribia (2011)

Furthermore, the operational design proposed by LOGIT implied several modifications of the existing public transit network, these changes are explained below:

- Eighteen regular lines (L) that were gathering passengers from the outskirts of the city and then transported them to the inner core area using the Eusebio Ayala corridor. These lines are shortened by removing the segments of the alignment that would overlap with the BRT. In this sense, these shortened lines become feeder lines (A) for the BRT. The replaced lines are listed in Table C.2. These changes apply for both directions of every line as well.
- Thirty-seven regular lines (L), from the base case which alignments overlapped with the BRT corridor along a given section. In this case the modified lines (M) are created by re-aligning the overlapping sections to a parallel street. Table C.3 lists the modified lines. These changes apply for both directions of every line as well. Note that Lines 203 and 41 are coded as a whole cycle (loop), in other words, their terminals are located in the same node.
- Sixteen regular lines (L) are added to the base case network, as shown in Table C.4.
- The alignments of the sixteen feeder lines (A) from the base case are kept intact. The only change is in the code name (AL). See Table C.5.
- Thirty-three regional lines (R), from the base case that operate along the proposed BRT corridor are replaced by their corresponding shortened version (S). In general, all these lines reached the inner core of the city, now they reach only to San Lorenzo where modal transfers can take place. The rationale for this replacement is to avoid competition between the BRT system and the current transit network, which is consistent with the main objective and benefit of the BRT system of addressing the current overcrowding of lines along the Eusebio Ayala corridor. The replaced lines are listed in Table C.6. Note that for every line mentioned, this applies in both directions. Also note that the only regional lines that were not shortened are lines 15 and 35.

Table C.2: Regular (L) Lines Shortened to Become Feeder (A) Lines

Initial56t code	DESCRIPTION	New code	Initial56t code	DESCRIPTION	New code
L128	Line 128	A128	L40	Line 40	A40
L15CA	Caaguazu	A15CA	L41.3	Line 41.3	A41.3
L15SL	Salinas	A15SL	L42	Line 42	A42
L20LU	Luque	A20LU	L44.2	Line 44.2	A44.2
L27	Line 27	A27	L454	Line 454	A454
L2SM	SMTC	A2SM	L48	Line 48	A48
L38	Line 38	A38	L53	Line 53	A53
L39.2	Line 39.2	A39.2	L58	Line 58	A58
L39	Line 39	A39	L7	Line 7	A7

Table C.3: Regular (L) Lines Overlapping with the BRT, Converted to Modified (M) Lines

Initial code	DESCRIPTION	New code	Initial code	DESCRIPTION	New code
L1.1	Line 1.1	M1.1	L13	Line 13	M13
L1.2	Line 1.2	M1.2	L13RO	Line 13-Red	M13RO
L13A	Line 13A	M13A	L14	Line 14	M14

Initial code	DESCRIPTION	New code
L14.2	Line 14.2	M14.2
L15PE	Petropar	M15PE
L15ST	San Antonio	M15ST
L16	Line 16	M16
L165	Line 165	M165
L203	Line 203	M203
L23	Line 23	M23
L232S	Line 232-Sur	M232S
L26ML	Mariscal Lopez	M26ML
L30AM	Line 30-Yellow	M30AM
L30AP	Line 30-Airport	M30AP
L30AZ	Line 30-Blue	M30AZ
L30RO	Line 30-Red	M30RO
L30VE	Line30-Green	M30VE
L35	Line 35	M35
L36	Line 36	M36

Initial code	DESCRIPTION	New code
L37AR	Artigas	M37AR
L37ES	España	M37ES
L37.1	Line 37.1	M37.1
L37.2	Line 37.2	M37.2
L37.3	Line 37.3	M37.3
L3I	Interno	M3I
L41	Line 41	M41
L41.2	Line 41.2	M41.2
L44	Line 44	M44
L47	Line 47	M47
L51	Line 51	M51
L54	Line 54	M54
L6SA	San Antonio	M6SA
L6I	Interno	M6I
L85	Line 85	M85

Table C.4: New Regular (L) Lines Added

Initial code	DESCRIPTION
L10I	Interno
L11I	Interno
L133	Line 133
L19	Line 19
L20RE	Reducto
L21CO	Corrales
L21IP	IPVU
L21ZN	ZNorte

Initial code	DESCRIPTION
L21ZS	ZSur
L26ZC	ZCue
L27	Line 27
L29DI	Directo
L29KO	Kokuere
L33	Line 33
L45	Line 45
L45SI	Sinalco

Table C.5: Feeder (A) Lines Relabelled

Initial code	DESCRIPTION	New code
A01	Feeder line 1	AL01
A02	Feeder line 2	AL02
A03	Feeder line 3	AL03
A04	Feeder line 4	AL04
A05	Feeder line 5	AL05
A06	Feeder line 6	AL06
A07	Feeder line 7	AL07
A08	Feeder line 8	AL08
A09	Feeder line 9	AL09
A10	Feeder line 10	AL10
A11	Feeder line 11	AL11

Initial code	DESCRIPTION	New code
A12	Feeder line 12	AL12
A13	Feeder line 13	AL13
A14	Feeder line 14	AL14
A15	Feeder line 15	AL15
A16	Feeder line 16	AL16

Table C.6: Regular (R) Lines Replaced by Shortened (S) Lines

Initial code	DESCRIPTION	New code
R1AC	Acahay	S1AC
R2AL	Altos	S2AL
R3AE	Arroyos Esteros	S3AE
R4AT	Atyra	S4AT
R5CP	Caacupe	S5CP
R6CG	Caaguazu	S6CG
R7CZ	Caazapa	S7CZ
R8CT	Caraguatay	S8CT
R9CR	Carapegua	S9CR
R10CE	Ciudad del Este	S10CE
R11EA	Eusebio Ayala	S11EA
R12VR	Villarica	S12VR
R13MB	Mbocayty	S13MB
R14MI	Misiones	S14MI
R16NS	Ñemby	S16NS
R17PA	Paraguarí	S17PA
R18PI	Pirayu	S18PI
R19PB	Piribebuy	S19PB
R20QU	Quiindy	R20QU
R21SB	San Bernardino	S21SB
R22SE	Santa Elena	S22SE
R23TO	Tobati	S23TO
R24VA	Valenzuela	S24VA
R25YA	Yaguaron	S25YA
R26YB	Ybicui	S26YB
R27YU	Yuti	S27YU
R28LO	Loma Grande	S28LO
R29CA	Cabañas	S29CA
R30GU	Guarambaré	S30GU
R31CU	Curuguaty	S31CU
R32OL	Oleary	S32OL
R331M	1ro de Marzo	S331M
R342J	20 de Julio	342J

C.4 LRT Scenario (Tren de Cercanías)

As it was mentioned in Section 5 of the first volume of this report, the proposed alternative acknowledges the limited space that the existing road infrastructure provides, and focuses on a rail alternative that does not impose additional demand on roads. Considering that there is an existing railroad infrastructure in the Greater Asunción Area, the proposed LRT corridor is along the same alignment of these railroads. However, most of the railroads will have to be rebuilt given its current non-operational state.

The potential demand profile was estimated in the study by a 4-step model which is fed by a traffic counting survey, an in-vehicle passenger counting survey, and a Stated Preference (SP) survey; the latter allows to adjust the modal shares considering the modal shifts to the LRT mode that are observed in the survey. The 2020 demand forecast provided in the study is shown in Figure C.6.

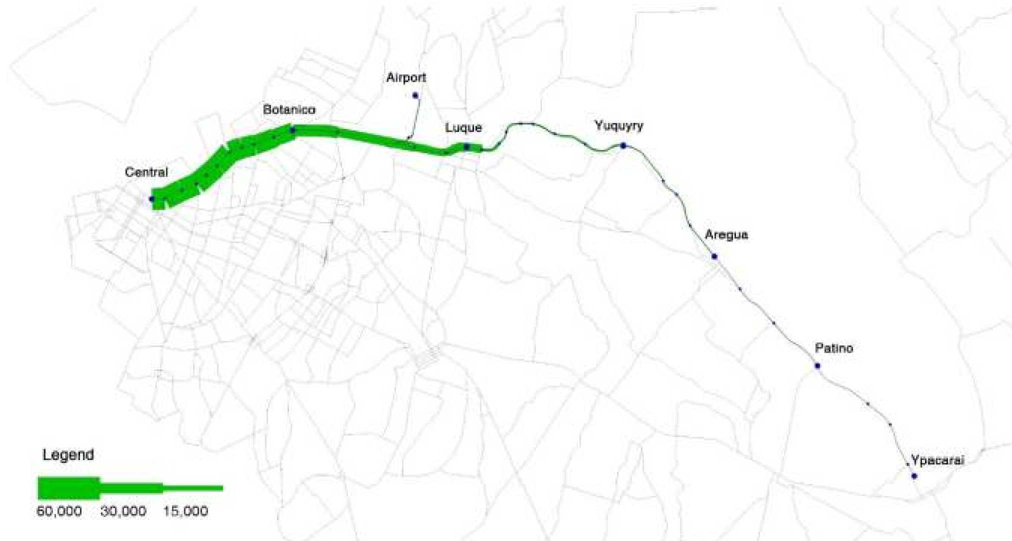

Figure C.6: LRT Demand for 2020. Source: Short Distance Passenger Train between Asunción and Ypacaraí Pre-Feasibility Study. (2014)

The alignment is split into four sections, as shown in Table C.7.

