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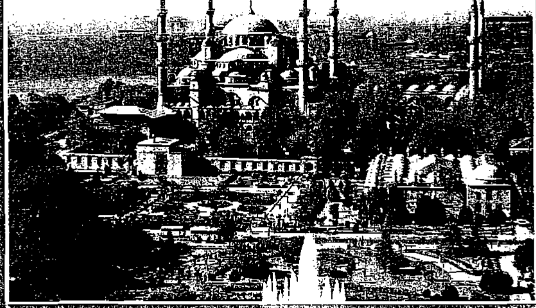

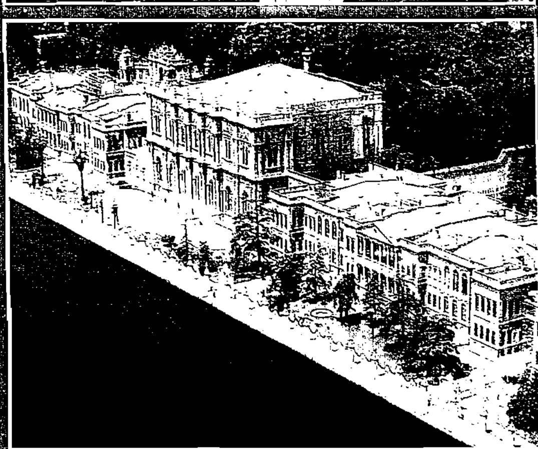

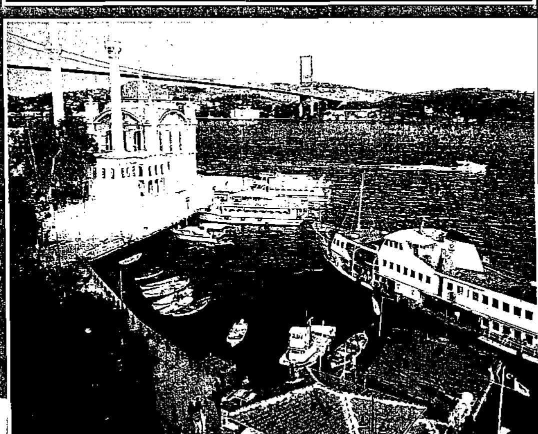

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DEVELOPING A GENERIC ALGORITHM FOR ASSESSING FINANCIAL FEASIBILITY OF BUILD-OPERATE-TRANSFER ROAD PROJECTS

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Abstract

This paper is concerned with developing a detailed generic algorithm to assist in conducting a comprehensive and structured financial feasibility assessment of private investment in road projects. The developed algorithm constitutes eight stages, namely defining the objectives of the project, traffic analysis, conducting Environmental Impact Assessments (EIA), estimation of potential costs, forecasting of project revenues, estimation of key financial criteria and comparing these with project financial objectives so as to determine project viability. Finally, the eighth stage is concerned with minimising uncertainties and risk through a three level procedure of conducing scenario analysis, sensitivity tests and risk analysis. Several conclusions are deduced, the most important of which is the importance to forecast and analyse the development of traffic flows over the life of a BOT road project. This forecast should particularly run over the time period considered for evaluating the proposed BOT scheme. The paper revealed the importance of using disaggregate traffic demand forecasting models for BOT road projects. Such quality traffic models are meant to forecast demand for different types of vehicles throughout the operation period rather than at peak periods. This is crucial for the rigor required in the forecasting of revenue, which is detrimental for establishing the project viability. The paper identified a number of parameters as critical to the financial success of a BOT road project. These include: length of the concession period, toll categories and rates, traffic growth rates, discount rate, etc.

Keywords: Feasibility assessment; Road projects; Build operate transfer
Topic Area: E1 Assessment and Appraisal Method w.r.t. Transport Infrastructure Projects and Transport Activities

1. Introduction

The eligibility of a Build-Operate-Transfer (BOT) road project depends on meeting several criteria, including economic, financial, environmental, technical, and legal criteria. In a BOT road project, the sponsoring highway agency is expected to conduct an economic feasibility study to verify the project worthiness from the society point of view, as well as a financial feasibility study to justify its choice of a bankable project and to assist in negotiating the concessionaire during the bidding and contracting phases. In addition, both the concessionaire and the financier are expected to undertake a financial assessment aimed at demonstrating the project financial viability and worthiness. The concessionaire wants to make sure that his investments would be worthwhile. On the other hand, the financier wants to guarantee project success and hence ability of concessionaire to service his debts.

This paper is concerned with developing a conceptual and computational algorithm for conducting a comprehensive and structured financial feasibility assessment of private investments in road projects, particularly those projects financed through the BOT mechanism. The structure of the developed algorithm constitutes generic stages, procedures, steps and models envisaged to assist sponsors, concessionaires as well as financiers in identifying bankable road

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projects. The first stage is concerned with defining the objectives of the project to provide the necessary background against which appraisal of alternatives is performed. Traffic analysis and forecasts presents the core of the second stage. The third stage involves conducting an environmental impact assessment, while the fourth is concerned with the estimation of potential costs. In this context, costs and risks in a BOT road project are identified in the paper and allocated in a matrix format onto the key stakeholders. In the fifth stage a forecast of project revenues is conducted. Stages six and seven are concerned with the estimation of key financial criteria and comparing these with project financial objectives so as to determine project viability. Finally, the eighth stage is concerned with minimising uncertainties and risk through a three level procedure of conducting scenario analysis, sensitivity tests and risk analysis.

The paper revealed the importance of using disaggregate traffic demand forecasting models for BOT road projects. Such models are meant to forecast demand for different types of vehicles throughout the operation period rather than at peak periods. This is crucial for the rigor required in forecasting revenue, which is detrimental for establishing the project viability. The paper also identified a set of parameters that are considered critical to the financial success of a BOT road project. These include: length of the concession period, toll categories and rates, traffic growth rates, discount rate, etc. Scenario analysis, sensitivity tests and risk analysis ought to be conduced taking into account the effect of variations in such parameters on projects viability.

