Economic Feasibility Analysis for Central Expressway Project

Annex 1:

Model Development and Existing Travel Behaviour Extracted from Economic and Financial Report on the Northern Expressway Affordability and Delivery Models, Appendix A – Traffic and Tolling Analysis Report by M/S SMEC International (PVT) Ltd, Australia.

Transportation Engineering Division
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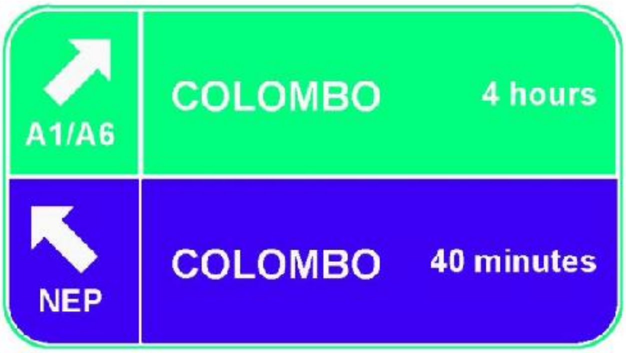
DEMOCRATIC SOCIALIST REPUBLIC

OF SRI LANKA

MINISTRY OF PORTS AND HIGHWAYS

ROAD DEVELOPMENT AUTHORITY

NORTHERN EXPRESSWAY PROJECT FEASIBILITY STUDY



ECONOMIC AND FINANCIAL REPORT ON THE NORTHERN EXPRESSWAY AFFORDABILITY AND DELIVERY MODELS

Appendix A – Traffic and Tolling Analysis Report

August 2013

5 Model Development

This section provides an initial introduction to the Cube Voyager software, how it works generically followed by a detailed explanation of how the Project Traffic Model was developed by component stage.

5.1 How does the Project Cube Model Work?

The objective of the project traffic model is to replicate current year traffic operations as a basis for predicting future year volumes along the expressway.

The project model has been developed using the modelling software package Cube Voyager. This is a widely used commercial package throughout the world.

The model structure is the industry standard 4-step approach where to, put simply, the traffic generated from defined areas called traffic zones is distributed to other zones within the study area based on the need to travel there. For instance, travelling from home to work. In some cases, depending on the spatial size of the zone this travel pattern occurs within the same zone. What mode of transport the individual uses; either private car, motorbike, three-wheeler public transport (bus/train) or walking is dependent on a range of factors including car ownership, availability of public transport, cost, household income etc. What route this travel is assigned to is generally related to the time it takes to do that trip and route choices. A model will generally seek to assign the trip to the quickest route, which maybe the shortest dependent on the capacity and other operating parameters of the road. For instance travelling to Kandy from Colombo by car would primarily be on the A1 although depending on where you are travelling from in Colombo some of this trip may be by another road.

Figure 5-1 below identifies the core elements in a standard 4-step traffic model

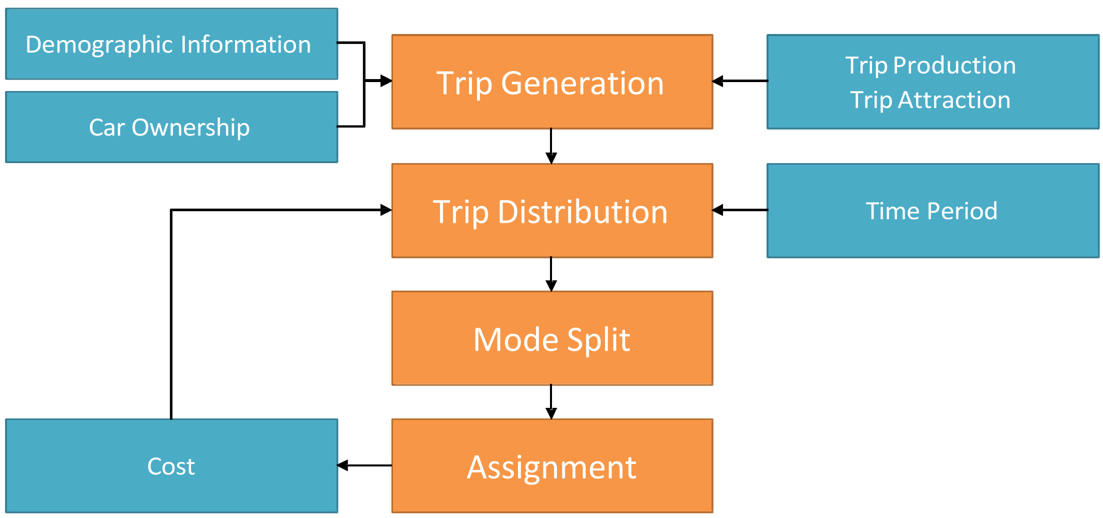


Figure 5-1: Standard 4- Step Traffic Model

One of the key aspects of any traffic model is the data input.

Model Data

To replicate existing travel patterns you need data on the following key aspects:

- **Existing Travel Patterns**

How people are normally travelling now through, for example, traffic counts on roads, or asking people where they are travelling to and from roadside origin and destination surveys or other data sources such as census, or household travel surveys.

- **Travel Options**

What is the extent and nature of the transport infrastructure – road, rail lines that they will use and what are their mode options – do they own a car, is there a public transport service along this route.

- **Travel Demand**

What is causing and influencing this travel patterns. For example, where people live and travel to work, shopping, recreation, school, etc.

To address this we have collected data on the following:

- Classified traffic counts along key roads
- Origin and destination surveys mostly at the same location of the count
- Travel times along key routes
- Land use patterns by type by area
- Population – total and household form, car ownership by place of residence and employment type by place of work
- Freight operations by surveying key freight forwarding and major businesses
- Toll operations on the southern expressway
- Vehicle operating costs
- Survey data collection and past report research on willingness to pay tolls and value of time
- Review of research and official government publications on travel behaviours in similar developing countries

The quality and extent of data is one of the key issues to address in developing a robust model. There have been challenges associated with this principally related to the limited amount of data being available and timeframe restriction in collecting new data. This is discusses in Section 5.16.

5.1.1 Does the Model Accurately Reflect Current Year Conditions?

The only way to confirm that the model is accurately replicating current traffic operations is to compare modelled outputs against observed traffic operations. The process is generally called Model Validation. Two key assessment criteria were used in this regard for 2012:

- Traffic Counts
- Travel Times

Traffic Counts

Traffic volumes along sections of A and B class roads was identified from commissioned and historical counts and compared against modelled volumes.

Travel Times

Travel time surveys were commissioned along key highways such as the A1 and A6 where a standard road vehicle fitted with a GPS tracker recorded travel time and speed along the route and in total. For instance, average daily travel time from Colombo to Kandy.

The evaluation identified a generally good fit with modelled data against counts and travel time observed data. Details are provided in Section 5.14.

5.1.2 Does the Model Accurately Reflect Future Conditions?

For future years one cannot obviously compare against observed conditions. The reliability of future year forecasts is based on how robust the base year model is and reliability of future year input parameters. For example, what will be the future year's population levels, where they chose to live, their level of car ownership, how they travel to work, shopping, recreation and how frequently. Future year employment by location, the volume of the commercial vehicle movements; where they go to and from and how frequently. What form will be the supporting road network and level of tolls?

The model allows a range of scenarios to be tested and how they change traffic volumes. Reference is made to official government projections, research or if available comparable examples of similar development in the country or throughout the world to help validate this potential future year scenarios. For this project five possible future year scenarios were developed and are reported upon in Section 7.

5.1.3 What are the Risks Associated with the Model Inputs?

Although the structure of the Cube model has been proven to work effectively through numerous worldwide applications and has internal checks and balances in respect to required inputs like any other model it is dependent on the quality of the data that is inputted into the model. Therefore, what confidence can be applied to this data is related to the level of risk the user is willing to accept.

For example, modelled traffic volumes are compared against observed counts along that road link on the assumption that the observed count volume is accurate. For counts commissioned by SMEC there is a relatively high level of confidence to their accuracy as the methodology of collection has been structured to industry standards and verified in part by selective on-site inspection. Influencing factors on traffic volumes such as location, weather, and special events such as festivals, holidays, road works, accidents and so forth have been taken into account. In contrast, historical count data with no or little supporting documentation on methodology and on-site conditions would be viewed with a low level of confidence, especially if undertaken a number of years ago and/or reports considerably different volumes as compared to a nearby commissioned count.

To address these risks SMEC has undertaken the following two tasks:

- An internal Peer review of the model methodology
- An At Risk Evaluation of the Risk associated with the data inputs and scenario developments

The outcomes of these two tasks are provided in full in **Appendix G**.

5.2 Stages of Development

With a program of data collection in place the next step was the Cube model development. In general this involved two key stages.

Development of a 2012 Base Model

The purpose of this model is to replicate present traffic operations and test these against observed behaviour. Data on traffic volumes at defined points along the road network, travel times along road links is collected and can be compared against modelled traffic operations to determine if the model is functioning within acceptable parameters. Once this is established the model can be deemed to be fit for purpose.

Development of Future Year Models

Although the core functions of a fit for purpose 2012 model have been established the reliability of future year model outputs is still dependant on the quality of input data. Therefore, in both stages of the model development particular care needs to be taken in the use of data in the model.

The section below identifies the process undertaken in the development of the Cube Project Traffic Model and how challenges in the reliability and availability of data were addressed.

The project traffic model is referred to as the Northern Expressway Strategic Traffic Model (NESTM).

5.3 Model Development - Overview

This section onwards provides a detailed description of how the Project Traffic model was developed using the Cube Voyager software as described earlier.

Cube Voyager is a widely used commercial package for developing four step strategic models. The four steps represent Trip Generation, Trip Distribution, Mode Choice and Assignment. These steps are now briefly explained:

1. **Trip Generation** – calculates by trip purpose the number of trips produced and attracted to zones. Trips are usually determined by the land use, household demographics and other socio-economic factors.
2. **Trip Distribution** – spreads the trips by zone (from Trip Generation so they have an origin and destination). The travel cost is normally applied as the impedance to undertake the trip which results in shorter trips being more favoured over longer ones.
3. **Mode Choice** - allocates each trip to a mode. Each trip is associated with a cost generally based on time, distance, tolls and parking costs for cars while fares, wait times, in-vehicle time, boarding penalties etc. are used for public transport. The total

cost is then fed into a mode choice model (logit) to assign a proportion of demand to each mode.

4. **Assignment** - allocates the route taken for each trip by mode. For highway trips, characteristics of that route, number of lanes, connection with the wider road network, where the travel demand is going to and from and so forth will help determine the 'attractiveness' of each route for each trip.

Where only highway assignments are required, the third step (Mode Choice) is often removed and the preceding two steps only relate to highway demand i.e. vehicle trips (as opposed to person trips). The Northern Expressway Strategic Traffic Model is a 3-Step strategic model as the focus is on the highway assignment along the Northern Expressway. The model structure is provided in Figure 5-2 and details for each process, the input data, the processing undertaken and the output data from the process.