Table C.7: LRT Sections

Section	Description	Design Speed (m/s)	Maximum Operational Speed (m/s)
1	Central to Botánico	50	45
2	Botánico to the end of Ñu Guasú highway	80	70
3	End of Ñu Guasú highway to Yuquyry	50	45
4	Yuquyry to Ypacaraí	80	70

From the 2020 demand estimations, the study proposed two lines that would provide service from Asunción to Ypacaraí. The four major stations are depicted in Figure C.6 (each line's directions are shown separately).

Figure C.7: Lines Coded in EMME with Major LRT Stations

Furthermore, a Train Performance Simulation (TPS) was conducted to determine realistic values for operating speeds and operating times. The values determined by this simulation consider running time (thus acceleration and deceleration of the trains) and dwell time at the stops/stations. The TPS results are presented in Table C.8.

Table C.8: Train Performance Simulation Results

Section	Operation Distance (Km)	Speed (m/s)	Operating Time (min)
Central-Luque	15.11	29.6	30.7
Central-Areguá	29.54	35.0	50.7
Central-Ypacaraí	44.15	33.8	78.3

Note that the simulated speeds are all calculated from Central to each destination, thus the sections are not mutually exclusive. For modelling purposes, the speeds for each section need to be defined; i.e. from Luque to Areguá, and from Areguá to Ypacaraí. These data can be calculated simply by using the existing operating time and distance data, as follows:

Speed from Luque to Areguá: $\frac{distance\ from\ Luque\ to\ Aregua}{operating\ time\ from\ Luque\ to\ Aregua} = \frac{(29.54-15.11)}{(50.7-30.7)} = 43.29\ {}^{Km}/_{h}$

Speed from Areguá to Ypacaraí:

$$\frac{distance\ from\ Aregua\ to\ Ypacaraí}{operating\ time\ from\ Aregua\ to\ Ypacaraí} = \frac{(44.15-29.54)}{(78.3-50.7)} = 31.76\ {}^{Km}/_{h}$$

Note that these speeds are assigned in EMME for each segment of each line, according to the section that they belong to. Finally the main attributes for the morning peak hour of the two proposed lines are shown in Table C.9.

Table C.9: LRT Morning Peak Hour Attributes

Line	Section	EMME code inbound	EMME code outbound	Headway (min)	Design Speed (m/s)
Central-Luque	N/A	CL1	LC1	5	29.6
Central-Ypacaraí	Central-Luque	CY1	YC1	30	29.6
	Luque-Areguá	CY1	YC1	30	43.29
	Areguá-Ypacaraí	CY1	YC1	30	31.76

It is noteworthy that the inbound and outbound directions have the same attributes. Also, the section from Central to Luque is designed as double-track and the section from Luque to Ypacaraí is single-track. Finally, the list of stations and their spacing is presented in Table C.10.

Table C.10: LRT Stations & Spacing

Section	#	STA.	Type	Name	Distance between Stations/ Stops (m)
1	1	0km000	Station	Central	-
	2	0km570	Stop	No.01	570
	3	1km460	Stop	No.02	890
	4	2km170	Stop	No.03	710
	5	2km740	Stop	No.04	570
	6	3km390	Stop	No.05	650
	7	4km220	Stop	No.06	830
	8	4km810	Stop	No.07	590
	9	5km360	Stop	No.08	860
	10	6km300	Stop	No.09	510
	11	7km235	Station	Botánico	475
2	12	9km200	Stop	No.10	1,965
	13	12km700	Stop	No.11	3,500
3	14	14km140	Stop	No.12	1,440
	15	15km110	Station	Luque	970
	16	15km780	Stop	No.13	670
	17	16km647	Stop	No.14	867
	18	17km260	Stop	No.15	613
	19	18km070	Stop	No.16	810
	20	18km580	Stop	No.17	510
	21	19km630	Stop	No.18	1,050
	22	21km100	Stop	No.19	1,470
	23	22km940	Station	Yuquyry	1,840
4	24	25km390	Stop	No.20	2,450
	25	26km250	Stop	No.21	860
	26	27km770	Stop	No.22	1,520
	27	29km540	Station	Aregua	1,770
	28	31km310	Stop	No.23	1,770
	29	33km470	Stop	No.24	2,160
	30	36km210	Station	Patińo	2,740
	31	39km080	Stop	No.25	2,870
	32	40km415	Stop	No.26	1,335
	33	42km330	Stop	No.27	1,915
	34	43km310	Stop	No.28	980
	35	44km150	Station	Ypacaraí	840

References

FEPASA (2014). Short Distance Passenger Train between Asunción and Ypacaraí Pre-Feasibility Study.

LOGIT. (2011) BRT Corridor Eusebio Ayala - Mariscal Estigarribia

LOGIT. (2015) Estudios Complementarios de Demanda y de Alternativas de Trazado para el BRT Asunción-San Lorenzo

APPENDIX D
EXAMPLE CASE STUDY MODELLING RESULTS

APPENDIX TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

D.1 INTRODUCTION

This appendix presents detailed results from the three network scenarios tested in this study, compared against each other. In all cases, base year (2012) population and employment levels are assumed. The three scenarios are:

- The base case.
- Implementation of the proposed BRT.
- Implementation of the proposed LRT.

Model results presented include:

- Transit ridership.
- Auto trips.
- Transit travel time distributions.
- Auto travel time distributions.
- BRT and LRT catchment areas.
- Place of residence distributions of Historic Centre workers.

In all cases, the data presented are meant to illustrate some of the outputs that can be generated by SATA. They should not be interpreted as definitive forecasts for BRT or LRT ridership or other impacts. As discussed in detail in Volume I, the SATA model system is currently very much a first prototype, developed as a proof of concept, rather than a fully calibrated operational forecasting tool. Improved data and additional time spent on model calibration and testing (both of which were not available within the limited time and budget of the current study) will be required before SATA outputs can be used for operational policy analysis.

D.2 TRANSIT RIDERSHIP

The impacts of implementing major infrastructure projects can be assessed in a myriad ways, one of them being comparing transit ridership among different scenarios. Table D.1 shows the changes in ridership product of implementing the BRT and LRT alternatives, both in the AM peak period and throughout the 24 hours of a day.

Scenario	AM Ridership	24-H Ridership
Base Case	294474	1320924
BRT	295251	1322466
LRT	296996	1328348

Table D.1: Transit Ridership AM and 24-Hhour

While the actual numbers shown in Table D.1 are outputs form a prototype model ant thus not reliable forecasts, positive impacts of implementing the BRT and LRT alternatives can be confirmed by the observed increases in ridership.

D.3 Auto Trips

Similar to Section D.2, the impacts of implementing the BRT and LRT projects can also be analyzed in terms of changes in the number of auto trips made at different time periods. These changes are shown on Table D.2.

Scenario	AM Trips	24-H Trips
Base Case	294653	1036160
BRT	294675	1036691
LRT	294166	1034262

Table D.2: Auto Trips AM and 24-Hour

Note that even though there is a small increase of auto trips for the BRT scenario, the increase in transit ridership is much higher. In the case of the LRT there is a strong reduction of auto trips, which is normally attributed to a shift in users' mode choice due to the implementation of an attractive transit mode such as the LRT. Furthermore, the proposed BRT corridor was already served by several bus lines in the base case, unlike the case of the LRT catchment area; this can explain the higher impacts of the LRT project on both auto trips and transit ridership.

D.4 Transit Travel Time Distributions

In addition to providing a classification of trips according to their travel times, travel time distributions also provide useful information about travel patterns. For instance, trip distances are implicit in trip travel times, varying from one mode to another according to their different speed. In other words, travel time distributions implicitly show the length of trips made within the study area. Figure D.1 shows the distributions of travel times for the transit mode in the AM peak period, for the three different scenarios that were analyzed (Base, BRT, and LRT), and Table D.3 has a detailed numerical description of the distributions shown in Figure D.1.