2. Generic algorithm for assessing financial feasibility of BOT road projects

The algorithm developed and described in this paper encompasses stages, procedures, steps and models envisaged to assist sponsors, concessionaires as well as financiers in identifying bankable road projects. The structure of the developed approach constitutes eight stages as shown in figure 1. These are explained below.

Stage 1: Identification & Quantification of Objectives. This stage is concerned with representing project objectives into several expected quantifiable financial indicators.

Stage 2: Traffic Analysis & Road Design. The traffic analysis is meant to produce traffic forecasts over the concession period. These forecasts act as input serving five important purposes namely in:

1. capacity analysis and geometric design of the proposed road,
2. estimation of Equivalent Single Axle Load (ESAL) over the design life of the road and consequently in the structural design of the proposed road,
3. assessing environmental impacts of the road and cost of proposed mitigation measures,
4. estimation (forecast) of costs expected as a result of design, construction, operation, maintenance, etc. of the proposed road project, and
5. estimation (forecast) of revenue expected to be generated as a result of tolls and fees collected for services provided by the road project.

A traffic model is meant to act as an appropriate representation, through a set of mathematical equations, of the effect of changes in: the road network, the socio-economic and land-use activities of an area; on the development of travel demand. These changes form the input to the model for future planning horizons. Forecasts of traffic demand, its distribution and assignment for a particular year are obtained as outputs of the model. Quality traffic models are warranted to forecast demand for different types of vehicles throughout the operation period rather than at peak periods. This is crucial to ensure quality forecasting of revenue which is detrimental for establishing project's viability. A comparison showing the significance of the role transportation modelling in privately financed road projects versus public ones is detailed in Carbonaro (1995).

Stage 3: EIA & Estimation of Cost of Environmental Mitigation Measures. In this stage a full EIA is conducted with all its components including screening, scoping, analysing significant environmental impacts and identifying potential mitigation measures throughout the pre-construction, construction, operation and maintenance phases of the road project. Such EIA has to be approved by the concerned environmental authority. Finally, agreed mitigation measures are quantified to represent a main component of costs incurred by the project.

Stage 4: Cost Estimation (Forecast). In this stage all types of costs are identified and thoroughly itemised. These costs are valued throughout the life of the concession taking into consideration inflation rates and shadow pricing. The main types of expected costs are costs incurred during design, construction, operation, maintenance, and implementation of environmental mitigation measures as well as debt service costs. Such cost estimations are done on a year by year basis over the concession period of the BOT road project.

Stage 5: Revenue Estimation (Forecast). This stage can run parallel to the cost estimation stage. In this stage and depending on; traffic forecasts, toll rates proposed and toll rate indexation; revenue generated out of toll collection is estimated. In addition, revenue expected out of fees collected for providing other types of road services should be also estimated. Such estimations are done on a year by year basis over the concession period of the BOT road project.

Stage 6: Computation of Project Viability Indicators. In this stage, the financial indicators, identified in stage 1 as representative of project's objectives, are computed. This is done using both the cost and revenue streams across the concession period. These streams are discounted using an appropriate discount rate that reflects expected opportunity costs and risks.

Stage 7: Judgment of Project Viability. In this stage a comparison is made between expected and output values of the identified financial indicators. These are utilised to judge the feasibility, viability and effectiveness of the project.

Stage 8: Scenario Analysis/Sensitivity Tests/Risk Analysis. Where a project is ill defined, scenario analysis has to be conducted. In this context, a range of scenarios covering future strategic possibilities that are likely to occur are examined. Possibilities may involve changes in road alignment, as well as in construction operation and maintenance programmes & technologies. Within each of the proposed scenarios, values of key input parameters can change so as to examine the sensitivity of project financial outputs to such variations. Where several parameters are identified through sensitivity tests to affect the project outcome, these should be varied in several different combinations to show their effect. This is known as risk analysis. Parameters identified as critical to the financial success of a BOT road project include: concession period, toll categories and rates, traffic growth rates, discount rate, etc.