In developing the project model the first step is to establish and validate the performance of a base case model. 2012 is the base case year for this particular model. Validation of the model occurs by comparing modelled traffic volumes along a link with observed volumes provided from traffic counts; also by comparing modelled travel times with observed travel times. If the modelled volumes are within acceptable bounds of the observed volumes, then the model can be seen as predicting representative traffic demand. If the travel time is within acceptable bounds as well, then the model is accurately reflecting the real life delay experienced traversing the network in the given time periods. Thus the model can be reliably used to forecast alternate scenarios and future year options.

In standard industry practice a historical set of classified counts, journey to work, travel time, household travel survey and other data is available as reference. However, in this case much of this data was unavailable and we had to rely on commissioned survey data and a limited set of invalidated traffic count data. This limited data set was a major factor in driving the model development process and the shape of the model as discussed below.

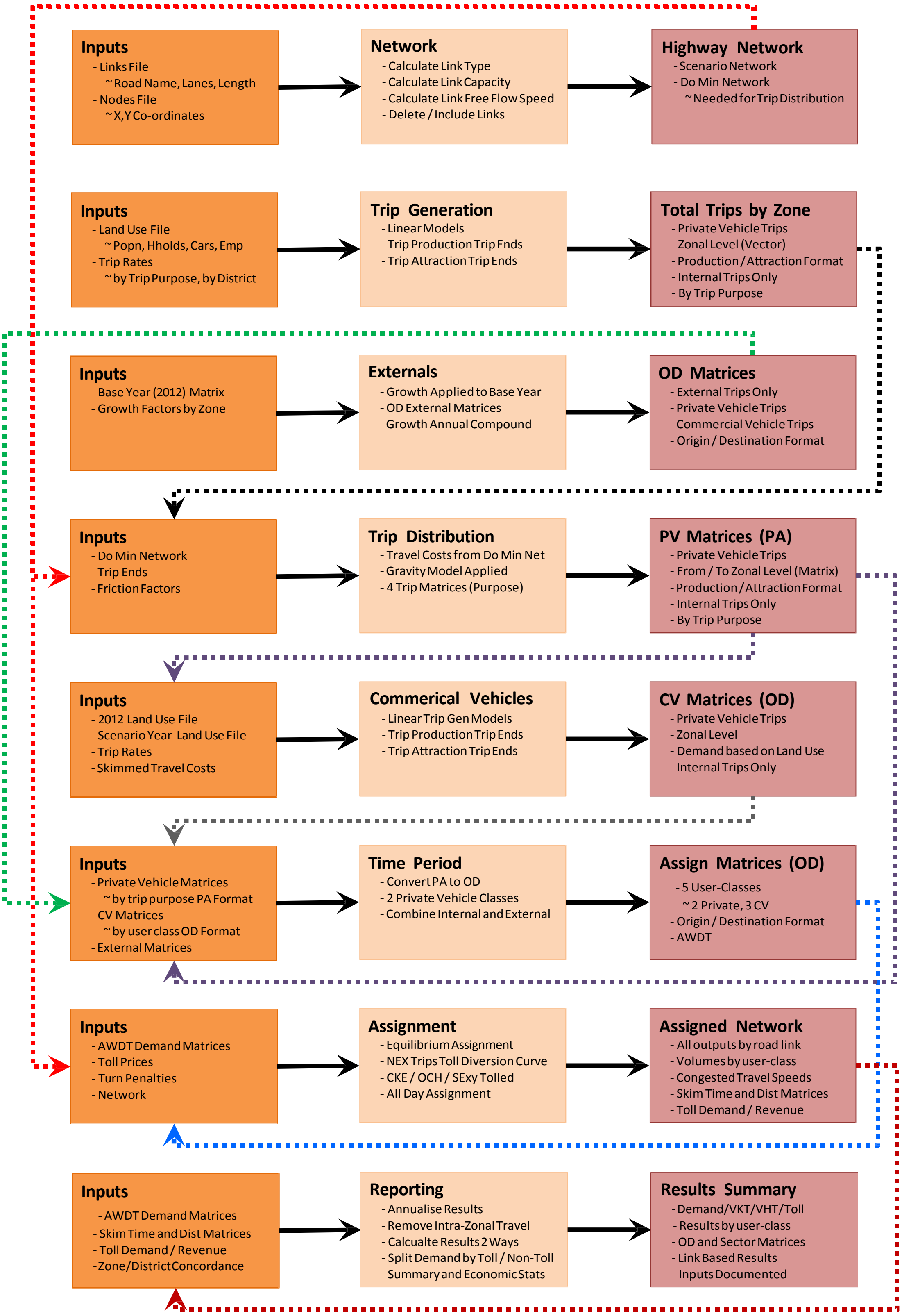


Figure 5-2: Northern Expressway Strategic Transport Model (Phase 1 & 2)

5.4 Network

5.4.1 Road Network Database

A road network database has been established that identifies a range of attributes of each section or road link. This includes road width, number of lanes, pavement type, level of access from adjoining land use, the type and nature of this land use, alignment, posted speed and so forth. In addition details on traffic counts along these road links are recorded.

This allows us to identify road link types that reflect common driving characteristics along that section of the road.

Road network data has been sourced from the University of Moratuwa's TransPlan model data base, RDA database, information from previous reports and supplemented by on-site surveys.

5.4.2 Traffic Count Data

Traffic count data were collected from the following sources:

- RDA
- University of Moratuwa TransPlan Model database
- OD and MCC traffic surveys undertaken for the Northern Expressway Project by the University of Moratuwa

All traffic count data was factored to 24 hour weekday average for use in the initial trip demand development and model calibration and validation.

Details of the location and type of traffic survey data commissioned for this project are shown in Section 4.

5.4.3 Traffic Zone System

The zone system in NESTM was initially based on the administrative sub-units known as Divisional Secretary Divisions (DSD). Phase 1 consists of 87 DSDs and the Phase 2 study area consists of 138 DSDs. However, due to the sizes and geographic locations of the land use activities within the DSDs, DSD level of land use data limited the ability to conduct reasonable vehicle assignment modelling to quantify the travel demand on transportation links. Therefore, the disaggregation of the following DSDs were undertaken in Phase 2 to better reflect local area access and demands:

- Trincomalee Town and Four Grave DSD in Trincomalee District
- Puttalam DSD in Puttalam District
- Pannala and Kurunegala DSDs in Kurunegala District
- Mawanella and Warakapola DISs in Kegalle District
- Kandy Four Gravets, Kundasale, Udunuwara and Yatinuwara DSDs in Kandy District
- All DSDs in Gampaha District
- Colombo, Hanwella, Homagama, Kaduwela, Kesbewa, Kolonnawa, maharagama, Motatuwa, Sri Jayawardanapura and Timbirigasyaya DSDs in Colombo District

Disaggregation was carried out using proportional allocation determined from the 2001 land use data in Grama Niladhari Administration (GN) Division level.

NESTM includes 187 internal and 29 external traffic zones across the Phase 1 and Phase 2 study area. The coverage and zone system of the traffic model are shown in Figure 5-3. Traffic zones and DSDs equivalent table is shown in **Appendix I**.

Figure 5-3: NESTM Model Coverage and Zone System (Phase 1 & 2)

5.4.4 2012 Base Year Network

The base year road networks supplied by the University of Moratuwa were reviewed and modifications were made to links where they were found to be inconsistent with the observed road network. The 2012 network system was then refined to include detailed representation of the road network. Link type, speeds and capacities were then allocated to the model network based on the road classes, number of lanes, districts and observed travel speeds.

The model network and the associated network parameters are shown in Figure 5-4 to Figure 5-5. Table 5-1 summarises the network parameters.

Figure 5-4: NESTM Model Lane Numbers

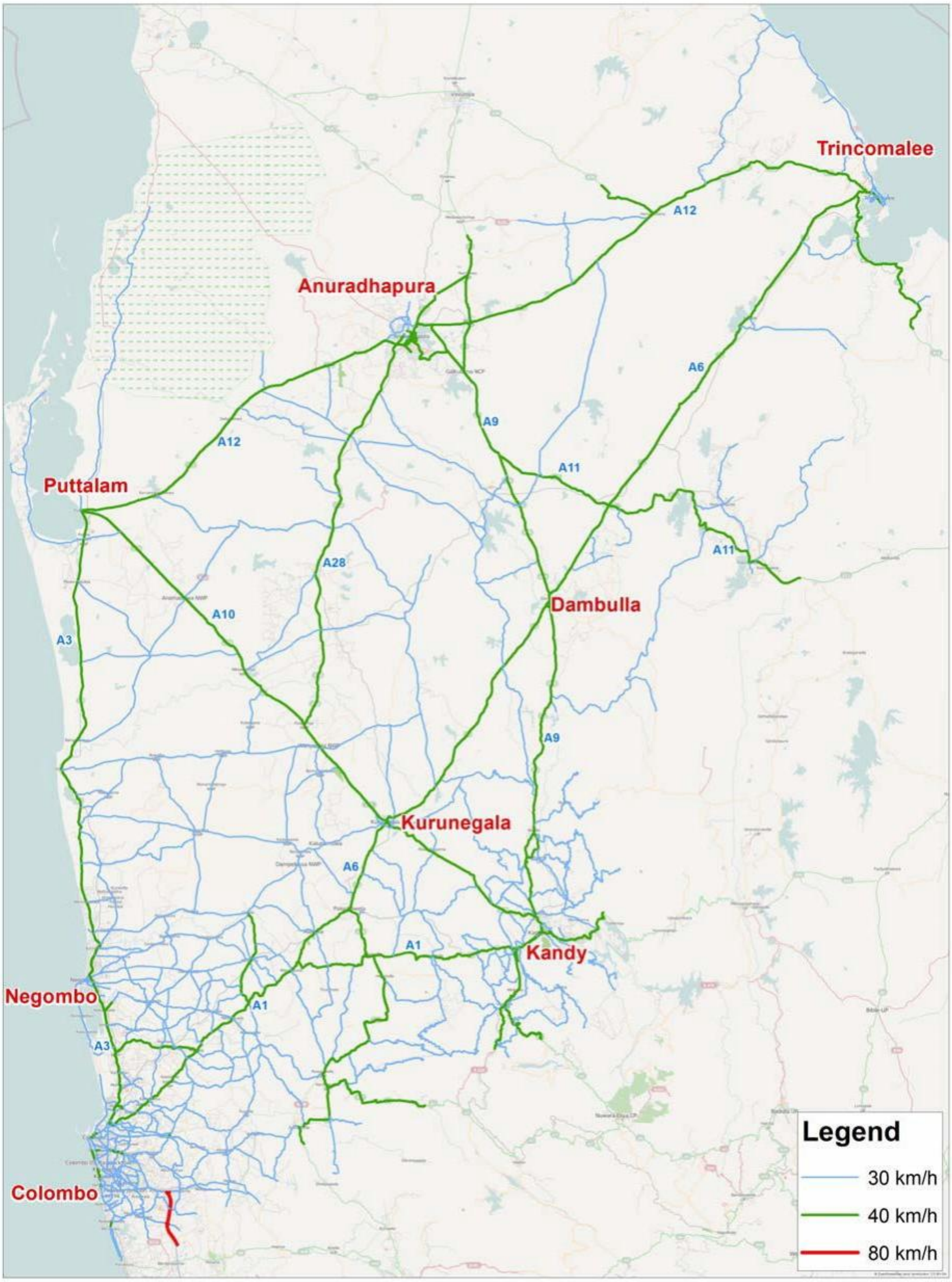


Figure 5-5: NESTM Model Free Flow Speed

Table 5-1: Network Parameters

Road Type	District	Number of Lanes	Link Type	Free Flow Speed (km/hr)	Daily Capacity (pcu per day)
Class A	Colombo	3	11	40	36,000
	Non-Colombo	3	21	50	36,000
Class A	Colombo	2	12	35	27,000
	Non-Colombo	2	22	45	27,000
Class A	Colombo	1	13	30	15,000
	Non-Colombo	1	23	40	15,000
Class B	Colombo	2	14	35	23,400
	Non-Colombo	2	24	40	23,400
Class B	Colombo	1	15	30	13,000
	Non-Colombo	1	25	30	13,000
Expressway	All		6	80	18,000 per lane
Expressway Ramp	All		7	60	18,000 per lane
Local Road	Colombo		18	30	8000 per lane
Local Road	Non-Colombo		28	30	8000 per lane
Centroid Connector	All		99	40	1,000,000

5.4.5 Future Year Network

Upgrades or new infrastructure in the future year road network were based on the National Road Master Plan 2007 – 2017 provided by Road Development Authority (RDA).