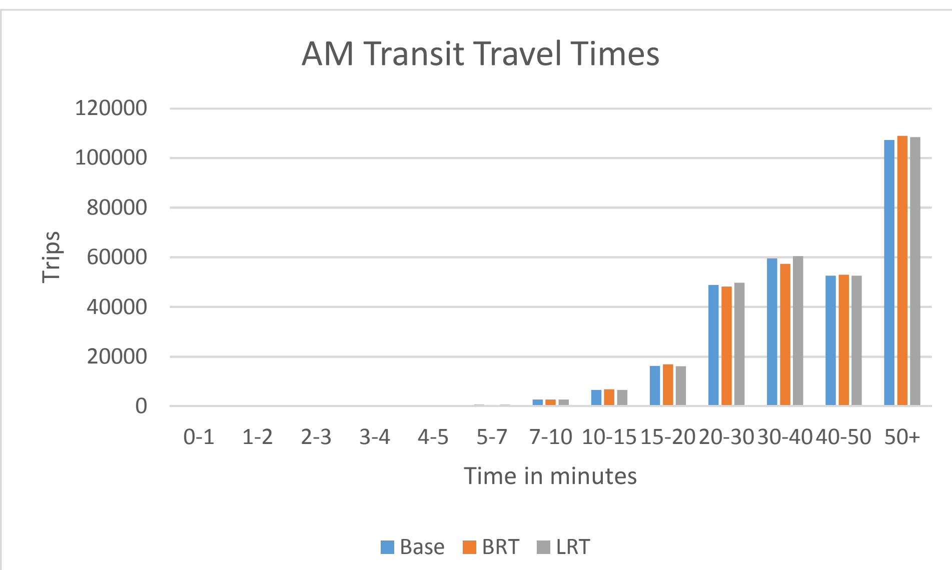

Figure D.1: AM Transit Travel Time Distribution

Category	Base	BRT	LRT
0-1	0	0	0
1-2	0	0	0
2-3	0	0	0
3-4	0	0	0
4-5	204.825	203.4	183.225
5-7	562.5875	513.4875	549.0375
7-10	2649.237	2600.45	2624.037
10-15	6583.528	6798.698	6536.589
15-20	16224.61	16783.82	16036.25
20-30	48845.77	48184.64	49686.55
30-40	59527.71	57396.89	60475.29
40-50	52543.61	52907.63	52513.49
50+	107332	108984.9	108392.2

Table D.3: AM Transit Travel Time Distribution

The absence of short trips taken by public transit is a general, very common trend in any urban area. Users normally prefer to take auto or even walk for short distances (the auto travel time distributions are shown in Section D.5 below). It can be clearly seen that as travel time increases (and thus distance) the number of trips taken increases as well, especially for trips with a travel time greater than 20 minutes.

The travel time distributions for midday are shown in Figure D.2 and Table D.4; where an increase in the share of 20 to 40-minute trips, coupled with a decrease in the share of 40 to 50-minute trips can be evidenced. This shows a different pattern in the length of trips that are made in the midday compared to the AM period.

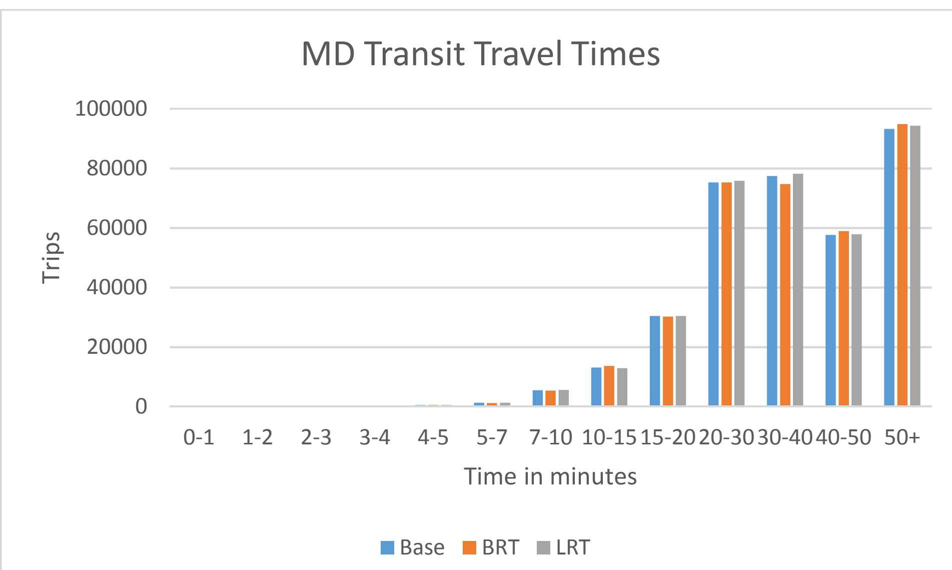

Figure D.2: Midday Transit Travel Times

Category	Base	BRT	LRT
0-1	0	0	0
1-2	0	0	0
2-3	0	0	0
3-4	0	0	0
4-5	553.3876	535.925	556.5125
5-7	1273.6	1148.737	1293.838
7-10	5465.675	5361.575	5516.15
10-15	13105.95	13603.08	12828.28
15-20	30379.83	30189.68	30433.8
20-30	75237.98	75259.61	75771.11
30-40	77318.91	74635.52	78170.17
40-50	57635.4	58923.25	57780.7
50+	93136.08	94818.02	94297.75

Table D.4: Midday Transit Travel Time Distribution

The PM peak transit travel time distribution is similar to the AM peak, and it is shown of Figure D.3 and Table D.5. Finally, Figure D.4 and Table D.6 portray the evening time period patterns which are similar as the PM peak period, however the total number of trips is considerably lower.

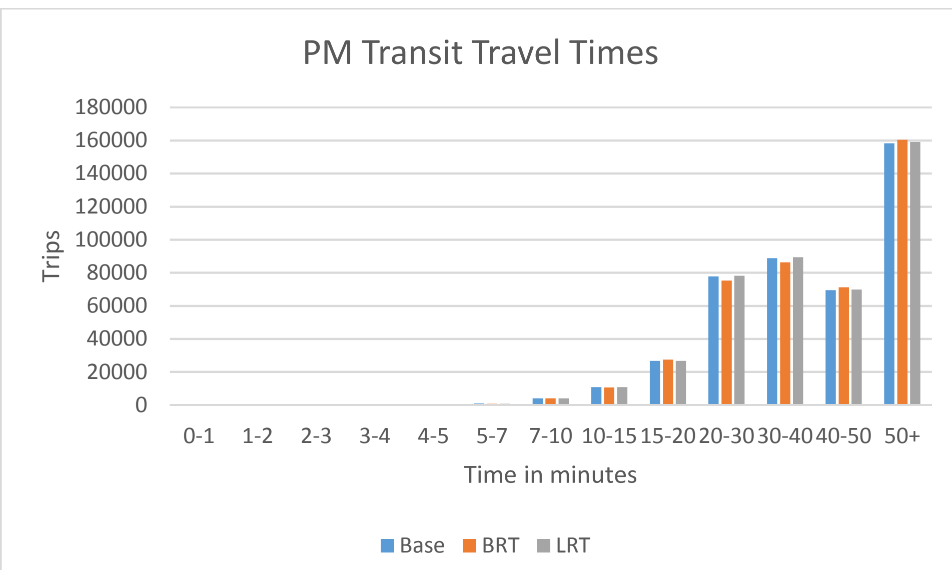

Figure D.3: PM Transit Travel Times

Category	Base	BRT	LRT
0-1	0	0	0
1-2	0	0	0
2-3	0	0	0
3-4	0	0	0
4-5	336.5375	332.8375	337.0625
5-7	827.9751	685.8251	823.9876
7-10	4111.825	4084.125	4081.438
10-15	10799.42	10656.86	10831.11
15-20	26655.34	27510.64	26709.91
20-30	77653.22	75318.27	78073.91
30-40	88855.77	86247.93	89357.33
40-50	69472.05	71197.19	69836.97
50+	158163.3	160372.7	158984

Table D.5: PM Transit Travel Time Distribution

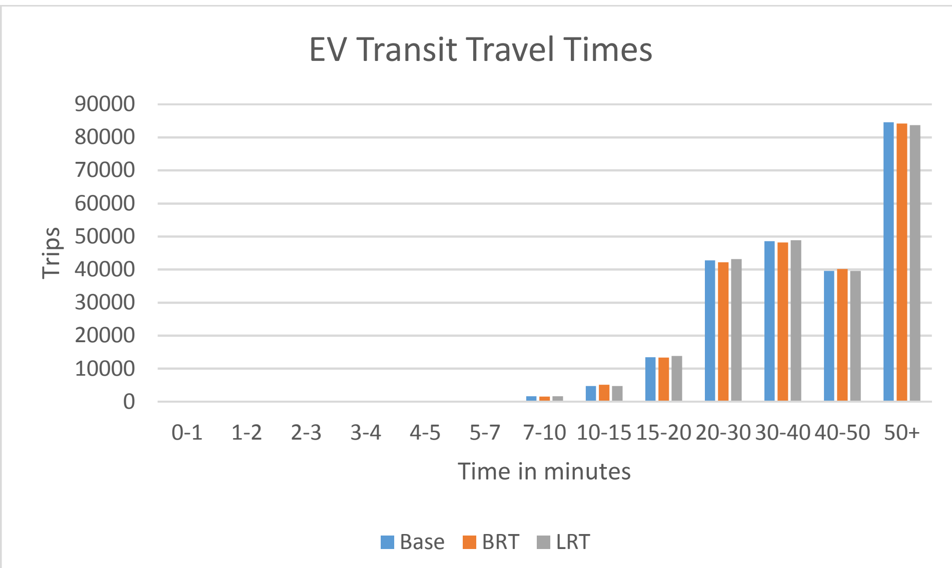

Figure D.4: Evening Transit Travel Times

Category	Base	BRT	LRT
0-1	0	0	0
1-2	0	0	0
2-3	0	0	0
3-4	0	0	0
4-5	99.15	86.2375	93.9
5-7	312.6625	285.575	311.5375
7-10	1598.087	1502.487	1607.162
10-15	4753.238	5145.613	4739.176

15-20	13399.9	13357.56	13783.06
20-30	42728.07	42161.11	43093.04
30-40	48515.04	48116.82	48847.74
40-50	39517.79	40178.61	39520.69
50+	84543.38	84114.27	83671.11

Table D.6: Evening Transit Travel Time Distribution

D.5 Auto Travel Time Distributions

When it comes to the auto mode, travel time distributions naturally have a very different pattern compared to public transit. As mentioned before, short trips are captured by this mode, which can be observed in Figure D.5 and Table D.7 for the AM peak period. Furthermore, it is also interesting to note that unlike other urban regions, longer trips are not captured by the auto mode but rather by the transit mode, as can be seen in Figure D.1. Having less dependency on the auto mode for longer trips is certainly a desirable feature, especially when dealing with negative transportation externalities such as congestion and pollution. As such, attractive and efficient public transit modes are key to maintain these patterns.