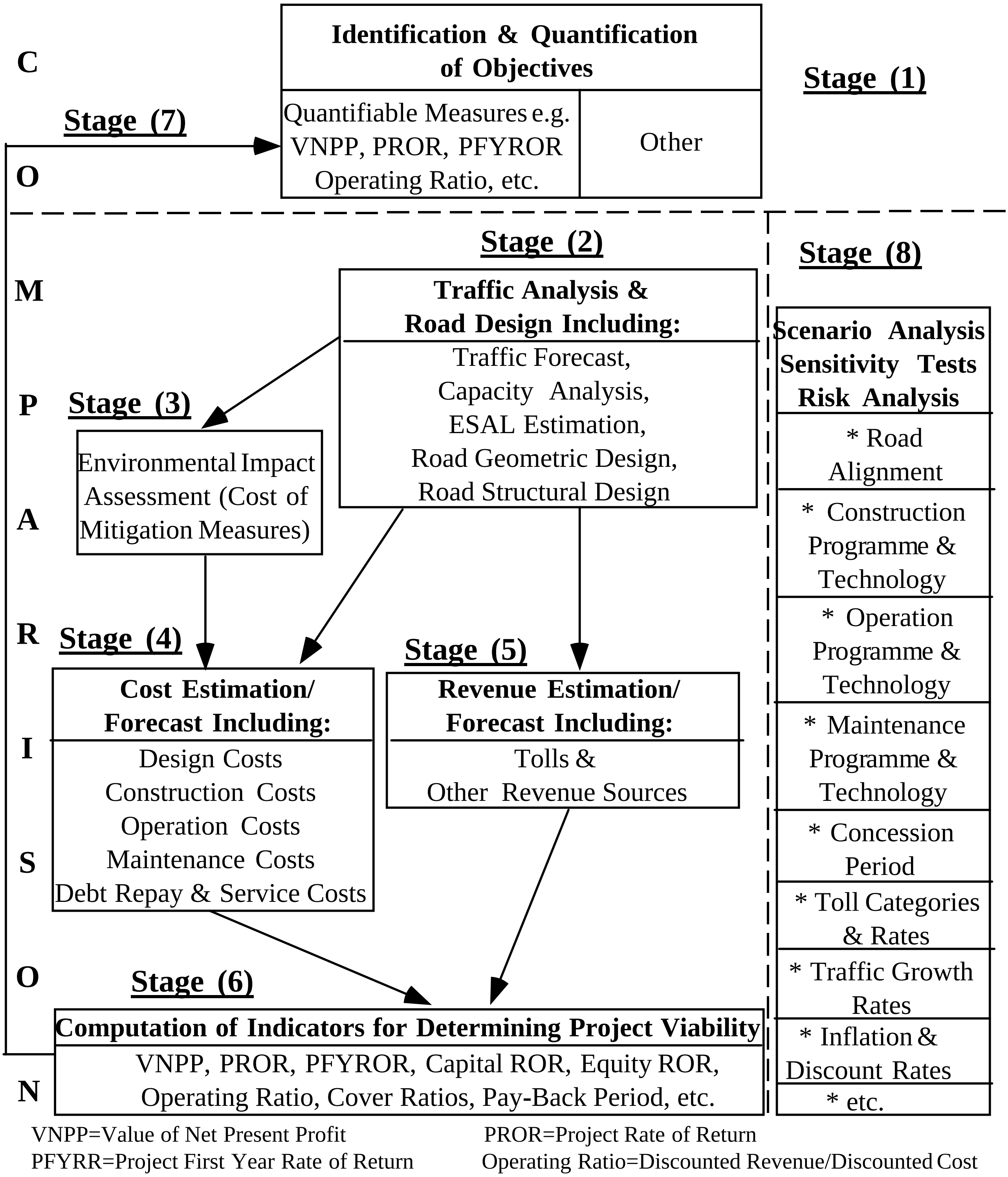

Figure 1: Main generic stages constituting algorithm for assessing financial feasibility for BOT road projects

The main stages and steps of this algorithm are detailed in figures 2 through 5. Detailed procedures and models are thoroughly discussed in the following sections starting with stage 2 i.e. traffic analysis and reaching stage 6 i.e. computation of project viability indicators. These are meant to be read in conjunction with figures 2 through 5.