The key projects that are included in the traffic model are listed in Table 5-2. Figure 5-6 shows the locations of the road projects.

Table 5-2: Future Year National Road Improvements

Model Year	Road Project
2016	Colombo – Katunayake Expressway (CKE) - Tolled Road
2016	Outer Circular Highway (OCH) - Tolled Road
2016	Duplication of Kelani Bridge - 3 Lanes
2016	Colombo Kandy Road (AA001) widening - Kadawatha to Nittambuwa
2016	Colombo – Galle – Hambantota – Wellawaya Road widening
2016	Colombo Ratnapura - Wellawaya Batticaloa Road (AA004) widening - Vilasitha Nivasa to Godagama
2016	Kandy - Jaffna Road (AA009) widening - Kandy to Katugastota (AA009)
2016	Kaduwela - Biyagama road (AB004) widening
2016	Inner Ring Road Battaramulla (AB015) widening - Palawatta access road to Koswatta
2016	Battaramulla Pannipitiya Road (B047) widening – Thalawatugoda to Pannipitiya

Model Year	Road Project
2016	Colombo Horana Road (B084) widening - Vilasitha Nivasa to Pokunuwita
2016	Orugodawatta Abathale Road (B435) widening - Orugodawatta to Abathale
2016	Peliyagoda – Puttalam Road (AA003) widening – PB (West/NWP) to Chilaw
2016	Ambepussa - Kurunegala - Trincomalee Road (AA006) widening - Ambepussa to Kurunegala
2016	Canada Friendship Road (AB009) widening
2016	Colombo - Hanwella Low Level Road (AB010) widening - Ambatale to Hanwella
2016	Ekala - Kotadeniyawa Road (B111) widening
2016	Kelaniya - Mudungoda Road (B214) widening - Bandarawatta junction to Mudungoda
2016	Kotte - Bope Road (B240) widening - Koswatta to Malabe
2016	Minuwangoda - Gampaha - Miriswatta Road (B288) upgrade - (0.00 - 2.81 km)
2016	Moratuwa - Piliyandala Road (B295) upgrade - (2.62 - 5.11 km)
2016	Colombo Ratnapura - Wellawaya Batticaloa Road (AA004) widening - Godagama to Avissawella
2016	Kadawatha - Ragama - Welisara Road (B168) widening
2016	Katunayake - Veyangoda Road (B208) widening
2016	Kolonnawa - Angoda Road (B231) widening - (0.00 - 3.10 km)
2016	Kolonnawa - Yakbedde Road (B232) widening - (0.00 - 2.64 km)
2016	Baseline Road upgrade
2016	A9 Dambulla to Anuradhapura upgrade
2016	A6 Dambulla to Trincomalee upgrade
2016	A20 Anuradhapura Ring Road upgrade
2021	A2 Road 6 lane from Bambalapitiya to Moratuwa
2021	Kuliyapitiya - Hettipola Road (B243) widening - (0.00 - 15.62 km)
2021	Colombo Kandy Road widening - Polgahawela Road Junction to Karadupona
2021	Kandy Jaffna Road (AA009) widening - Katugastota to Ambatenna
2021	Veyangoda Ruwanwella Road (B445) upgrade - Veyangoda to Nittambuwa
2021	A12 Upgrade – road widening, alignment, pavement improvements

Figure 5-6: Future Year National Road Improvements

5.4.6 Future Year - Northern Expressway Staging Options

As identified in Section 2 three stages of Northern Expressway and the Kandy Ring Road were investigated in Phase 1 of the traffic analysis. For Phase 2 this was extended to include a fourth stage but excluded the Kandy Ring Road as part of the Northern Expressway project. In addition there were also changes to alignment and interchanges. The stages modelled under Phase 2 and as reported here are

- Stage 1 - Enderamulla to Ambepussa
- Stage 2 – Meerigama to Pellandeniya (intersection with A10 near Kurunegala)
- Stage 3 – Ambepussa to Kandy
- Stage 4 – Pellandeniya to Dambulla

Extents of each stage of the Northern Expressway and the locations and details of the expressway interchanges are shown in Figure 2-1 and Table 2-1 in Section 2.

5.4.7 Future Year Network - Connecting Roads to the NE

From our review of the operations of the Southern Expressway, as discussed in Section 4, it was identified that poor local road connectivity to intersections along the expressway appeared to be playing a role in the relatively low number of vehicles using this expressway. From Scenario 2 onwards the following connecting local road upgrades were modelled. The location of the connecting road upgrades is shown in Figure 5-7.

- Stage 1 - B445 to A1 from Veyangoda
- Stage 1 - B208 from Veyangoda to A3/CKE at Katunayake /airport
- Stage 1 – Direct link from OCH intersection to CKE and onwards via the CKE to a dedicated port link via the new Kelani Bridge
- Stage 1 – A33 from Gampaha intersection to A3 via Ekala. In part where upgrades to two lanes in each direction was required.
- Stage 2 – A10 to Kurunegala from Kurunegala intersection
- Stage 3 – A6 link to A1 from Ambepussa intersection
- Stage 3 – A19 link to A1 from Devalegama intersection
- Stage 3 – upgrade to A10 from intersection with NE at Galagedara to intersection with KRR at Hedeniya

These connections were identified on the basis that they would enable improved access to key local roads or urban centres from interchanges along the Northern Expressway. This is a modelling process where the road network characteristics are adjusted within the model and does not include any engineering, environmental, cost or other assessment.

In terms of accessing the NE from Colombo a further change from Scenario 1 was a direct link to the CKE from the intersection with the OCH and a dedicated port road link (commercial vehicles only) from the CKE intersection with the A3 at the Kelani Bridge. This connecting road scenario is shown in Figure 5-7 as part of the discussion of Scenario 2 in the model outputs section.

For the modelled connection upgrades along the B208 and B445 that access the proposed NE Veyangoda interchange these have already been identified for upgrades as part of the RDA roads program as identified in Figure 5.6.

Figure 5-7: Northern Expressway Connecting Road Upgrades

5.5 Demographics – Land Use

Data has been collected on the land use patterns and demographic data for each of the traffic zones (DSD) within the study area and more broadly outside, as relevant to generating traffic to and from the study area. This has included population, total and by age group, number of households, number of registered vehicles per zone, education enrolments and by employment at place of work by employment categories as used in the census. Data has been obtained from the 2001 and 2011 census, government departments and land use mapping commissioned from Image Scientific (Pvt) Ltd through the Department of Planning and Policy.

A data set has been established for each of the traffic zones for each of the modelled time periods.

The approach adopted in collecting this data is detailed in Section 4.7 of this report.

5.5.1 Land Use Forecast

Forecasts years were identified as 2016, 2021, 2026 and 2036.

A number of growth areas identified in the National Physical Planning Policy & Plan as prepared by the National Physical Planning Department, Ministry of Construction, Engineering Services, Housing and Common Amenities were located within the study area. Very little information on the demographic profile of these growth areas was provided by this department outside of the general intent on their potential size, location and role. Based on existing land use densities and form identified for 2001 and 2011 from the census and land use mapping data potential demographic profiles were identified for the traffic zones where these growths areas were located in the National Plan.

Land use growth for the areas without forecast data were determined based on the historical growth, national growth projections provided by the Department of Labour and the following assumptions:

- Annual growth rates will progressively slowdown in the long term future
- Average household size will gradually reduce in the future
- Vehicles per household will gradually increase in the future
- Employment: population rate will gradually increase in the future
- Total population and employment growth within the study area was balanced against the projected growth rate for that date period

Figure 5-8 and Figure 5-9 identify projected population and employment growth by DSD within the study area based on data supplied by the Department of Labour. This was identified as the standard case as a modelling variable input. A high growth scenario was identified as a sensitivity test for Scenario 5.

Figure 5-8: Phase 1& 2 Study Area = Population Growth 2012-2036

Figure 5-9: Phase 1& 2 Study Area - Employment Growth 2012-2036

Figure 5-10 identifies the growth areas within the study area.