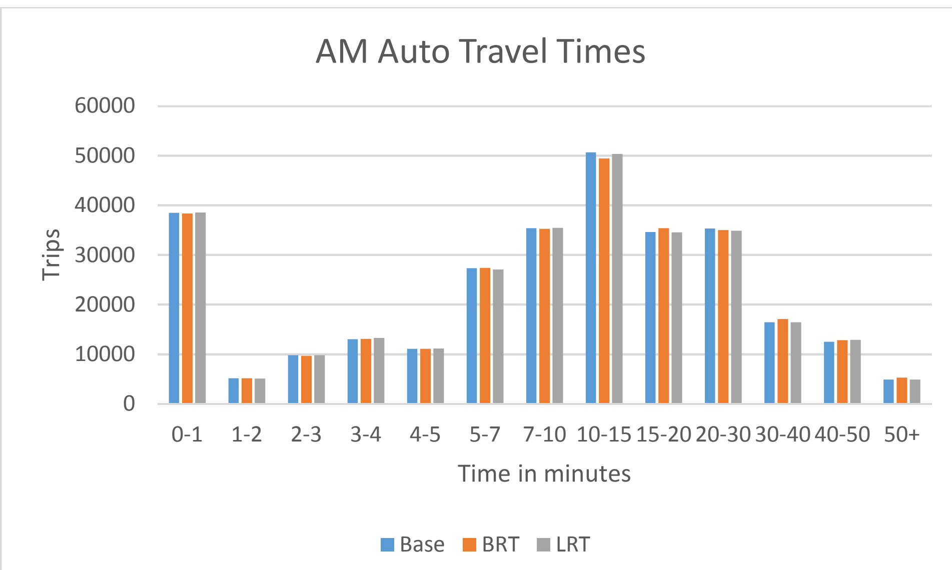

Figure D.5: AM Auto Travel Time Distribution

Category	Base	BRT	LRT
0-1	38458.88	38364.82	38550.2
1-2	5155.062	5111.837	5083.814
2-3	9788.888	9649.145	9760.226
3-4	13028.26	13048.25	13270.37
4-5	11088.86	11087.38	11115.1
5-7	27309.83	27360.32	27085.85
7-10	35402.84	35251.07	35430.04
10-15	50668.31	49442.26	50367.77

15-20	34634.18	35402.58	34544.23
20-30	35332.77	34990.44	34852.45
30-40	16426.06	17060.87	16418.48
40-50	12493.36	12787.63	12841.76
50+	4866.039	5236.526	4846.751

Table D.7: AM Auto Travel Time Distribution

In the case of midday auto travel times, Figure D.6 and Table D.8 show a clear shift towards shorter trips. Even though this shift in travel time distributions from the AM peak period to midday was also observed in the transit modes, it is much more marked in the auto mode. This pattern can be explained by the nature of midday activities, which imply shorter trips, thus using the automobile becomes an attractive choice for users given that it becomes convenient and easy.

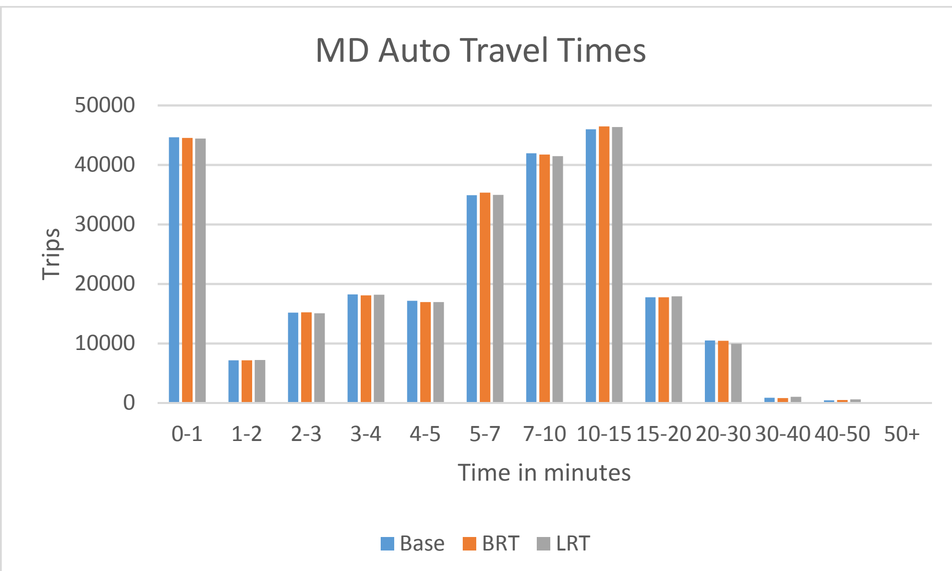

Figure D.6: Midday Auto Travel Times

Category	Base	BRT	LRT
0-1	44605.16	44513.27	44433.06
1-2	7147.96	7149.865	7206.461
2-3	15147.29	15235.29	15089.89
3-4	18230.46	18073.76	18164.08
4-5	17141.47	16956.47	16957.52
5-7	34881.81	35302.98	34941.16
7-10	41938.44	41714.13	41461.26
10-15	45961.35	46447.66	46367.34
15-20	17753.74	17749.07	17915.89
20-30	10490.78	10465.52	9954.612
30-40	865.6249	838.575	1039.15
40-50	432.5375	471.825	604.0125

50+	117.0375	115.6375	117.025

Table D.8: Midday Auto Travel Time Distribution

Similar to what was discussed in Section D.4 for transit, travel time distributions for the PM peak periods and evening periods show the same patterns as the AM period, with the exception of the total number of trips for the evening period which again is considerably lower. These patterns and volumes are presented below in Figures D.7 and D.8, and in Tables D.9 and D.10.

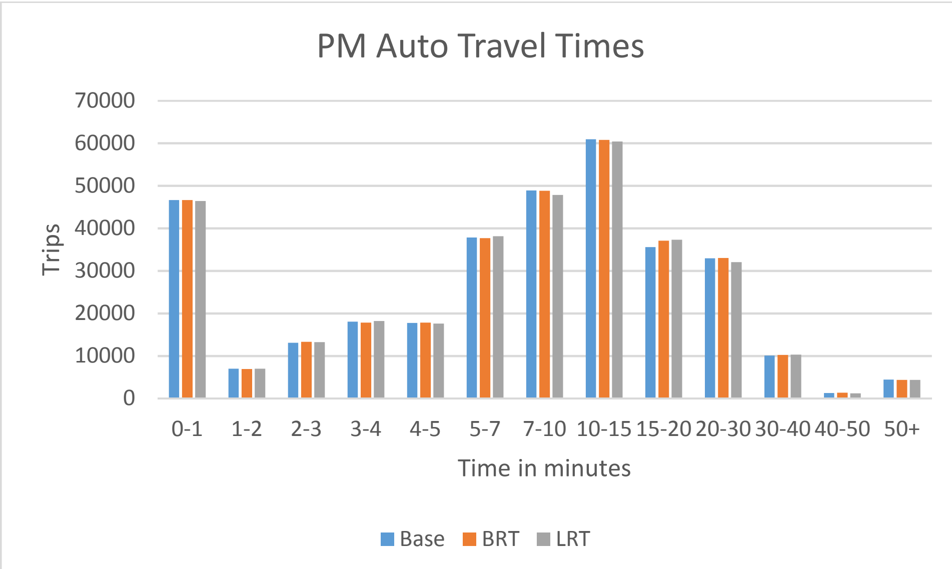

Figure D.7: PM Auto Travel Times

Category	Base	BRT	LRT
0-1	46645.04	46609.81	46405.53
1-2	6960.639	6906.274	6943.235
2-3	13093.45	13300.88	13210.39
3-4	18029.83	17775.17	18190.17
4-5	17712.64	17787.81	17566.08
5-7	37852.14	37684.47	38096.69
7-10	48876.01	48779.13	47809.98
10-15	60926.99	60766.03	60368.25
15-20	35552.21	37047.19	37327.34
20-30	32928.84	33031.78	31992.84
30-40	10059.79	10240.49	10308.84
40-50	1271.162	1356.362	1206.288
50+	4430.988	4344.076	4357.2