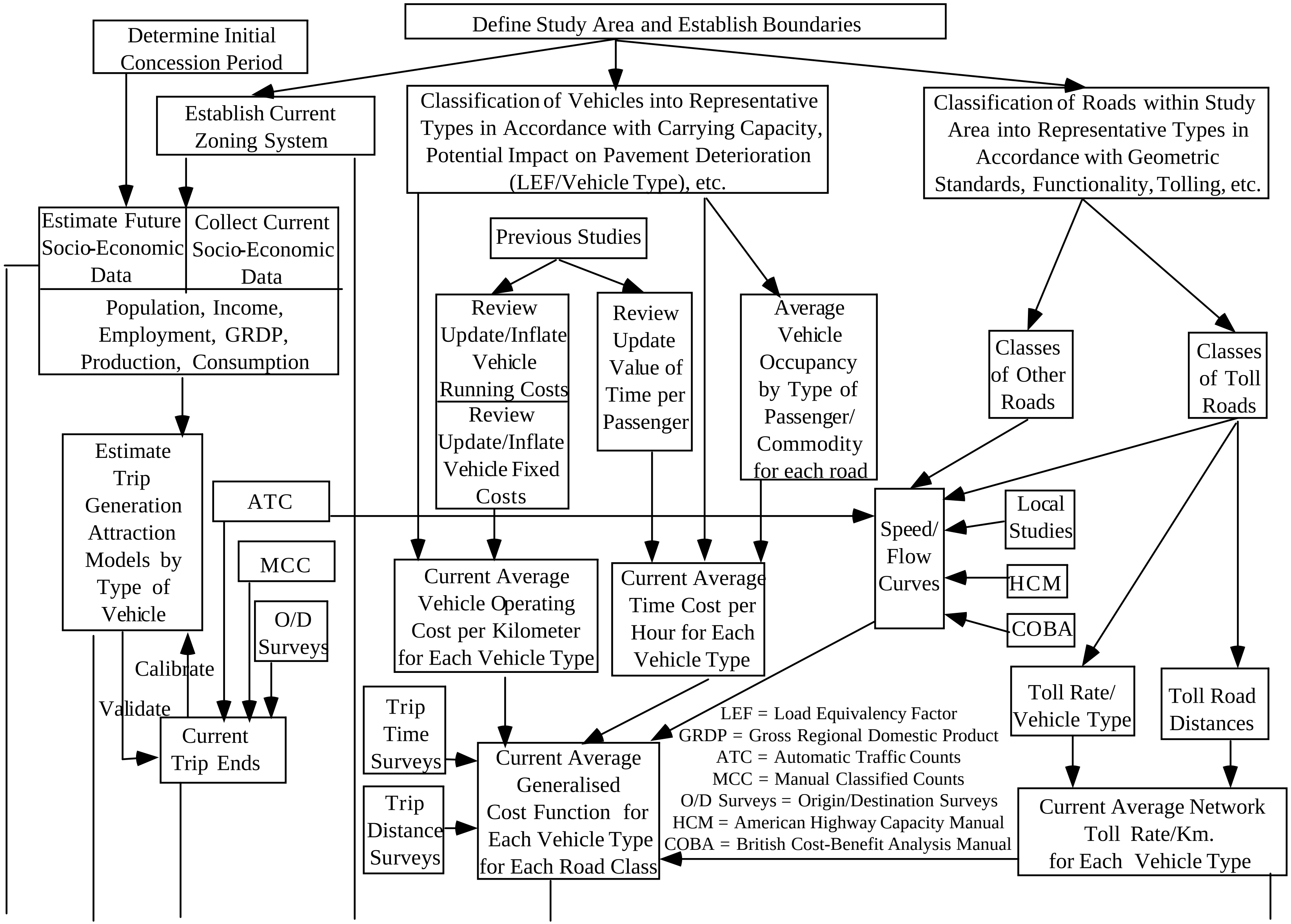

Figure 2: Stages & Steps constituting algorithm for conducting assessment of financial feasibility for a BOT road project

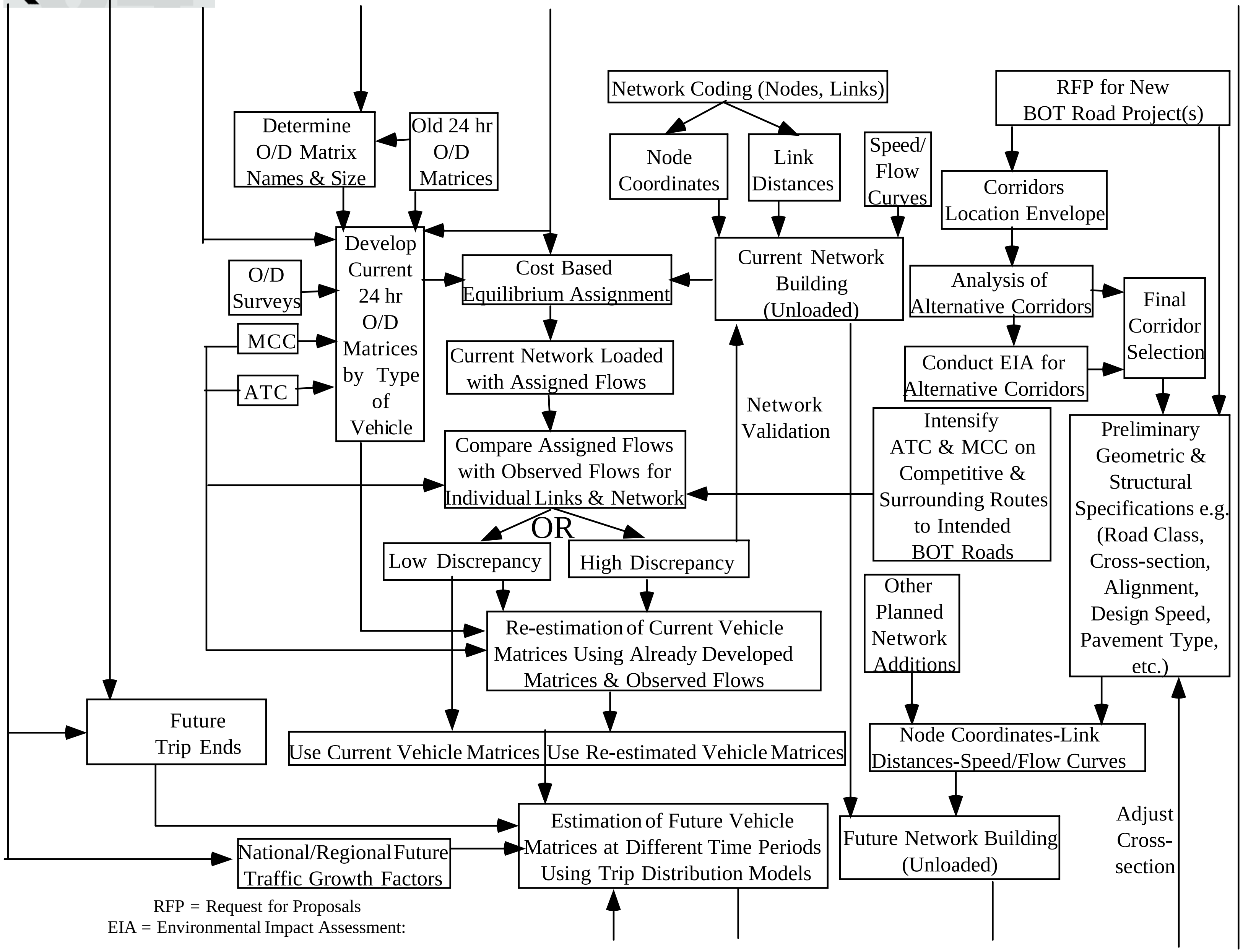

Figure 3: Main generic stages constituting algorithm for assessing financial feasibility for BOT road projects (Continued)