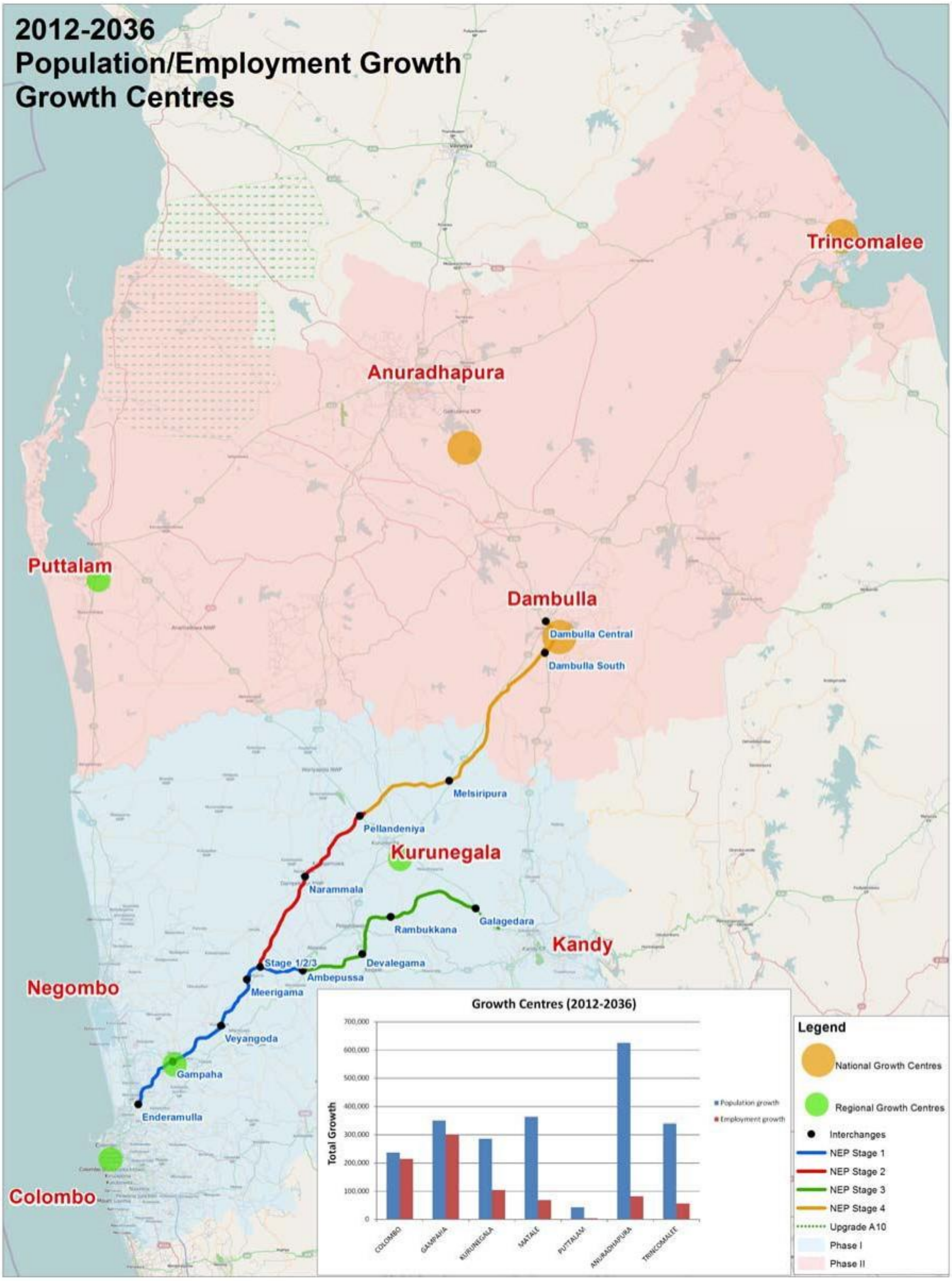


Figure 5-10: Growth Centres located within the Study Area

Summary of demographic growth rates for the standard case model options are shown in Table 5-3.

Table 5-3: Demographic Data Growth Rates, as Modelled

	2011 - 2016	2016 - 2021	2021 - 2023	2026 - 2036
Employment	1.79%	1.65%	1.44%	1.24%
Population	1.41%	1.26%	1.12%	0.99%
Household	1.93%	1.85%	1.78%	1.46%
Motor Car Registration	7.28%	6.61%	5.96%	5.43%

5.6 Initial Demand Using Survey

The preferred approach for building a strategic model is to develop and undertake a household travel survey (HTS) of the study area and use the information from the HTS to estimate the various models within the 4 step process, along with assessing/determining the underlying travel characteristics/parameters to be used within the model. The HTS provides detailed information regarding the households and individuals surveyed, along with their travel information for usually one or two days (all trips within those specified days). The households are randomly, but selectively chosen from within the study area with the objective of providing an unbiased sample regarding the typical compositions of households (persons, cars, workers, etc.) and their travel behaviour. The survey is analysed to understand key trends and is expanded to represent the total population i.e. all travel demand within the study area. The dataset can then be used to estimate some of, if not all of the following models/input parameters:

- Household structures i.e. household size, ratio of males/females, dependents/workers, etc.
- Car ownership
- Trip Purpose
- Trip Generation
- Trip Distribution
- Mode Choice
- Time Periods
- Average parking costs, vehicle occupancy rates, fares, Value of Time

At the time of development, no HTS had been undertaken in Sri Lanka[1]. To supplement this missing information, a set of initial demand matrices were developed by trip purpose and user class to provide 24 hour average weekday travel demand by vehicular user class (Table 5-4) and for private vehicles, also by trip purpose (Table 5-5). The initial demand matrices developed during this project were used as a substitution not only for the HTS, but also for the required Freight surveys and

[1] A HTS is currently being carried out in Colombo by the Consultants JICA for the Colombo Metropolitan Transport Master Plan. However, it is understood that results from the HTS may not be available until at the earliest by September 2013.

surveys on external traffic i.e. trips that enter/exit the study area. The initial demand matrices helped govern/guide the development of the following components of NESTM:

- Trip Purpose
- Trip Generation
- Trip Distribution
- Commercial Vehicles
- External Trips

The initial demand matrices were developed by using the information collected from the OD surveys and applying matrix estimation (ME) to improve their accuracy and provide sensible travel demand patterns for the study area. The screenlines derived and used for this ME process (from the available counts as of the time of development of the initial demand matrices) were also used as the screenlines to calibrate and validate the final model.

The location of these screenlines are identified in Figure 5.11.

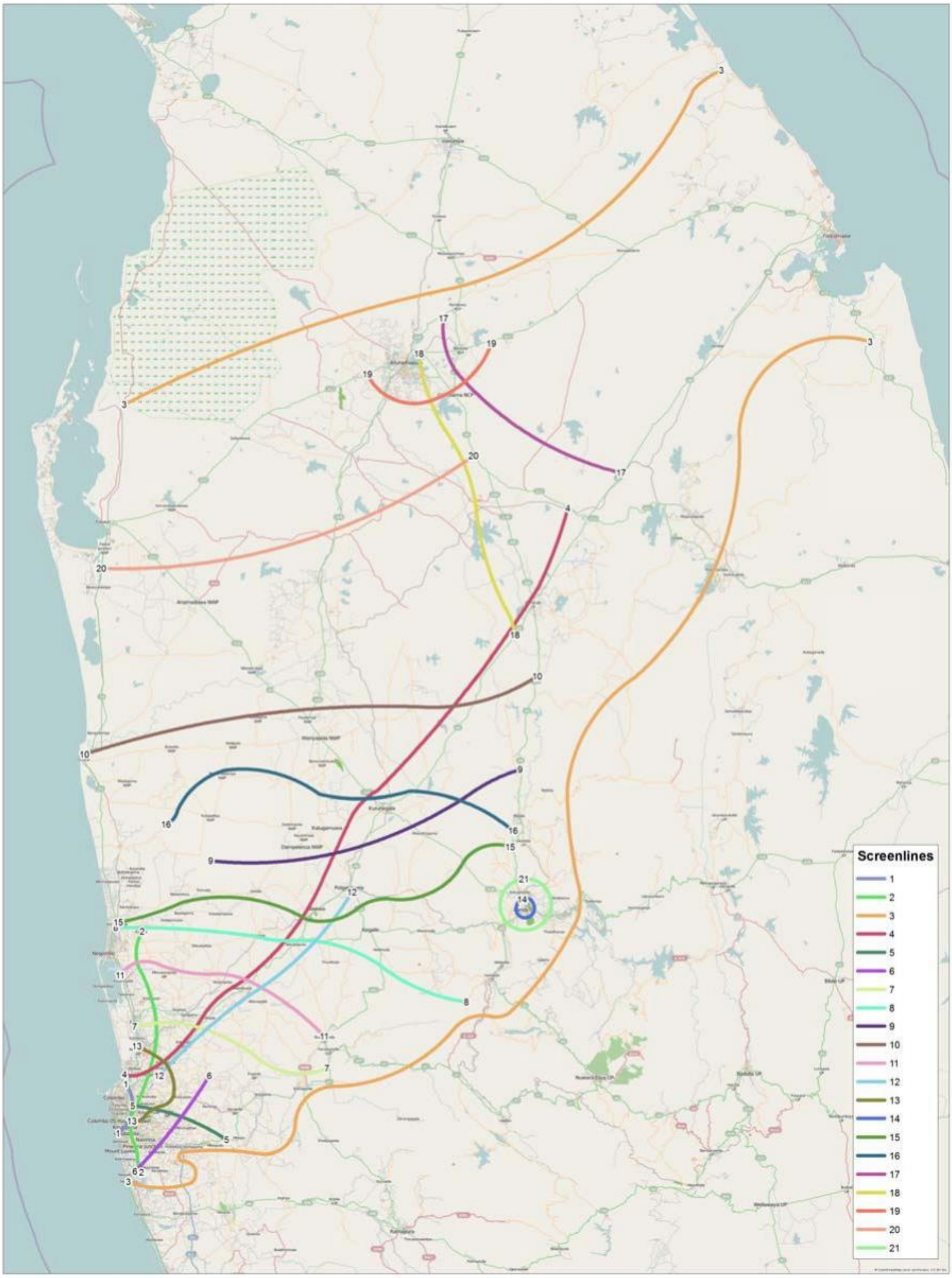


Figure 5-11: Project Screenlines

The output OD matrices from the ME process were re-formatted into production-attraction formats for Home-Based (HB) trip purposes so that Trip Ends could be provided for the estimation of the Trip Generation Models. The PA matrices were also used to estimate the Trip Distribution Model parameters.

Table 5-4: User Classes Assigned to the Network

User Class	Description
PV NB	Private Vehicle Non-Business Car Trip
PV B	Private Vehicle Business Car Trip
LCV	Light Commercial Vehicle Trip
MCV	Medium Commercial Vehicle Trip
HCV	Heavy Commercial Vehicle Trip

Table 5-5: Private Vehicle (Car) Trip Purposes

Purpose	Description	User Class
HBW	Home Based Work	PV NB
HBO	Home Based Other	PV NB
NHBO	Non-Home Based Other	PV NB
NHBB	Non-Home Based Business	PV B

Table 5-6: Initial Demand Matrices Summary

Parameter	PV	LCV	MCV	HCV
Demand	721,200	60,600	225,400	12,200
VHT	496,500	56,100	223,900	11,500
VKT	13,919,400	1,701,700	6,811,100	339,200
Avg Trip Distance	19.3	28.1	30.2	27.7
Avg Trip Time	41.3	55.5	59.6	56.3
Avg Trip Cost	92.4	72.0	88.4	121.3

5.6.1 Data Source of Initial Demand

The OD surveys and classified counts commissioned by the project team have formed the basis of the initial demand matrices. Key information provided from the OD surveys included the origin and destination zones of each trip, the origin and destination trip purposes for car trips, occupancy rates (car), vehicle classification (CV), vehicle payload (CV) and a question regarding the willingness to pay a toll for a specified time saving (car and CV). Along with the OD surveys, classified counts were undertaken at the same time which allowed the information obtained to be expanded to represent daily trip totals. Analysis of the survey data was conducted to confirm whether any bias in the results existed (with respect to time of day, trip purpose, occupancy, payload etc.) and whether the results seemed sensible and reliable enough to be used as the basis for the development of the model initial demand matrices. Due to the lack of any alternative data source regarding the travel information collected, there was no way to assess whether there was any inherent bias in the sample. Further work bore out a key sampling issue which impacted on how the data was used.