Table D.9: PM Auto Travel Time Distribution

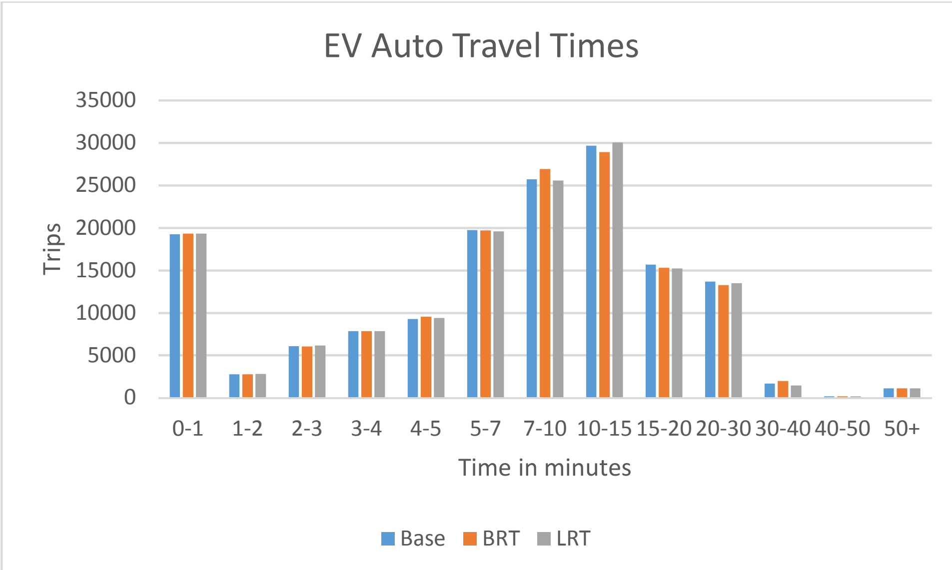

Figure D.8: Evening Auto Travel Times

Category	Base	BRT	LRT
0-1	19251.31	19328.37	19302.22
1-2	2761.912	2774.35	2789.087
2-3	6052.514	6049.135	6142.512
3-4	7827.723	7824.395	7855.661
4-5	9249.988	9544.686	9382.854
5-7	19717.38	19676.25	19584.19
7-10	25694.31	26908.24	25547.24
10-15	29665.52	28913.56	30054.63
15-20	15654.76	15282.33	15229.65
20-30	13658.58	13269.8	13476.25
30-40	1675.613	1981.712	1436.488
40-50	148.9125	144.8	146.0125
50+	1095.138	1109.413	1114.3

Table D.10: Evening Auto Travel Time Distribution

D.6 Catchment Areas

This section presents several maps generated in ArcGIS, constructed with output data from the SATA model. Namely, spatial data regarding origins and destinations of trips for the AM peak period, for BRT and LRT scenarios. As its name suggests, the term catchment areas specifically refers to the zones where trips using the new transit systems originate or are destined for.

Figure D9 shows the total number of trip origins per zone that would choose the BRT as their mode of transportation, should the BRT be implemented; while Figure D.10 shows the total number of destinations per zone that result from trips made in the BRT mode.

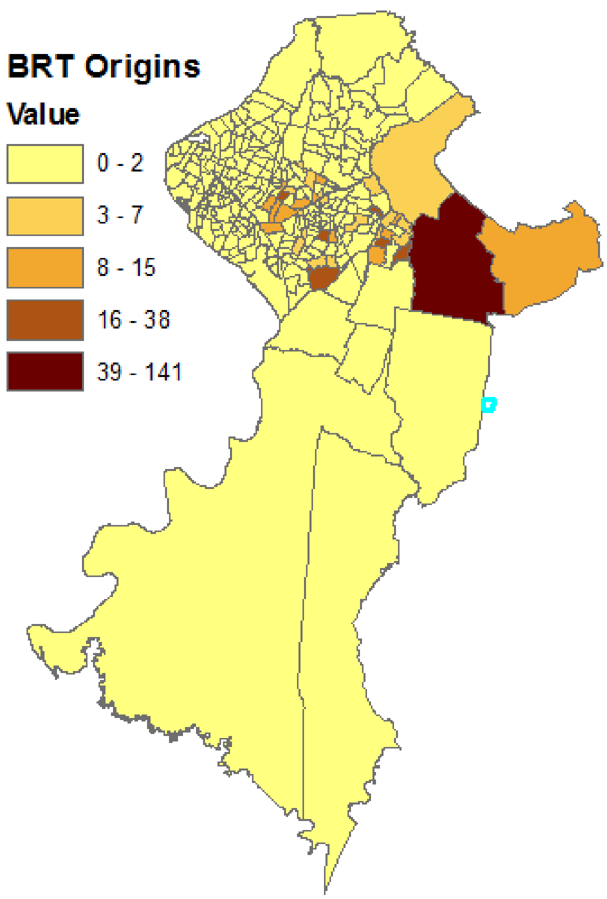

Figure D.9: AM BRT Origin Catchment Area

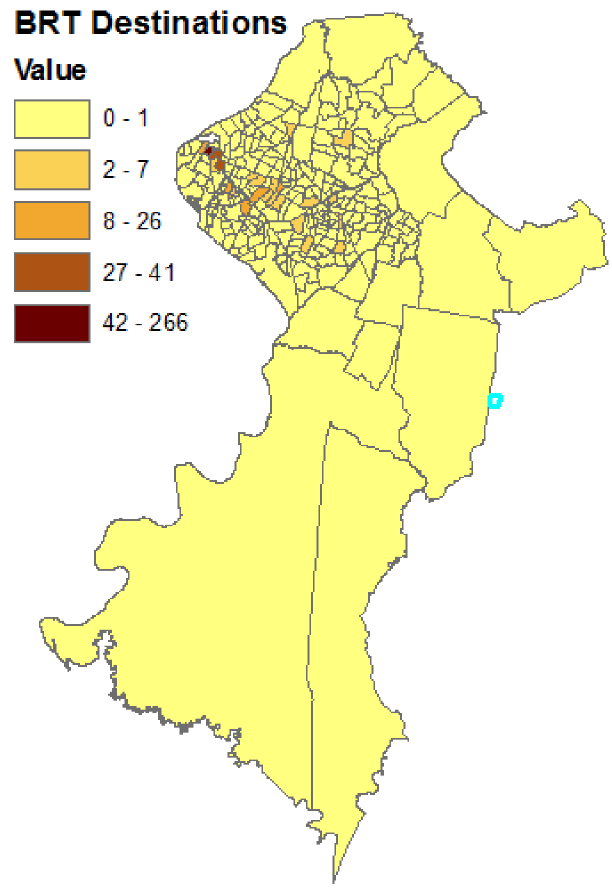

Figure D.10: AM BRT Destination Catchment Area

The spatial travel patterns observed in the BRT scenario show that trip origins are somewhat dispersed in the outskirts of the metropolitan area, mainly generated from the San Lorenzo-Capiatá area; while destinations are practically condensed at the Asunción Historic Center.

The spatial patterns for the LRT scenario are fairly different from the BRT scenario, mainly because the LRT alignment covers a currently poorly served area in the outskirts of the city, gathering demand from Mariano Roque Alonso, Luque, Areguá and other northeastern towns.

Figure D.11 shows the total number of origins per zone that would choose the LRT as their mode of transportation, should the LRT be implemented; likewise Figure D.12 shows the total number of destinations per zone that result from trips made on the LRT.