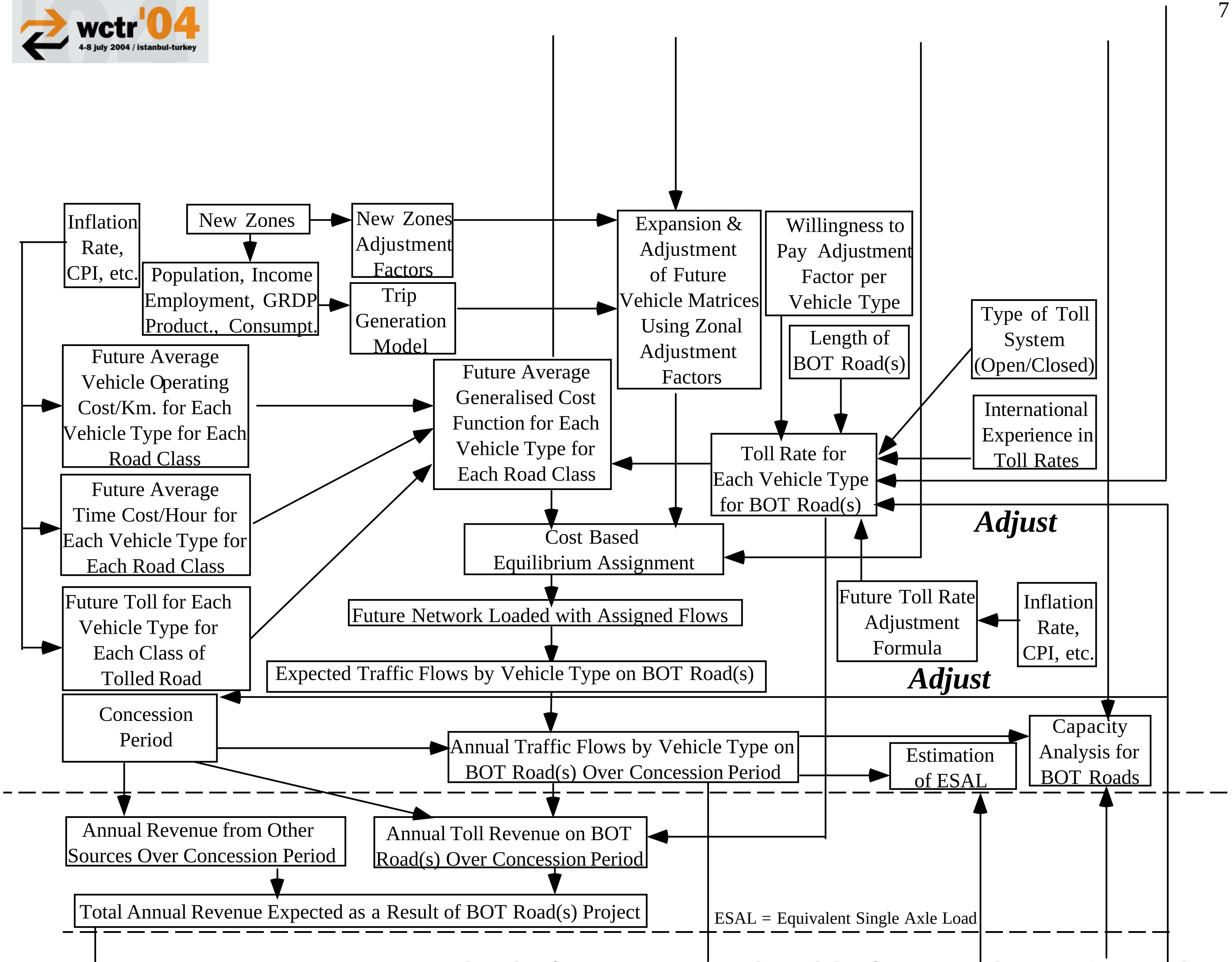

Figure 4: Main Generic Stages Constituting Algorithm for Assessing Financial Feasibility for BOT Road Projects (Continued)