In order to conduct the surveys themselves, there were several limitations in performing the survey (which is not an uncommon occurrence when collecting data). The key limitation assessed from the analysis of the results was the fact that the surveys were not able to be conducted within town centres or within central Colombo. This was due to the inability of police to pull drivers over either as a result of the environment (no place to stop drivers without holding up traffic significantly) or the congestion within the network which made it unsafe to pull over motorists. The compromise adopted due to these limitations was that all surveys were conducted outside of busy locations (where pulling over drivers was safer and was in fact possible) i.e. not within Colombo or town centres of rural townships.

The issue caused by this limitation became apparent in the estimation process. As the locations were between towns, a very low proportion of trips were locally based; rather most trips were inter-regional trips i.e. travelling from one town to another. This bias proved to be an impediment in developing the initial demand matrices as the overall trip patterns from the OD surveys predominantly were comprised of long (inter-regional) trips. This did not correlate with the subsequent estimated matrices which used traffic counts throughout the model to alter the matrix. The estimation process indicated that the average trip length for trips was significantly shorter and that the sample over-represented the real proportion of long trips.

This is a sensible and reasonable conclusion to reach when the sizes of the zones are taken into consideration. The traffic zones adopted are large parcels of land that usually encompass entire towns and in some instances several towns (zones are much bigger than would be used in a metropolitan model). Thus it would be expected that a high proportion of trips are within a given zone i.e. within the town itself, resulting in a high level of intra-zonals. The OD survey results showed a very low percentage of intra-zonals which is counter-intuitive when considering the size of the zones. The results can be rationalised however when taking into consideration where the surveys were conducted and the types of trips that would be expected to be surveyed i.e. not within the town thus are more likely to be inter-regional.

5.6.2 Approach Adopted to Generate Initial Demand Matrices

Aside from the issue regarding the over-representation of inter-regional trips, a second issue arose during the matrix estimation process. Due to the small sample sizes, the OD surveys provided sparse trip matrices for the study area i.e. many OD pairs did not contain any trips which meant they could not be altered in the estimation process. Several zones did not contain any trips at all, and several more only contained trips from external sources i.e. no internal to internal trips. This lead to illogical processing of the OD matrices during the estimation process, producing lumpy assignments and matrices i.e. several roads with little or no demand assigned to them and uneven factoring of zones with some OD pairs having very large factors applied to them to account for the missing information of other OD pairs with no trips from the survey to factor.

In order to overcome the sparse nature of the data and subsequent illogical factoring of the matrix, a synthesised OD survey matrix was developed. The process adopted and the overall process to develop the initial demand matrices is provided below in Figure 5-1. Several iterations of this process were undertaken to improve the performance of the Initial Demand Matrices to provide the most realistic results and suitable initial demand matrices. A consistent outcome from the estimation process was that the trip length of the synthesised OD input matrix (using the OD trip distributions) was much longer than the subsequent estimated matrices trip length. Average trip costs reduced by around half which indicated that the input profiles were biased and were not representative of the likely trip distributions i.e. an over-representation of inter-regional trips.

Matrix Estimation is a process that requires careful application and understanding of both the inputs and outputs. Significant changes to the initial matrix should be avoided as it indicates that the original matrix is almost certainly not representative of actual travel patterns. Matrix estimation processing that generates numerous large adjustment factors to the initial matrix, will likely result in illogical travel demand patterns being estimated. They are in effect, compensating errors for the illogical/unrepresentative inputs provided. Thus, they should be avoided at all costs.

During the modelling it was noted that due to the complexities of the model covering urban and rural environments (with the majority of trips within the urban environment), the distribution process simplified the trip profiles in an attempt to reflect both trip profiles as best as possible. Due to the heavy weighting of the urban trips, the profile more reflected an urban environment and known travel routes (such as Kandy to Colombo) yielded small trip totals which did not reflect the survey results accurately enough. Thus an analysis of the initial travel demand from the survey, analysis of the land use data and an analysis of average trip profiles was undertaken to better understand how to reflect the trip profiles more suitably.

Analysis indicated that there were key demand areas (based on population density) and corresponding analysis of trip profiles indicated that they needed to be separated when developing a factored OD survey matrix for use in the estimation process. The three travel profiles are described below and are correspondingly explained via Table 5-7.

1. Travel wholly within either the Colombo –Gampaha Districts or the Kandy District (urban travel);
2. Travel wholly outside of the Colombo, Gampaha and Kandy Districts (rural travel); and
3. Travel between Colombo / Gampaha and Kandy, or travel from outside Colombo, Gampaha and Kandy to Colombo, Gampaha and Kandy (urban to/from rural travel).

Table 5-7: Origin / Destination Movements by Trip Profiles

O/D	Colombo/Gampaha	Kandy	Remaining Area
Colombo/Gampaha	1	3	3
Kandy	3	1	3
Remaining Area	3	3	2

Three trip profiles for each mode were developed which reflected the OD survey profiles, but produced more suitable results for the various types of trips i.e. input and output matrices that reflected different travel profiles based on the origin and destination were adopted. Based on analysis and calibration, the process to combine the trip profiles was by using a weighted combination of the demand matrices from each of the respective trip distribution profiles. The ultimate demand matrices developed by this process worked efficiently to provide an improved set of initial demand matrices.

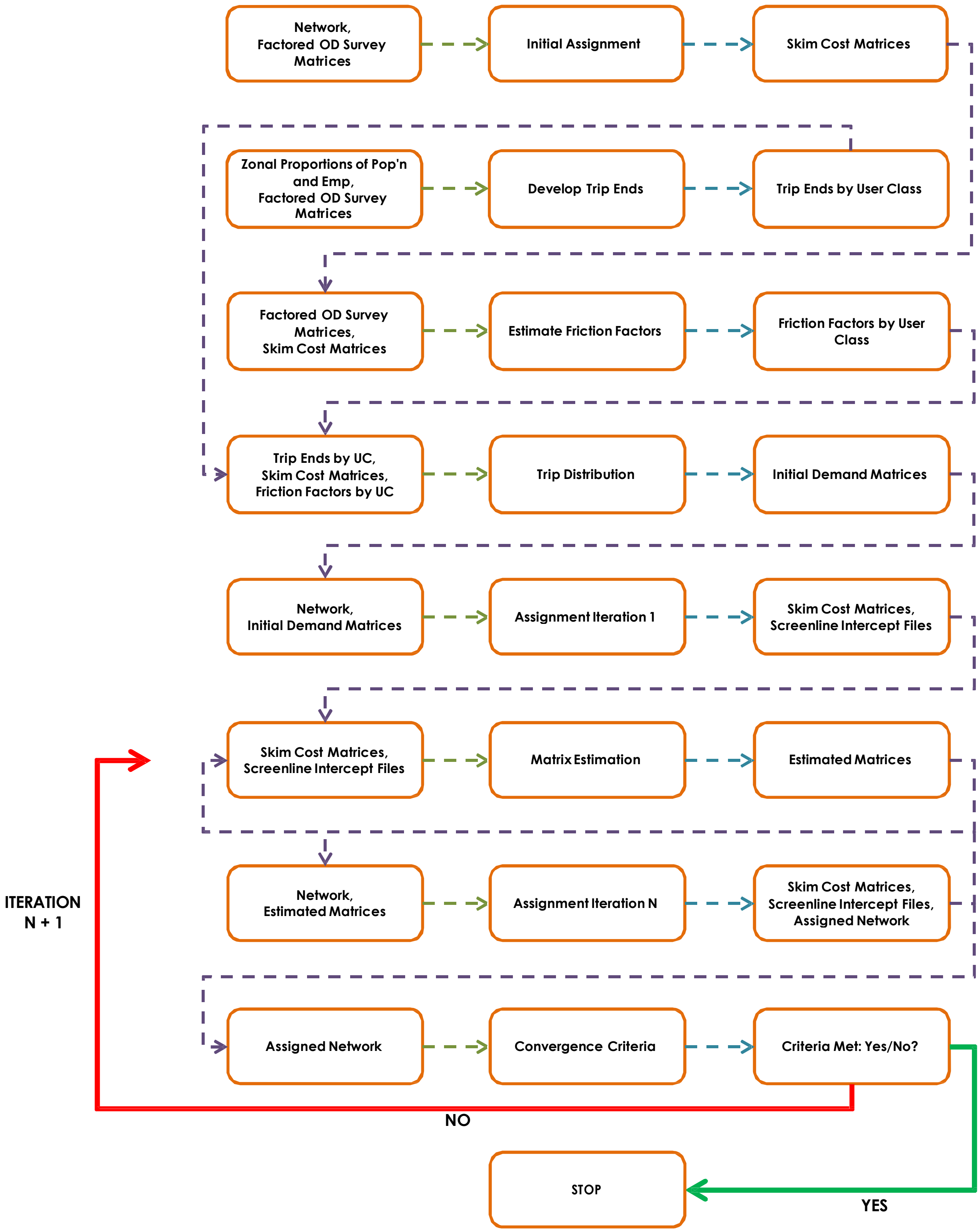


Figure 5-12: Derivation of Initial Demand / Matrix Estimation Process

5.7 Trip Generation

5.7.1 Trip Generation Models

The trip generation models comprise a 24 hour private vehicle trip production model and trip attraction model. Trip productions and attractions are produced separately for four trip purposes – home based work (HBW), home based other (HBO), non-home based non-business (NHBNB) and non-home based business (NHBB). A separate model is used to forecast commercial vehicle (CV) generation and the CV model is detailed in Section 5.7.

The key inputs into the development of the trip generation model were socio-economic data and daily vehicle trip rates for different trip purposes. As detailed in Section 4 and Section 5, Section 5.3, the socio-economic data has been obtained from numerous sources based on the reliability of the source and the level of fit to the zone system adopted for this study.

The production model estimates daily private vehicle trip rates for population by age groups. The population and household data in each geographical area were obtained for the base year from the 2011 Census of Population and Housing provided by Department of Census and Statistics. Motor car registrations were provided by Department of Motor Traffic and Local Authorities. Future year forecasts of were provided by Department of Planning for years 2016, 2021, 2026 and 2036.

The attraction model estimates the distribution of the non-home ends of each trip. The land use attributes used for this purpose include retail and non-retail employment data. Employment data were obtained from the Department of Labour and from the Sri Lanka Labour Force Survey provided by Department of Census and Statistics.

The trip rates used to develop trip generations were based on regressions of observed trip productions and attractions. Observed trip productions and attractions were derived from initial trip demands determined from traffic surveys. Table 5-8 provides the vehicle trip generation rates.