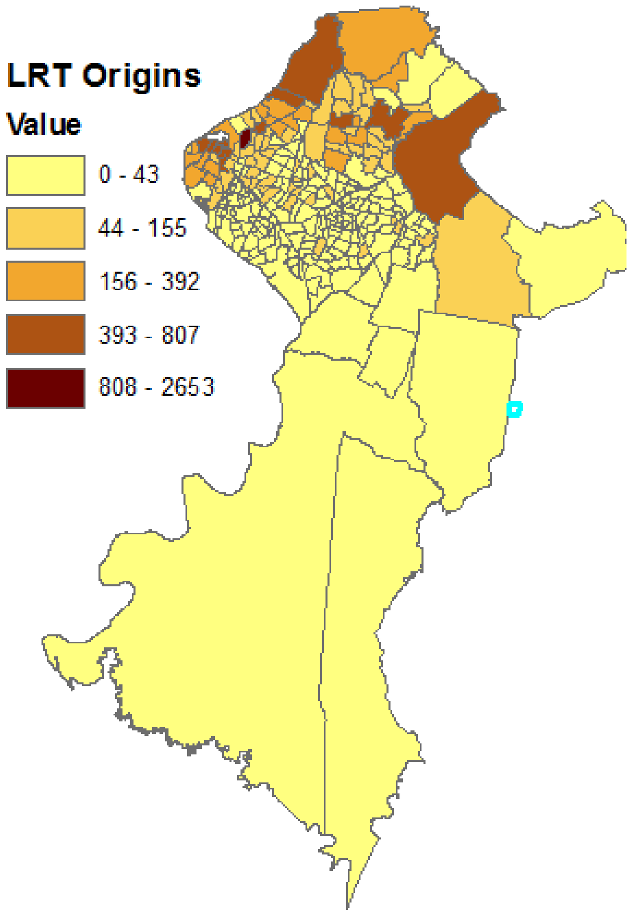

Figure 11: AM LRT Origin Catchment Area

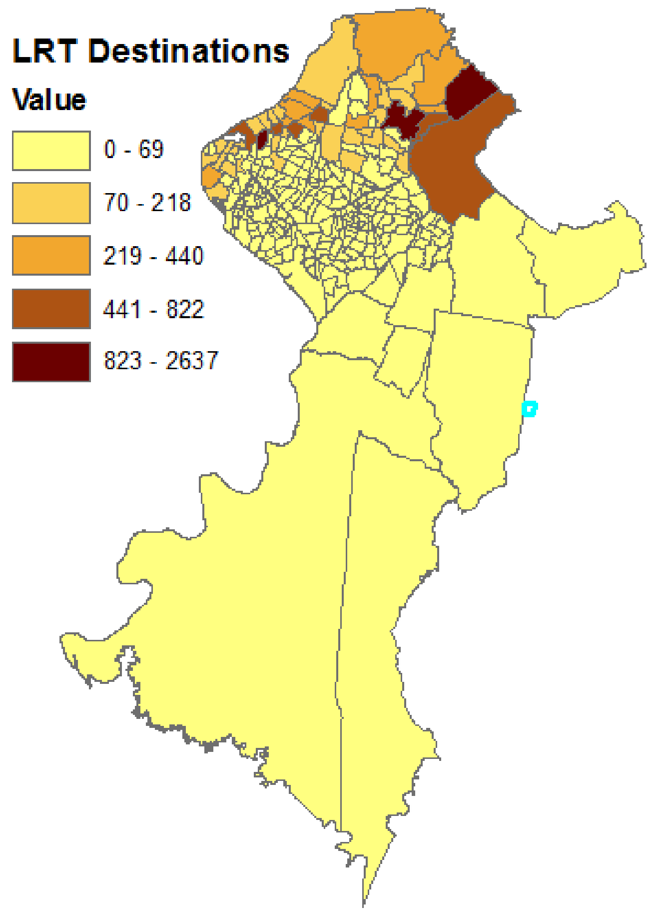

Figure 12: AM LRT Destination Catchment Area

Note that both the origins and destinations catchment areas are practically defined by the LRT alignment, however, it can be noted that some trip origins are actually generated in southern zones with respect to the LRT routes, showing the attractiveness of this mode. Additionally, the fact that the highest concentration of origins and destinations is outside of the Historic Center is because the terminal station of the LRT only reaches Brasil Avenue.

D.7 Place of Residence For Hisorical Centre Workers

The following figures show the results of the Place of Residence – Place of Work (PoRPoW) component of SATA which predicts work places for workers, given their place of residence. The graphical representation is in the form of maps at the traffic-zone level. Namely, Figures D.13 to D.15 show the distribution of different places of residence, for each employment type, for people that work in the Historic Centre, in the base case; likewise, Figures D.16 to D.18 show the same outputs for the BRT scenario; and Figures D.19 to D.21 for the LRT scenario.