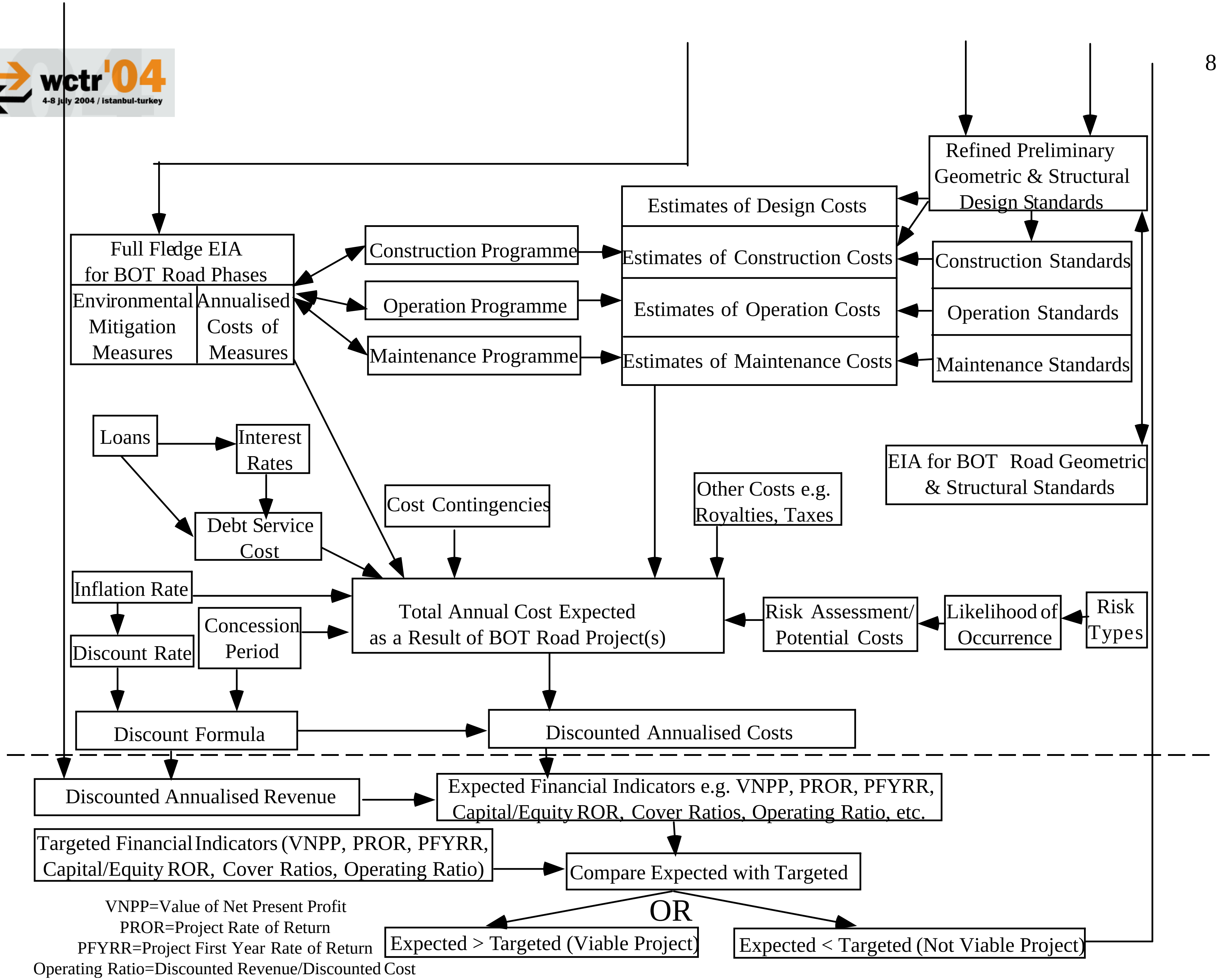

Figure 5: Main Generic stages constituting algorithm for assessing financial feasibility for BOT road projects (Continued)

3. Traffic analysis

It is of vital importance to forecast and analyse the development of traffic flows over the life of a BOT road project. This forecast should particularly run over the time period considered for evaluating the proposed BOT scheme. In order to accurately forecast traffic flows for a BOT road project, a computer-based simulation model ought to be developed. The following presents the steps followed for the development and utilisation of a proper traffic model.

3.1. Define study area and establish boundaries

This is considered a crucial initial step as it sets the scene to detail and level of required work. The study area should include all roads affecting and affected by new BOT road project. It should include land use zones being served by such a network. Boundaries of the study area could be either imaginary lines or actual physical boundaries such as rivers, mountains, sea, road, etc. It should take into account lines of already established administrative divisions.

3.2. Development of a base year zoning system

In order to model the way trips are made throughout a study area, a zoning system should be developed, whereby the study area is divided into several representative divisions, known as internal traffic zones. These would mainly conform with already established administrative boundaries subject to modifications and adjustments tailored to the projects scope. In addition, a number of external zones are determined to represent effect of areas outside the designated study area. These are considered as the main basic units used for simulating trip generation and attraction within a study area. The number of zones in a study area affects the data collection task as well as the estimation of components of the traffic model. Socio-economic and travel pattern data used to estimate trip generation models is collected for each of the considered traffic zones.

3.3. Classification of roads into representative types

In this step, the road network within the study area is thoroughly reviewed. Such network should be classified either in accordance with already established classifications or being reclassified for purpose of the study. Road classification is basically dependent on the existing geometric characteristics, level of access control, average travelling speeds, type of traffic, length of trips, functionality, etc. Typical American classifications include freeways, multilane and two lane highways, see USDOT (2000). Recently, the UK Department of Transport (UKDOT) provided a comprehensive classification and sub-classification of roads according to their functionality. The main UKDOT road classification are urban (6 sub-classifications), suburban (6 sub-classifications), and rural (9 sub-classifications) roads, see UKDOT (2003). Furthermore, all tolled roads within study area should be identified and classified.

3.4. Classification of vehicles into representative types

This step is concerned with the classification of vehicles using the road network within the study area into representative types. There are several basis for such classification, each depending on the objectives of the analysis. In the context of conducting a financial feasibility study for a tolled BOT road, vehicles ought to be classified in accordance with their carrying capacity and their potential impact on pavement deterioration (represented by Load Equivalency Factor/Vehicle Type). These two parameters are considered significant in affecting the choice of appropriate toll rates and hence in determining potential benefits that vehicles incur and damage that vehicles may cause. Typical generic classifications include: passenger cars, buses, minibuses, and several types of heavy goods vehicles.

3.5. Determination of a concession period

In a BOT road project, the period over which financial evaluation and hence the traffic forecasts are conducted, is expected to be equal to the concession period. In the UK, road schemes benefits and costs are assessed over a 30-year period from scheme opening. It is also common practice to consider the concession period for a BOT road scheme to be in the range of 30 years from initial year of opening to traffic. However, while conducting the feasibility study, this period can be adjusted in an effort to achieve required rate of return on invested capital.

3.6. Collection of socio-economic data & conducting traffic and travel surveys

In order to develop and estimate trip generation and distribution models, the following data should be collected for each of the traffic zones in the study area.

- Current socio-economic data based on available information, in addition to estimating future socio-economic data should be estimated taking into consideration expected economic status of the study area as a whole as well as alternative development scenarios. A typical set of socio-economic data include population, income, employment, Gross Regional Domestic Product (GRDP), production and consumption of goods.
- Current trip patterns obtained by conducting Automatic Traffic Counts (ATC), Manual Classified Counts (MCC) and Origin/Destination (O/D) surveys. ATC are concerned with counting link volumes. MCC are concerned with classifying link flows into considered vehicle classes. Traffic counts are carried out in order to assist in model calibration and validation. In addition, it provides data on the breakdown of traffic flows by vehicle type across the road network within the study area. On the other hand, O/D surveys are concerned with characterising trips in accordance with their pair of origin and destination, frequency, purpose, time, in addition to other factors affecting trip patterns.