Table 5-8: Vehicle Trip Generation Rates

Trip Purpose	Trip Production				Trip Attraction		
	Total Population	Population (15–59 yrs)	Household	Motor Car Registration	Household	Retail Employment	Non Retail Employment
Colombo District							
HBW	0.00775			1.16391	0.00331	0.15758	0.12116
HBO	0.00715			1.03545		0.14434	0.11184
NHB Non Business	0.00042			0.07450	0.00076	0.00955	0.00733
NHB Business	0.00208			0.39506	0.00425	0.04878	0.03776
Gampaha and Kandy Districts							
HBW		0.04304		0.42278		0.11120	0.10817
HBO		0.03698		0.43046		0.13943	0.08529
NHB Non Business		0.00225		0.02380		0.00382	0.00567
NHB Business		0.01220		0.18145		0.05003	0.03024
Other Districts							
HBW		0.00817		0.01175		0.04284	0.00875
HBO		0.00733		0.00767	0.00622	0.01607	0.00656
NHB Non Business			0.00252	0.00101		0.00258	0.00203
NHB Business		0.00328		0.00491	0.00756	0.00696	

5.7.2 Future Year Trip Generation

It was assumed that vehicle trip production rates and trip attraction rates are the same in all forecast years. Traffic zones with high land use growth will result in higher vehicle trip generations in the future. Special growth areas inside the model area and with available land use forecast data were also taken into account. However, special development outside the model area was not included in the study.

5.8 Trip Distribution

The initial demand matrices were used as the basis for the development of the Trip Distribution models. The standard model used for Trip Distribution is the gravity model and this was adopted for this model. Friction Factors were calculated using the gamma function (see below) which represents the impedance to travel. Factors were estimated for all user-classes and for private vehicle, were estimated by trip purpose as well (Table 5-4 and Table 5-5). As discussed in the development of the prior matrix, split distribution profiles were adopted to develop a prior matrix that exhibited both urban trip making profiles and rural trip making profiles. In order to develop a distribution model that reflected this fact a multi-distribution model process was set up to produce travel profiles that were reflective of the trip profile groups:

1. Urban trips;
2. Rural trips; and
3. Urban to/from rural trips.

Following detailed testing, of a 1, 2 and 3-layered distribution process, the 3 layered process (consistent with the prior development) was implemented. As NHBB trips utilise a different VoT value and thus different trip costs, NHBB was estimated separately to the other car trip purposes. Thus different modelled parameters were estimated for the three trip profiles for each of the 5 user classes assigned to the network.

The average trip lengths by user-class for the various stages are provided in Table 5-9. Although the Initial Demand matrix was used as a basis for the distribution, the process to derive it was such that it would not be possible to replicate the performance very closely within the model. Thus, the calibration process focused on key performance indicators such as screenlines and aggregate travel demand between regions to assess the performance of the trip distribution model, rather than the average costs (the average trip costs are within 20% of the initial demand value) or the trip profiles.

The corresponding trip distribution profiles (which are based on the generalised cost of the trip (time in minutes) are displayed in Figure 5-13 (non-business vehicle trips), Figure 5-14 (business private vehicle trips), Figure 5-15 (LCV), Figure 5-16 (MCV) and Figure 5-17 (HCV). The profiles show the majority of trips are less than 100 generalised minutes per trip, but have a lengthy tail that extends out appreciably to around the 300 minute mark for most user-classes. This is not possible with a standard gamma function and highlights the improved performance that the multi-layered trip distribution process provides.

Due to the lack of intra-zonal trips, intra-zonal trips were factored up to yield a sensible proportion of trips within the zone. Although these trips are not assigned to the network, it is important for generating the right level of demand on the network, thus sharp peaks at the start of the profiles are generated for the initial demand to represent the intra-zonal travel. However, as mentioned above, the focus was not on replicating the prior, rather producing a sensible base year model with robust and realistic results.

5.8.1 Future Year Trip Distribution

This model is a mixture of urban and rural environments. Standard 4-step strategic modelling literature is focused around the metropolitan environment, where most things are readily available and trip making is easy due to the close proximity of places like the CBD, shopping centres, sporting grounds, restaurants etc. Thus when changes are made to the network, and travel is easier and faster, users are far more willing to pay any additional trip cost to access the new areas that are opened up to them due to the change in the network. However, the study area for this model is predominantly a rural setting, where trips are much longer, local short trips are less possible and improvements to the network provide increases across long distances.

Thus based on past experience with similar models, it was decided that the trip distribution model be fixed for each model year's land use scenario. That is, network improvements do not alter the travel distribution, only changes to the land use. It is viewed that any improvements to the network will not entice additional travel due to the much longer travel distance and times required to make trips on average. In essence, this assumption infers that network improvements in a rural environment will alter route choice, but will not induce additional trips due to the cost of the trip (time, travel behaviour (clustering activities into one large day trip as opposed to making single trips across several days), and running costs of the vehicle). It should be noted that commercial vehicles are driven by industry demand and thus, redistribution of the land use is expected to drive the induced demand as travel becomes easier in the designated areas.

The gamma function: $f(x) = \alpha\, x^{-\beta}\, e^{-\gamma x}$

Where: x=trip cost in generalised minutes; ~⁞ ⁞and ¥⁞are estimated.

Table 5-9: Trip Distribution Gamma Function Values

Trip Profile	Parameter	PV				LCV	MCV	HCV
		HBW	HBO	NHBO	NHBB			
1	Alpha	19,565	18,000	1125	7,500	15,000	34,000	2000
1	Beta	0.4	0.4	0.4	0.7	0.1	0.2	0.15
1	Gamma	-0.025	-0.025	-0.025	-0.051	-0.035	-0.026	-0.02
2	Alpha	30.43	28	4.67	15	100	100	1.5
2	Beta	1.1	1.1	1.1	1.1	0.6	0.9	1
2	Gamma	-0.013	-0.013	-0.013	-0.017	-0.014	-0.015	-0.01
3	Alpha	65	60	10	30	2	35	0.075
3	Beta	0.6	0.6	0.6	0.6	1.6	1	1.6
3	Gamma	-0.0075	-0.0075	-0.0075	-0.01	-0.022	-0.013	-0.012

Table 5-10: Weighted Average Trip Costs (Mins)

Input	PV NB	PV B	LCV	MCV	HCV
Initial Demand	70.38	46.49	52.24	64.70	89.34
Modelled	84.79	41.64	63.91	76.07	99.83