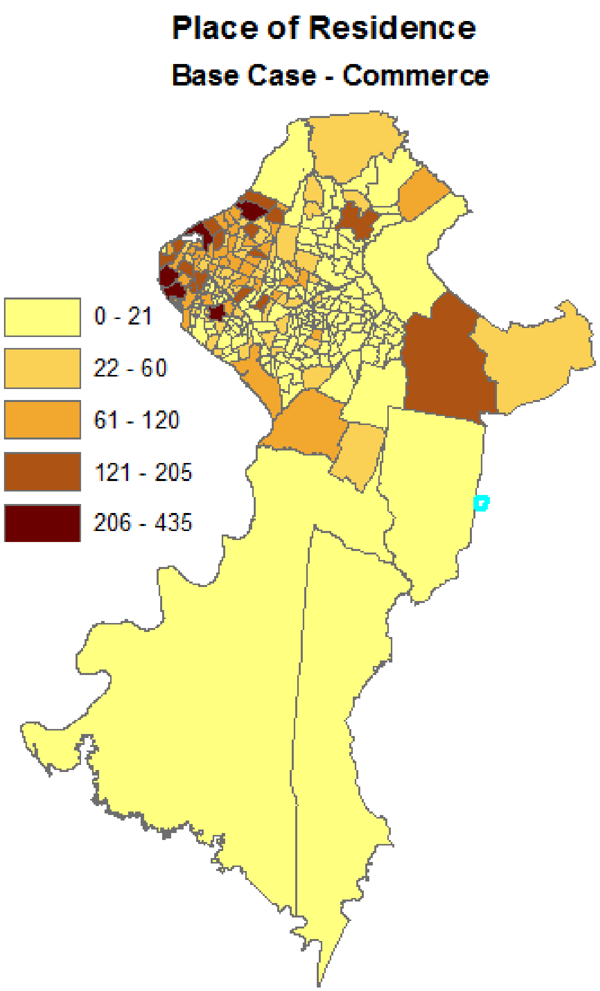

Figure D.13: Base Case - Place of Residence for Historic Centre Commerce Workers

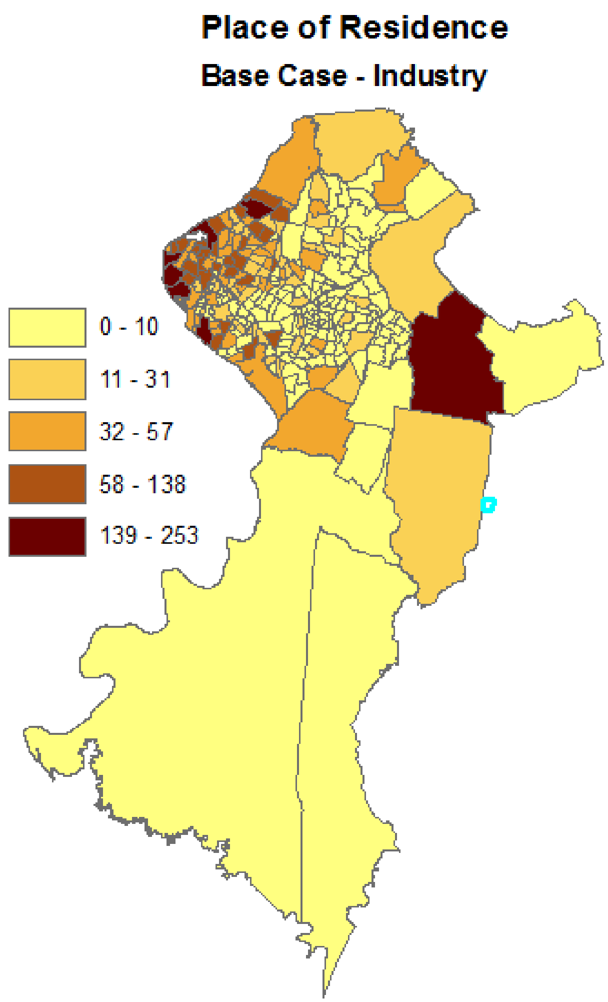

Figure D.14: Base Case - Place of Residence for Historic Centre Industry Workers

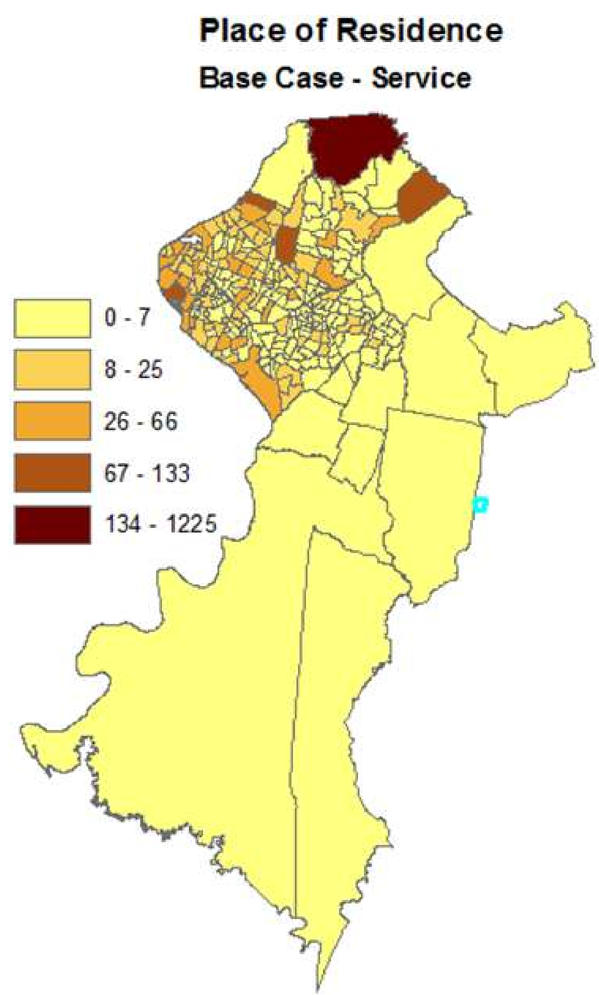

Figure D.15: Base Case - Place of Residence for Historic Centre Service Workers

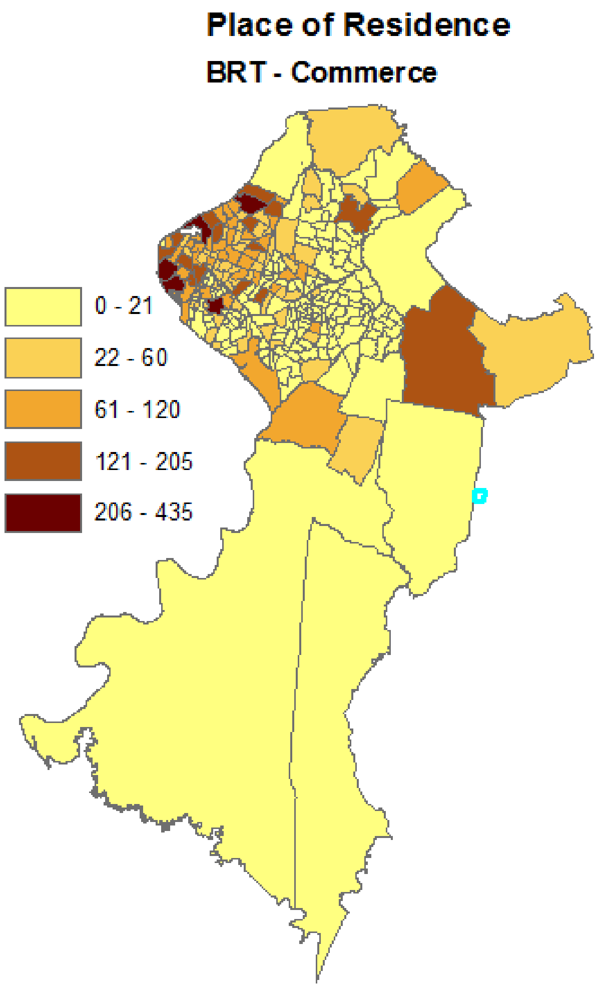

Figure D.16: BRT - Place of Residence for Historic Centre Commerce Workers

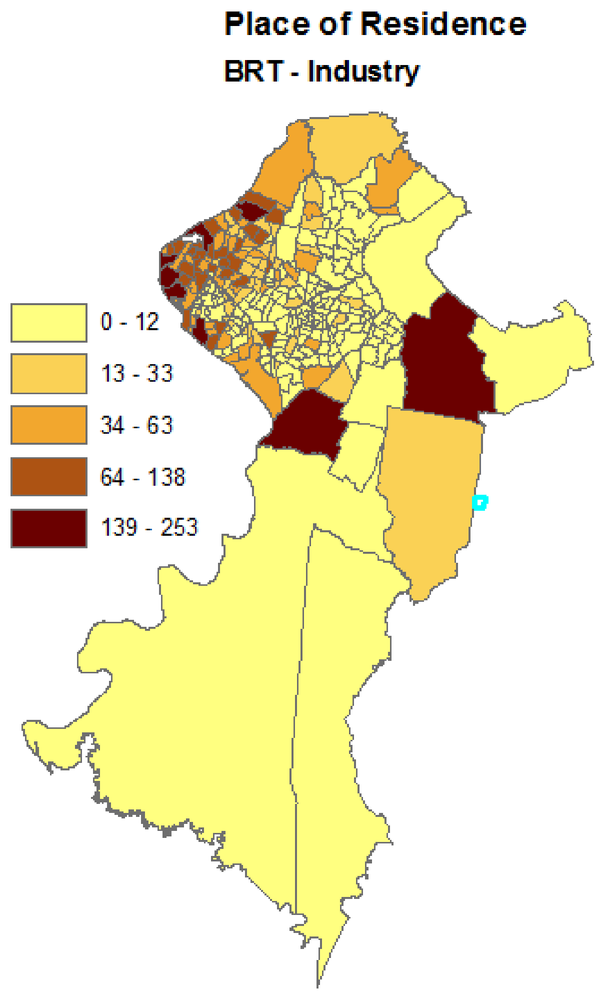

Figure D.17: BRT - Place of Residence for Historic Centre Industry Workers

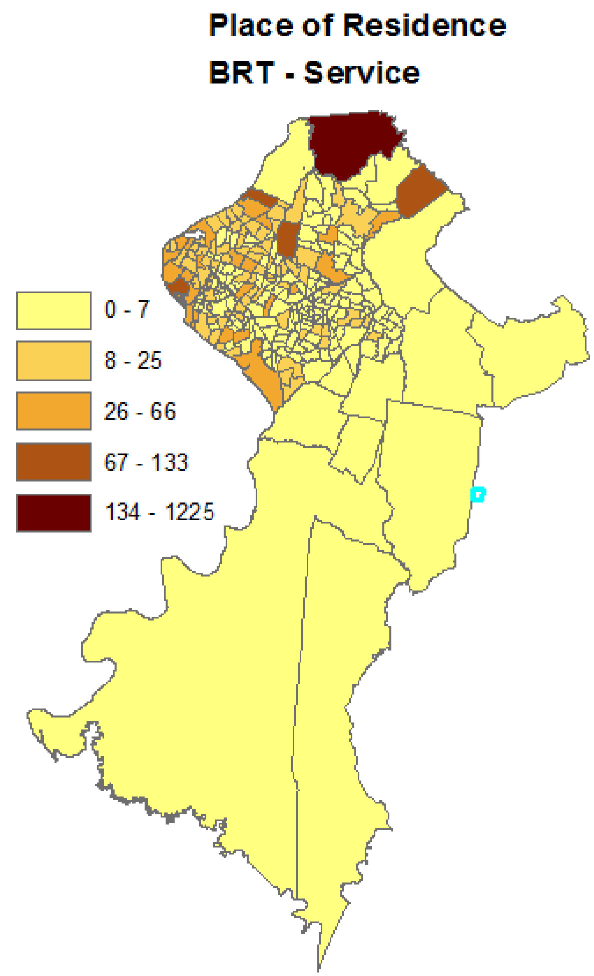

Figure D,18: BRT - Place of Residence for Historic Centre Service Workers

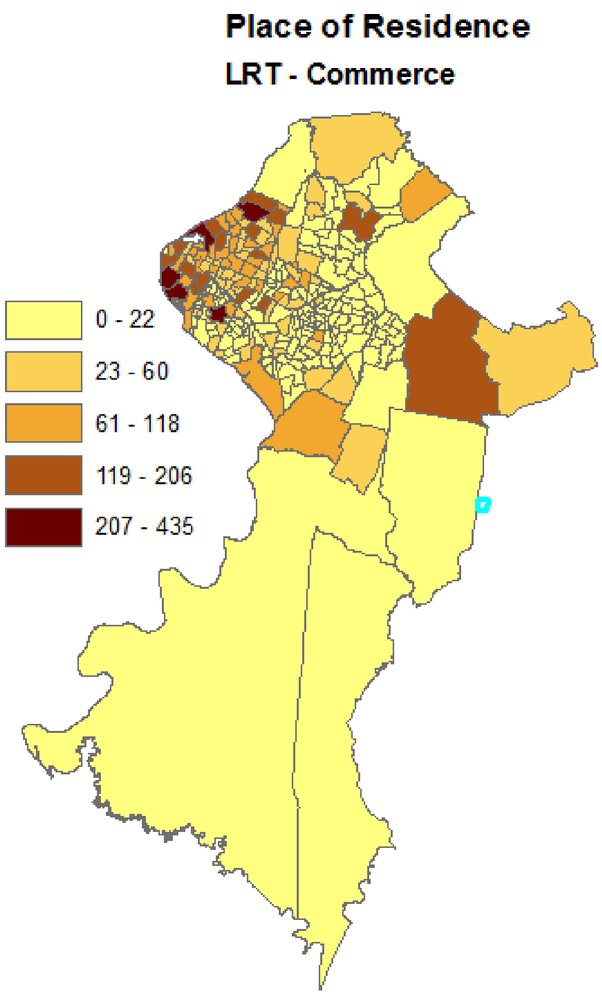

Figure D.19: LRT - Place of Residence for Historic Centre Commerce Workers

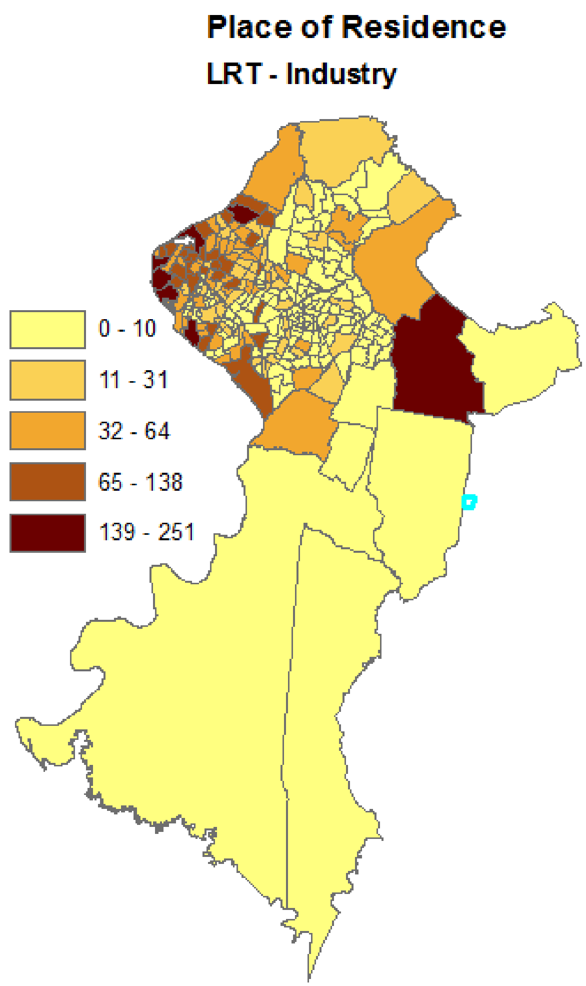

Figure D.20: LRT - Place of Residence for Historic Centre Industry Workers

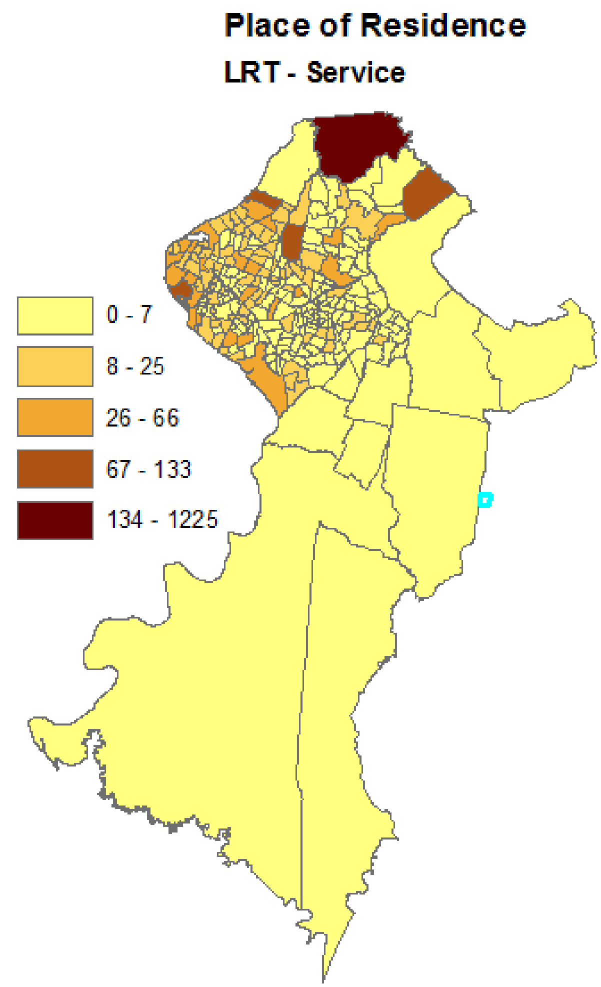

Figure D.21: LRT - Place of Residence for Historic Centre Service Workers

The graphical outputs presented above are very useful to demonstrate one of the capabilities of SATA which is capturing the influence of transit infrastructure investment projects such as the LRT and the BRT. Namely, implementing a massive capacity transit infrastructure project improves mobility and thus the Level of Service (LOS) attributes of the transit modes; this in turn influences economic activity patterns in terms of spatial location. In other words, the distribution of worker types among the study region depends on the Level of Service provided by all competing transportation modes.

APPENDIX E
PROPOSED PHASE 2 DATA NEEDS & TASKS

APPENDIX TABLE OF CONTENTS

LIST OF TABLES

E.1 INTRODUCTION

The proposed Phase 2 project is intended to build upon the prototype model developed in the Phase 1 project to develop a fully operational and calibrated version of SATA that can be used for planning and policy analysis applications. This work will involve three major components:

1. Gathering new travel survey data for the Asunción region to support a much more detailed and robust calibration of SATA.
2. Gathering other types of data that are also required for model calibration and testing.
3. Model calibration and testing.
4. Report and documentation writing.
5. Training of Asunción and CAF staff.

Each of these components are briefly discussed below.

E.2 TRAVEL BEHAVIOUR DATA COLLECTION

The biggest challenge in Phase 2 is the development and execution of a data collection program to gather the data needed to do a full calibration of SATA. Ideally we need a home-interview survey of a representative sample of households within the Asunción metropolitan region that gathers complete travel information for every member of the household for a typical weekday. This information should, at a minimum, include:

- Household attributes:
    - Number of persons in the household.
    - Number of personal use vehicles (cars, light trucks, motorcycles).
    - Number of bicycles?
    - Household income.
    - Household dwelling type.
    - Household address.
- For each person:
    - Age.
    - Gender.
    - Employment status (full-time, part-time, not employed).
    - Student status (full-time, part-time, not attending school).
    - Driver's licence (yes/no)
    - For employed persons:
        - Occupation category.
        - Workplace address.
- For each trip made by each person:
    - Trip purpose.
    - Trip start time.
    - Trip origin location.
    - Trip destination location.
    - Trip mode(s).

There are many methods for conducting such a survey, including:

- In-home, face-to-face interview.

- Telephone interview.
- Self-completed questionnaire mailed back.
- Self-completed web-based questionnaire.

There are also many ways of sampling households, including:

- Sampling households by their place of residence.
- Place of employment-based survey.
- School-based survey.
- Transit on-board surveys.
- Roadside intercept surveys.

In addition to these conventional survey methods new/emerging methods for gathering travel information include:

- Cellphone "call record" data.
- Smartphone app data.
- Transit smartcard data (where smartcards are used).

Each of these methods, of course, have their advantages and disadvantages. Generally speaking the conventional survey methods, while potentially providing very detailed and complete information concerning household trip-making are expensive to execute and it can be difficult to recruit appropriate respondents in terms of:

- Establishing an appropriate *sampling frame* (e.g., list of households by residential location with contact information).
- Contacting and recruiting respondents.

Cellphone "call record" data, if obtainable from one or more telephone companies can generate a large amount of trip information, but issues with this type of data include:

- Spatial precision.
- Trip mode and purpose need to be imputed.
- Linking individual trips back to a household is usually not possible.

Smartphone apps are becoming increasing sophisticated and useful as a means of collecting travel data with good to excellent spatial precision, but, as with cellphone data, trip mode and purpose generally need to be imputed and, again, individual trip making is generally observed without linkage back to a household.