3.7. Calibration of trip generation/attraction models

Based on the above collection of socio-economic data, traffic counts and travel surveys; trip generation models by type of vehicle can be developed. A trip generation model is meant to simulate the generation/attraction of zonal trips (i.e. number of trips generated from/attracted to a particular zone). Several methods exist for estimating trip generation/attraction models. These include, simple traffic growth rate models, elasticity models showing changes in travel demand with respect to changes in socio-economic parameters, regression models and category analysis based models. It is common practice to develop trip generation/attraction models using multiple regression formulation, where the number of trips originating/attracted is the dependent variable which varies with changes in the independent socio-economic variables such as population, employment, GRDP, ..etc. The number of points used to develop the regression model is equal to the number of internal and external zones representing the study area. The following represents formulation of typical trip generation and attraction models.

$$\text{Trips Generated}_{(i, VT)}^{(P)} = a_{(VT)}*\text{population}_{(i)}^{(P)} + b_{(VT)}*\text{GRDP}_{(i)}^{(P)} + \text{constant-G} \quad (1)$$

$$\text{Trips Attracted}_{(i, VT)}^{(P)} = c_{(VT)}*\text{employment}_{(i)}^{(P)} + d_{(VT)}*\text{working areas}_{(i)}^{(P)} + \text{constant-A} \quad (2)$$

Where: i = 1, ..Z (Number of Trip Generating Zones) j = 1, ..Z (Number of Trip Attracting Zones)
a, b, c, d = calibration parameters showing the effect of each of the independent variables on the generation/attraction of trips. VT = Vehicle Type (1,.......NVT) P = Present Values
constant-G/-A= Constant values representing unexplained part of the variation in trips generated/attracted

3.8. Development of appropriate speed/flow curves

A major component of describing a road network is to establish the capacity and speed/flow relationship representing the traffic conditions for each link constituting the network. If local studies exist that classified the national road network into different classifications as well as developed local speed/flow relationships for each road classification, these should be examined and possibly adopted. However, in most developing countries, such studies either do not exist or are currently being undertaken. In such circumstances speed/flow curves of the American Highway Capacity Manual, see USDOT (2000) or those of the British Cost Benefit Appraisal

Manual, see UKDOT (2003); can be adapted to suit local conditions. For each road classification and sub-classification, these manuals, through long research experience, provide representative speed/flow curves.

3.9. Estimation of base year average vehicle operating cost

The estimation of Vehicle Operating Cost (VOC) serves three purposes:

1. It constitutes one of the main components used in formulating Generalized Cost Functions (GCF). GCF are used to represent deterrence factors faced by drivers in making their route choice decisions. GCF are necessary input to assignment models used to simulate drivers' behavior.
2. It is used in the computation of economic benefits in terms of society savings in VOC as a result of construction and operation of the proposed BOT road scheme.
3. It is used for computation of road users' benefits in terms of savings in VOC. This acts as a main input in assisting the concessionaire to determine potential toll rates covering such benefits and generating extra income.

Components of VOC can be categorised into two main categories, namely fixed and running costs, these are detailed in table 1. Fixed costs are time dependent. On the other hand, running costs depend on: rates of consumption such as fuel consumption, rates of wear and tear such as tyre wear and tear, as well as rates of utilisation such as battery utilisation. All these rates are kilometer based. Values of such rates vary in accordance with travel conditions on the different road classes. In particular these values are speed dependent. In case previous studies exist that estimated average VOC by type of vehicle, these values should be revised and updated/inflated to account for current and future conditions. It is always recommended to conduct local studies to capture such variations, however this is not usually possible due to time and other resource constraints. In most cases, values from other studies are borrowed and adapted. For ease of computation, it is common practice to convert running costs into kilometer based costs.

Table 1: Generic categorisation and itemisation of VOC

Vehicle Operation Costs (VOC)	
Fixed costs	**Running costs**
Capital costs (depreciation), Long term interest costs, Crew costs, Licensing & Insurance fees	Fuel, Oil, Lubricant, Tyre, Battery, Maintenance spare parts, Maintenance labor costs

The following is a representation of computation of VOC/Km taking into consideration variations in accordance with vehicle and road classifications.

$$VOC_{(VT)}^{(P)} = \text{Fixed Costs}_{(VT)}^{(P)} + \text{Running Costs}_{(VT)}^{(P)} \quad (3)$$

3.10. Estimation of base year average value of time

Time costs is an important component of travel cost. The derivation of a representative Value of Time (VOT) for each vehicle type is a vital step that serves the following purposes:

1. It constitutes one of the main components used in formulating GCF. GCF are used to represent deterrence factors faced by drivers in making their route choice decisions. GCF are necessary input to assignment models used to simulate drivers' behavior.
2. It is used in the computation of economic benefits in terms of society savings in time costs as a result of construction and operation of the proposed BOT road scheme.
3. It is used for computation of road user benefits in terms of savings in time costs. This acts as a main input in assisting the concessionaire to determine potential toll rates covering such benefits and generating extra income.

In case previous studies exist that estimated VOT by type of vehicle, these should be revised and updated/inflated to account for current and future conditions. In developing countries, little research has been carried out to derive VOT. It is common to base estimates on research undertaken in developed countries. The conventional approach used depends upon whether time savings are expected to result in increased production or increased leisure time. Time savings are, therefore, normally divided into working time savings and non-working time savings.