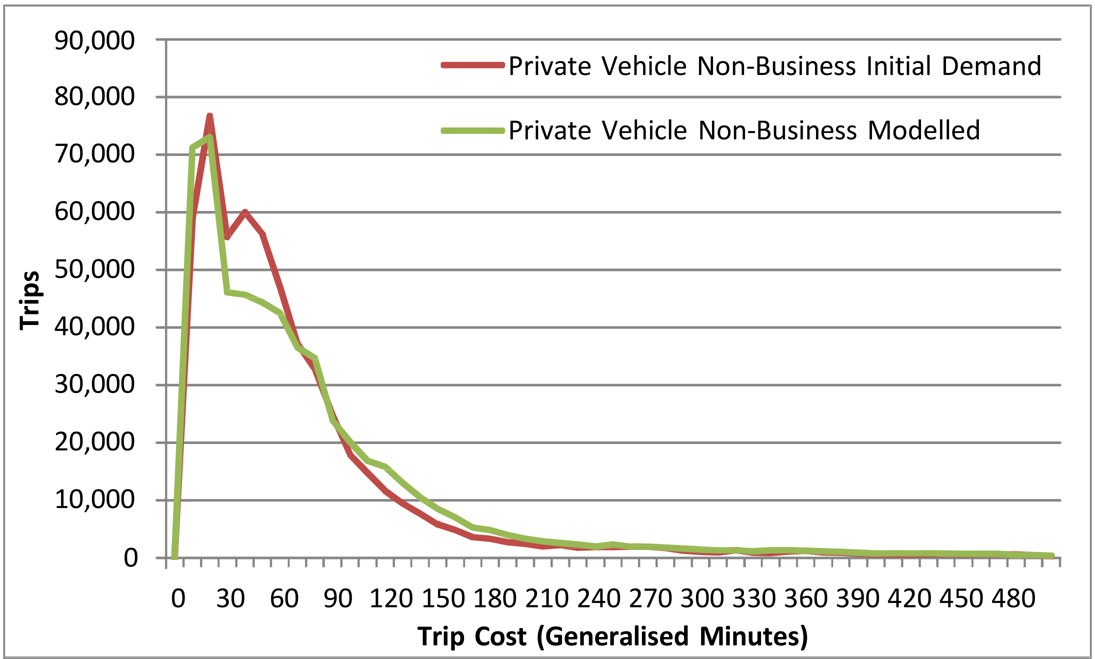


Figure 5-13: Trip Distribution Profile – Non-Business Private Vehicle Trips

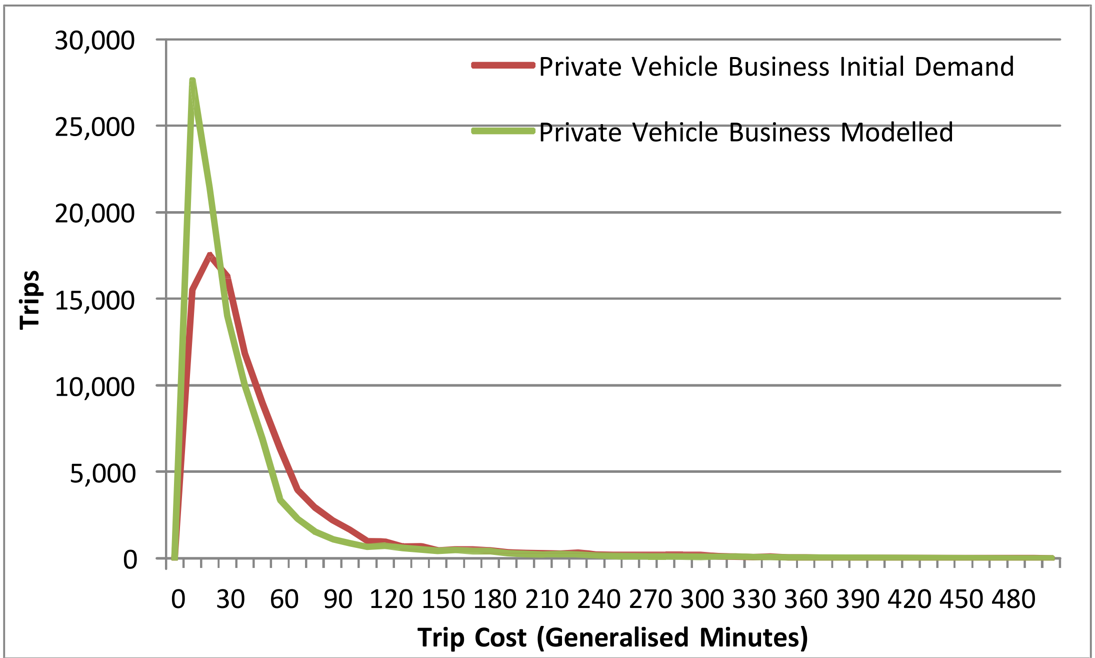


Figure 5-14: Trip Distribution Profile –-Business Private Vehicle Trips

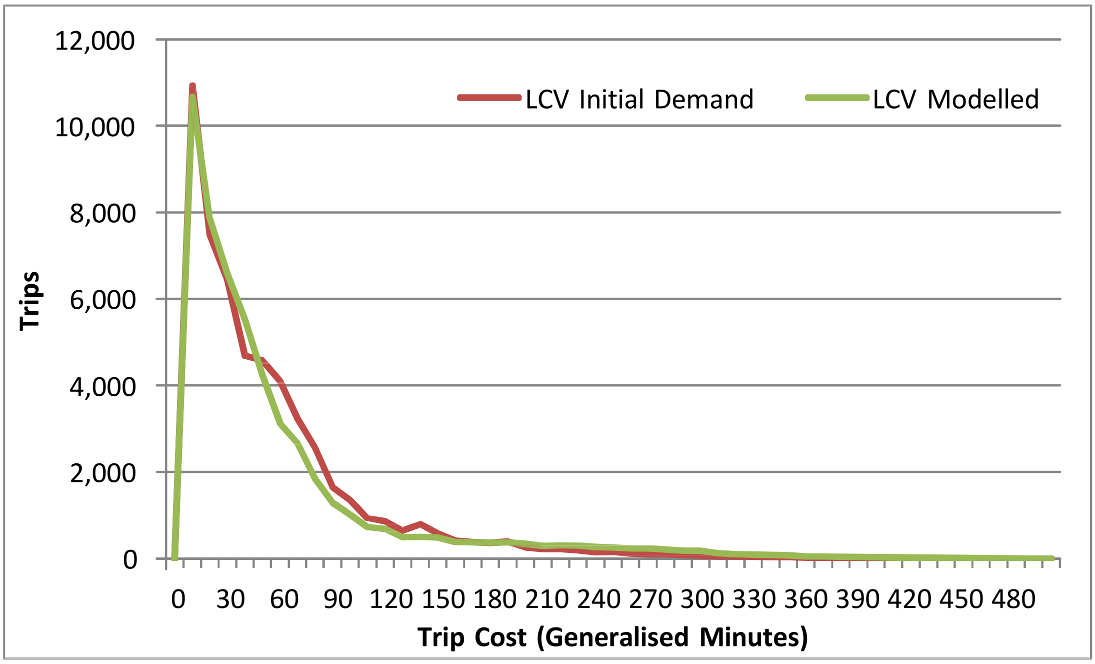


Figure 5-15: Trip Distribution Profile – LCV

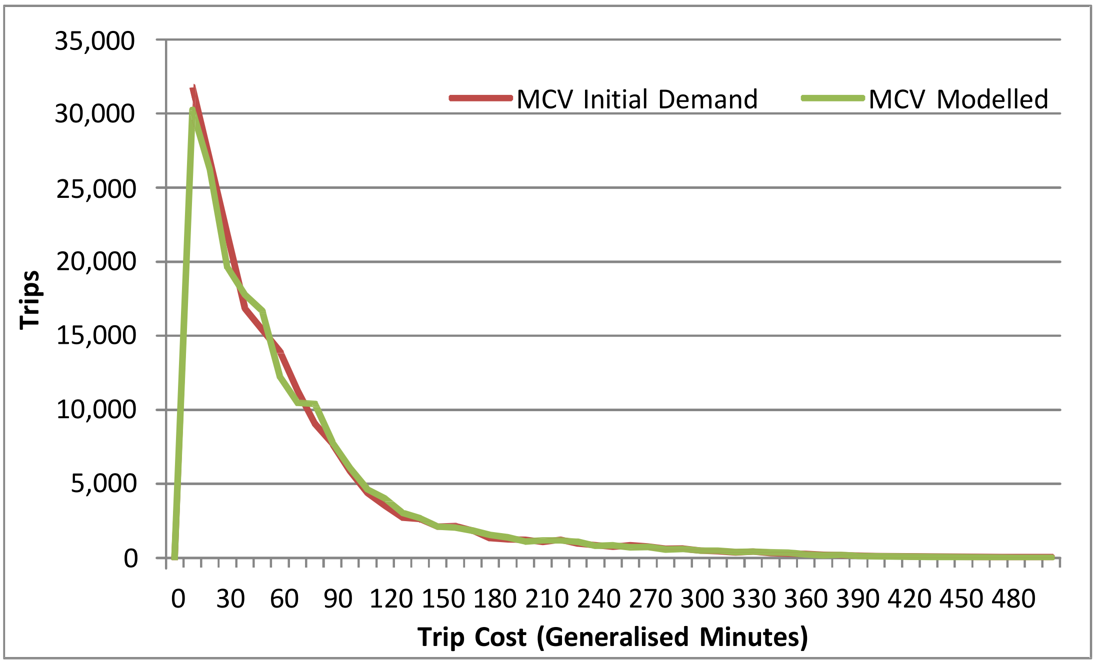


Figure 5-16: Trip Distribution Profile – MCV

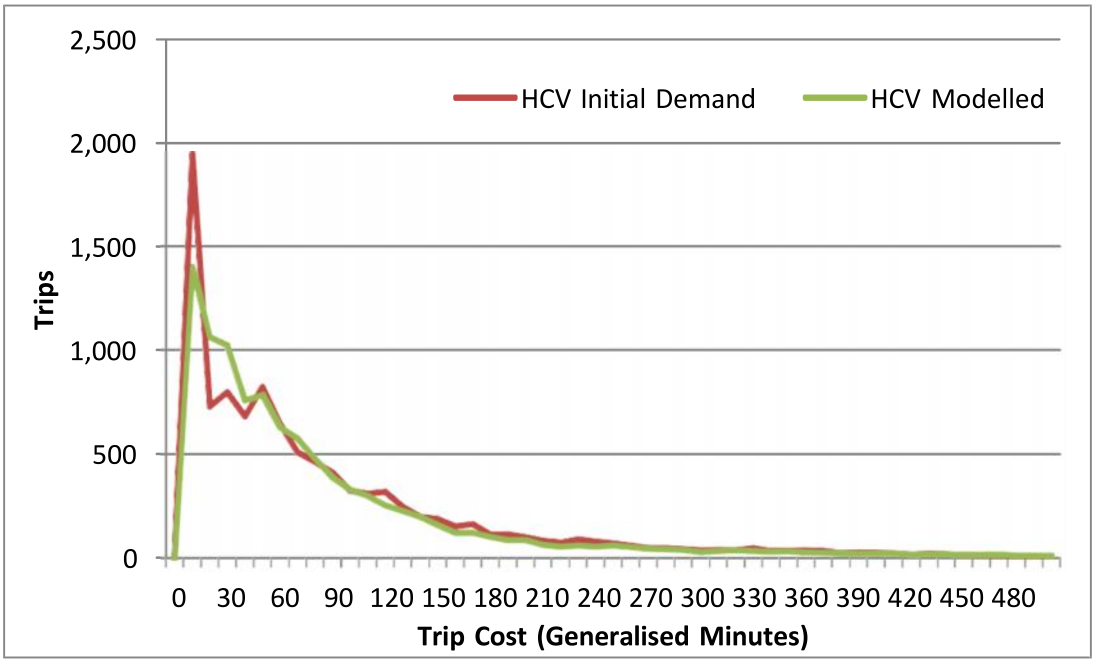


Figure 5-17: Trip Distribution Profile – HCV

5.9 CV Model

Ideally a Freight model instead of a Commercial Vehicles model would be developed and implemented. A freight model can model supply chains as opposed to individual trips and also forecasts demand based on commodity types which then in turn is converted to equivalent vehicles needed to move the goods. However even where detailed survey data has been collected, at best these models are big, difficult to calibrate, complicated and take a long time to develop. In this instance, we had limited data and time so the more common approach of developing a commercial vehicles model which models individual freight trips was used.

The Commercial Vehicles model produces average weekday OD vehicular trip matrices for Light, Medium and Heavy Commercial Vehicles separately. As with private vehicles, external demand for these user classes is accounted for in the Externals Model. With the understanding of the potential development within the study area and how it might affect travel along the corridor of interest, trip generation models were developed to allow the maximum level of flexibility in terms of travel demand being sensitive to changes within land use. The base year demand is created by calculating Trip Ends by user class (using trip rates as displayed in Table 5-11) and then distributing the Trip Ends by user class (using the process described in the Trip Distribution section).

The Trip Generation rates were estimated using multi-linear regression (see equation below), while the distribution models were estimated via gamma functions (as mentioned above). The resultant internal demand by user class for the base and project years (assuming Medium Growth) is provided in Table 5-11. This table demonstrates consistent growth between car and commercial vehicles with CV growth fractionally higher.

$f(z) = a_1x_{1Z} + a_2x_{2Z} + a_3x_{3Z} + a_4x_{4Z} + \ldots + b$

Where: x_{1z}, x_{2z} are land use parameters x_1 and x_2 for zone z, and a_1, a_2 are estimated

Table 5-11: Commercial Vehicle Trip Generation Rates

Employment Category	Colombo, Gampaha and Kandy			Rural Districts		
	LCV	MCV	HCV	LCV	MCV	HCV
Agriculture	0.026	0.117	0.004	0.007	0.018	0.001
Mining	0	0	0	0	0	0
Manufacturing	0.021	0.078	0.005	0.012	0.058	0.003
Utilities	0	1.434	0	0	0	0
Construction	0.048	0	0	0	0	0
Retail	0	0	0	0	0	0
Hospitality	0	0.464	0	0	0	0
Transport	0.063	0	0	0	0	0
Financial	0	0.177	0.025	0	0	0
Public Administration	0	0	0	0	0	0
Education	0	0.333	0	0	0	0
Health	0.114	0	0	0	0	0
Community	0	0	0	0	0	0

Table 5-12: Average Weekday Daily Internal Trips by User Class

Demand	2012	2016	2021	2026	2036
Private	665,200	709,600	767,900	820,800	909,100
Light CV	52,900	56,600	61,300	65,600	72,500
Medium CV	194,100	206,500	222,100	236,000	259,400
Heavy CV	10,200	10,900	11,700	12,500	13,800

5.9.1 CV Growth Using GDP

Advice provided by the economic team regarding growth rates for CV's in developing countries such as Sri Lanka was provided and adopted as an optional input to the model. Growth rates for Commercial Vehicles can now either adopt the initial approach (linked solely to employment projections) or use forecast GDP growth rates. The latter option still utilises the existing trip generation rates and distribution of trips within the study area. However, the total growth for trips within the study area is controlled by the GDP growth rates.

As GDP relates to the entire country, the growth rates that are applied are applied uniformly to all zones, including external trips. The GDP growth rates in Table 5-13 are applied to CV trips when activated and Table 5-14 shows the relative difference of the two methods and the change in total commercial vehicular demand. The demand displayed is a combination of LCV, MCV and HCV trips.