Defining an appropriate data collection process for Asunción will require detailed conversations between UTTRI researchers and Asunción stakeholders (The Municipality of Asunción, MOPC, CAF, etc.) in order to identify the approach that best fits local conditions, capabilities, needs and budget. Until we have scoped out this process together it is very difficult to estimate any sort of budget for this portion of the Phase 2 work, so this needs to be a major topic of conversation on Day 2 of our meeting next week. In terms of timeline, regardless of the methods adopted, a serious data collection effort will likely take at least 6-8 months to design and implement.

E.3 OTHER DATA REQUIREMENTS

In order to develop a fully operational model, other data issues that will need to be addressed include:

- Better road and transit network data are needed to upgrade the current Emme networks.
- Better land use data would be extremely helpful in improving the inputs to SATA. If any sort of cellphone or smartphone app based data are to be used it will be imperative that good land use data are available so that trip purposes at observed destinations can be imputed.
- Better socio-economic data (ages, employment status, auto ownership, income, etc.) would be extremely helpful in improving inputs to SATA. If a comprehensive travel survey of some sort can be undertaken, this will go a very long way towards addressing this need. If, on the other hand, cellphone and/or smartphone app data are a primary source of travel data, then other sources of socio-economic data become more important in terms of supplementing the observed trip data for model-building purposes.

The collection/assembly/analysis of these data should be able to go on in parallel to the travel data collection effort and so should not add to the overall timeline for the Phase 2 project.

E.4 MODEL CALIBRATION & TESTING

Once a new, more complete database has been assembled the current prototype SATA model system will be completely re-estimated and re-calibrated using the new data. This may result in some modifications to the current model specifications and the mode system code, but it is not expected that these changes will be modest. Model system estimation and calibration is always an open-ended, iterative process. While we do not expect any major obstacles to completing this task successfully, it will take time to make sure that the new version of the model system is robust and ready for operational application.

As part of the testing and validation of the updated model system, the BRT and LRT scenarios examined in the Phase 1 study will be revisited.

It is expected that the model calibration and testing component of the work will take 6-8 months after completion of the data collection tasks.

E.5 DOCUMENTATION

As in Phase 1, a final report and a set of detailed technical appendices will be produced to document the work done and the findings of the project. In addition a SATA User's Manual will be produced providing detailed instructions concerning how to run the model system. Preparation of the documentation will take approximately 1 month after completion of the calibration and testing tasks.

E.6 TRAINING

Once the new model system is fully operational and the documentation is complete, UTTRI staff will provide in-depth training to local technical staff in the maintenance and use of SATA. This may either be undertaken in Asunción, or it may be useful for the local staff to come to Toronto for the training. In either case, it is likely that 3-5 days of training time will be required.

E.7 BUDGET & SCHEDULE

Given the very cursory discussion above, it is clear that there are a number of unknowns to be sorted out before a firm budget and schedule can be determined. In order to start the discussion, however, a very preliminary budget and schedule are shown in Tables E.1 and E.2, respectively, to illustrate the sort of level of effort that is likely to be required to undertake the Phase 2 study. Variations on project length, scope and budget can all be considered.

Table E.1: Preliminary Draft Phase 2 Budget

Expense Item	Amount	Notes
Travel data collection	$50,000	1
Graduate Student	$37,500	2
TMG technical staff time	$15,000	3
Asuncion Emme licences	$20,000	4
Travel	$20,000	5
Miscellaneous expenses	$500	
Sub-total, direct research expenses	$143,000	
University overhead @40%	$57,200	
Total, Canadian $	$200,200	
Total, US $	$150,150	6

Notes:

1. This is an extremely rough guess, just for the sake of discussion.
2. 1 graduate student for 1.5 years @ $25,000 per annum.
3. UTTRI Travel Modelling Group (TMG) technical staff support. 250 hours @ $60/hr.
4. 2 500-zone Emme licences for use by Asuncion staff to run SATA.
5. 2 trips of 2 people each @ $10,000 per trip.
6. Assumed exchange rate: CA$1.00 = US$0.75.

Table E.2: Preliminary Draft Phase 2 Schedule

	MONTH																	
TASK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Travel data collection																		
Other data collection/assembly																		
Network coding																		
Model calibration & testing																		
Report writing																		
Training																		