Table 5-13: GDP CV Growth Rates Adopted

2012-2019	2020-2029	2030-2036
5.4%	5.3%	4.9%

Table 5-14: Comparison of CV Growth Rates (Medium Land Use Scenario)

Year	Employment Growth Rate			GDP Growth Rate		
	Internal	External	Growth Rate	Internal	External	Growth Rate
2012	211,980	36,290	-	257,090	36,290	-
2016	227,540	40,010	1.7%	317,140	44,730	5.4%
2021	246,930	45,260	1.6%	411,750	58,090	5.4%
2026	265,450	51,280	1.4%	533,070	75,210	5.3%
2036	301,080	65,950	1.2%	869,980	122,750	5.0%

**Growth rates represent the average growth rate between the current year and the previous modelled year i.e. 2021 growth is the growth between 2016 and 2021.*

5.10 Externals

The externals model accounts for the travel demand that enters/exits the study area. There are 29 external zones for which demand can enter or exit the study area (including the Southern Expressway). The base year external matrices were derived from the initial demand matrices as follows:

- The initial OD matrices were aggregated to the five user-classes
- All internal to internal demand i.e. any trip travelling to/from any zone from 101 to 287 was removed from the matrices.
- A factor for each entry and exit point was then calculated (based on the relevant observed count) to closely match the count:
  - Rounded to the nearest 10 or 5 where appropriate.
  - PV NB and PV B trips were combined at this step to calculate a single factor by entry/exit point to be applied to both PV NB and PV B trips.
- The derived entry (row) and exit (column) factors were then applied to the respective row and columns of the matrices.

Due to the time constraints and lack of available land use data outside of the study area, growth rates were applied as follows:

1. A-Class roads received an annual compound growth rate of 3%
2. B-Class roads received an annual compound growth rate of 2%
3. External Zone 1 received a weighted annual compound growth rate of 2.6667% based on the fact it represents traffic from both an A-Class road and a B-Class road.

The total demand by user-class for external travel into/out of the study area is displayed in Table 5-15. External traffic accounts for less than 12% of the demand in any given year.

Table 5-15: Average Weekday Daily External Trips by User-Class

Demand	2012	2016	2021	2026	2036
Private	49,400	54,700	62,100	70,600	91,500
Light CV	6,100	6,700	7,600	8,500	10,900
Medium CV	28,500	31,500	35,600	40,400	52,000
Heavy CV	1,700	1,800	2,100	2,400	3,100

5.11 Assignment

Trip assignment is where trip tables are loaded, or assigned to the road network based on vehicles following the path of least cost between each origin and destination. This is also where travel time and traffic speeds are calculated.

The assignment of traffic to routes on the network is dependent on the assignment method used and the relative generalised costs (GC) of alternative routes. The generalised cost is calculated as a combination of time, distance (captures vehicle operating cost related costs) and toll costs. The vehicle operating cost and toll are specified as monetary costs then converted to generalised minutes using values of time (VoT) before being added to the travel time.

5.11.1 Generalised Cost (GC)

In the assignment model, path building was based on a generalised cost of the form:

[illegible]

Where
Time = Travel Time (minutes)
Distance = Travel Distance (km)
VOC = Perceived vehicle operating cost (Rs/km)
VOT = Perceived value of time (Rs/hr)
Toll = Toll cost (Rs)

A 24-hour multi-class model, where the vehicle demands are segmented and different choice parameters are applied to each class, was used in the assignment model. The following vehicles class segments were used in the model:

- Private Car Non Business
- Private Car Business
- Light Commercial Vehicles
- Medium Commercial Vehicles
- Heavy Commercial Vehicles

Choice parameters for each vehicle class are summarised in Table 5-16.

Table 5-16: NESTM Routing Parameters (2012 Rs value)

Trip Purpose	Parameters	
	VOC (Rs/km)	VOT (Rs/hr)
Private Car Non Business Purpose	8	186
Private Car Business Purpose	8	466
Light Commercial Vehicles	8	844*
Medium Commercial Vehicles	13	844*
Heavy Commercial Vehicles	32	844*

** weighted average of light, medium and heavy commercial vehicles*

The values of time as shown in Table 5-16 were adopted from previous research undertaken by the Sri Lankan government and the University of Moratuwa. Values of time based on research on international values adopted on other projects were adopted as optional input to the model. Values of time for each model scenario are listed in Table 5-17.

Table 5-17: NESTM Routing Parameters – Value of Time (2012 Rs value)

Trip Purpose	Value of Time (Rs/hr)				
	Conservative	Improved Connections	Mid-way	GDP linked CV Growth	Ultimate Development
Private Car Non Business Purpose	186	186	237	237	284
Private Car Business Purpose	466	466	592	592	710
Light Commercial Vehicles	844*	844*	301	301	361
Medium Commercial Vehicles	844*	844*	1359	1359	1631
Heavy Commercial Vehicles	844*	844*	4459	4459	5351

** weighted average of light, medium and heavy commercial vehicles*

5.11.2 Delay Function

Delay function is used to calculate travel time on each link of the road network. The standard Bureau of Public Roads (BPR) formula was used in the traffic model:

Where

Time = Travel Time (minutes)

T_0 = Free Flow Time (minutes)

TCCOEFF = Travel time function coefficient

TCEXP = Travel time function exponent term

NESTM uses a coefficient of 2 and exponential of 4 which produces a realistic representation of capacity restraint in Sri Lanka road network.

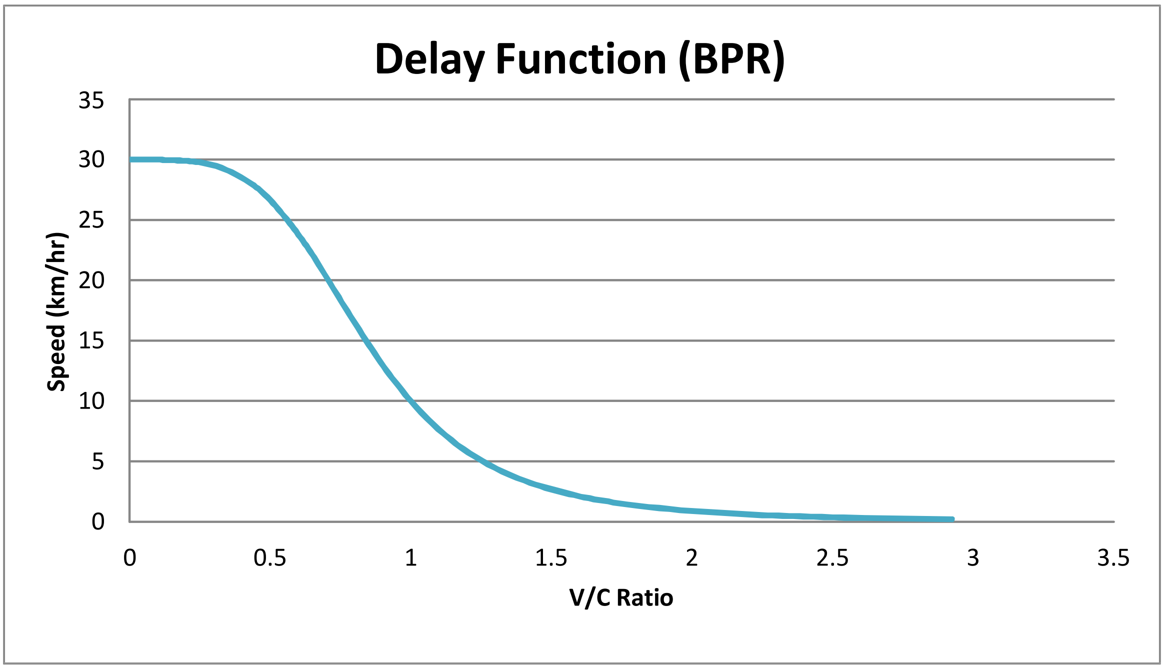


Figure 5-18: Form of BPR Delay Function

5.11.3 PCU Assignment

Due to the high proportion of commercial vehicles within the study area, a decision was made to modify the assignment from using vehicles to PCUs. The purpose of this modification was to better reflect the loss in capacity due to the large volume of medium and large commercial vehicles on the roads. Factors of 1.3 (for Medium Commercial Vehicles) and 2.3 (for Heavy Commercial Vehicles) were adopted. These factors are based on medium commercial vehicles by in large representing rigid trucks and heavy vehicles representing articulated trucks. These factors have been adopted from a metropolitan Australian Strategic Transport Model.

5.11.4 Toll Model Methodology

Two basic options were considered for the toll choice modelling of NESTM:

Route Choice Method

In a route choice model, the choice to use a tolled road is made within the normal route choice model which is a component of all traffic models. The route choice model is a where the relative costs of all alternative paths between each origin and destination are calculated and the least cost paths determined. This will generally involve an iterative process so that an equilibrium point is reached between the paths used and the delays experienced (the objective is to reach a point where a motorist cannot reduce their travel costs by choosing a different path). The input to this model is the total demand between each O-D pair for each market segment, and the outputs are the flows on the tolled and untolled routes.

Logit Model

The Logit model in NESTM determines the probability of the vehicles between each origin and destination using the toll road (and consequently also those who will not). The inputs to the model are the relative costs of the two choices, and the output is the proportion of users willing to pay the toll to use the toll route. This probability is then used to segment the demand into users and non-users, which are then loaded to separate road networks within the route-choice model. Those who have been pre-determined as not using the tolled route will not have access to the tolled route and hence be forced to use the alternative. Those who have been determined will use the toll route have access to the toll route.

5.11.5 Adopted Approach

The route choice method is simpler to implement and can easily test alternative toll location strategies. It cannot however accommodate complex toll strategies, including toll caps and discounts.

A logit choice model can handle more complex strategies such as caps and discounts. However, the model has to be configured specifically for each strategy and testing alternative strategies can involve significant re-structuring of the models. These types of models provide a response more representative of the distribution of attributes within a demand segment, and they can generally be calibrated to reflect surveyed attributes (e.g. the distribution of VoT).

Both approaches, if implemented appropriately are valid toll models and are commonly used. It is also not unusual for both types to be used for a particular project.

For the purpose of this study, a combined route choice and logit approaches were used. Logit models were used for the traffic flow and revenue predictions on the Northern Expressway as more complex toll strategies were required to be investigated. On the other hand, a route choice method was used on Southern Expressway, Outer Circular Highway (OCH) and Colombo – Katunayake Expressway (CKE) and Kandy Ring Road (in Phase 2 only as investigation of different toll strategies on these roads is outside the scope of this study.

5.11.6 Toll Logit Model

Logit toll diversion function, commonly used in toll studies, was used to predict the demands on Northern Expressway (toll road). The form of the logit model is as shown below.

Where:

P_{toll} = probability of choosing a tolled route

λ = scale parameter (i.e. coefficient defining the 'steepness' of logit slope)

C_{nt} = generalised cost of best non-tolled route

C_t = generalised cost of tolled route

The generalised cost was calculated based on perceived value of travel time and operating costs as detailed in Section 5.11.1. Toll charges are detailed in the following Section 5.11.7. The scale parameter (λ) was derived from the willingness to pay (WTP) response from the OD surveys. The WTP response from the survey and the calibrated logit curve are shown in Figure 5-19. The calibrated value of scale parameter (λ) is 0.075 for all vehicles.