If an individual saves travel time in the course of working activities, it is assumed that this time saving will be translated into increased output. Average wage rates for different groups of road users can be estimated on the basis of the average monthly income per household and the average number of employed persons per household. The value of non-working time is usually determined on the basis of empirical studies of willingness of individuals to pay for such savings. These studies attempt to determine an effective price that people are prepared to pay for saving time. Results of most studies have indicated values of non-working time savings between 25-35% of the individual's wage. In both cases, it is essential to determine the average passenger occupancy by vehicle type. In addition, time savings by type of freight commodity transported should be investigated. In this context, VOT in accordance with the type of transported commodity should be determined. It is also important to determine average passenger occupancy as well as average load by type of commodity per heavy goods vehicle. The following is a representation of VOT computation for a passenger vehicle and a freight vehicle.

$$VOT_{(PV)}^{(P)} = (ANPW_{(PV)} * WVOT^{(P)}) + (ANPNW_{(PV)} * NWVOT^{(P)}) \quad (4)$$

Where: PV = Passenger Vehicle by type (1,....... NPV)
ANPW = Average Number of Passengers in a Working Trip
ANPNW = Average Number of Passengers in a Non-Working Trip
WVOT = Working Trip Value of Time NWVOT = Non-Working Trip Value of Time

$$VOT_{(FV)}^{(P)} = (ANPW_{(FV)} * WVOT^{(P)}) + (AFT_{(FV)} * FVOT_{(CO)}^{(P)}) \quad (5)$$

Where: FV = Freight Vehicle by type (1, ..., NFV)
AFT = Average Freight Tonnage FVOT = Freight Value of Time
CO = Commodity Type (1, ..., NCO)

3.11. Estimation of base year average GCF

GCF are used to simulate the deterrence factors faced by drivers in making their route choice decisions. This is necessary for running traffic assignment models and predicting the extent of traffic expected to use various routes constituting the road network. The average GCF per vehicle type on a particular road link is computed as the summation of the average VOC multiplied by the travelled distance, average VOT multiplied by travel time, and average toll rate (if applicable i.e. road is tolled) of this vehicle type. In order to obtain such values two types of surveys ought to be conducted for components of the road network, namely trip distance and trip time surveys. The following is a representation of GCF computation for each link on the road network taking into consideration variations in accordance with vehicle and road classifications.

$$GCF_{(VT,RL)}^{(P)} = VOC_{(VT)}^{(P)} * TD_{(R)} + VOT_{(VT)}^{(P)} * TT_{(VT,RL)} + [\text{Toll Rate}_{(VT,RL)}^{(P)} \text{ if applicable}] \quad (6)$$

Where: TD = Trip Distance in Kilometers TT = Trip Time in Hours RL = Road Link

3.12. Estimation of base year average network toll rate

Derivation of a representative average network toll rate is vital in serving several purposes:

- It is used as a guide and basis for the determination of toll rates for the BOT road project.
- It constitutes one of the main components used in formulating the GCF.
- The toll rate can act as a representative bench mark to simulate the sensitivity of travel behaviour and toll revenue as a result of changes in this basic toll rate.

- The toll rate is used in the financial analysis to arrive at the expected toll revenue that would be generated as a result of tolling the proposed BOT road.
- The toll rate can be used in the economic analysis to represent costs that society might incur in case a private concessionaire is expected to transfer his toll revenues abroad.

A two step procedure is used to derive initial representative toll rates for each vehicle type. First, existing toll roads are reviewed, whereby toll rates per journeys of different lengths for different types of vehicles are obtained. Second, average toll rates per kilometer are computed for each journey for every vehicle type. The following is a representation of computation of average network based toll rate per kilometer by type of vehicle.

$$NBTR_{(VT)}^{(P)} = \left(\sum_{(TR=1)}^{(TR=NTR)} \text{Toll Rate}_{(TR,\,VT)}^{(P)} \;/\; \text{Length of Toll Road}_{(TR)}^{(P)}\right) / NTR^{(P)} \qquad (7)$$

Where: NBTR = Network Based Toll Rate TR = Toll Roads Considered (TR = 1,.....NTR)

3.13. Building of base year road network

A representation of existing road network should be developed. To facilitate this step, the network is usually coded into nodes and links. Information for each link include link coordinates, distance, class, appropriate speed/flow curve and generalised cost function. On the other hand, a node is used in network description to represent either a change in link alignment or an intersection. A node is positioned in the network with X & Y coordinates depicting relative location of each node.

3.14. Development of base year 24 hour O/D matrices

This stage is concerned with developing squarised 24 hour O/D matrices representing current main directional Annual Average Daily Traffic (AADT) by vehicle type within the study area. In building such matrices, one should first determine the size and the exact names of trip origins/destinations. The size is a squarised matrix equal to number of internal and external zones constituting the study area. In order to obtain complete base year O/D matrices, several methods can be followed, namely:

1. Collection of O/D data for each zonal pair

2. In many situations, financial, human and time resources could be limited to conduct a complete set of O/D surveys. In such cases, synthetic gravity models can be used to estimate trips for each cell in the matrix without using observed trip patterns. Such models rely on having a good matrix representation of Generalised Cost (GC), in addition to observed trip ends. Classical representation of a gravity model can take the following form:

$$T_{(ij)}^{(P)} = A_{(i)}^{(P)} O_{(i)}^{(P)} B_{(j)}^{(P)} D_{(j)}^{(P)} f(GC_{(ij)}^{(P)}) \qquad (8)$$

Where: $T_{(ij)}$ = Number of trips generated from zone (i) and attracted to zone (j)

$A_{(i)}$ = proportionality factor for origin trip end $O_{(i)}$ = Origin trip end

$B_{(j)}$ = proportionally factor for destination trip end $D_{(j)}$ = Destination trip end

$GC_{(ij)}$ = Generalised Cost of travel from zone (i) to zone (j)

$f(GC_{(ij)})$ = a function of generalised cost with parameters for calibration, where there are three classical forms, namely: Exponential function: $f(GC_{(ij)}) = \exp(-\beta GC_{(ij)})$ or Power function: $f(GC_{(ij)}) = (GC_{(ij)})^{-n}$ or Combined function: $f(GC_{(ij)}) = (GC_{(ij)})^{-n} \exp(-\beta GC_{(ij)})$ (9)

3. In other cases, O/D surveys are conducted, however, due to survey cost constraints, partially filled matrices are constructed. These can be completed using old matrices (if available) which could be updated, and incomplete cells of the matrices are synethesised using a form of gravity models.

4. In case no (or few) O/D surveys are carried out, a widely used technique, known as matrix estimation from traffic counts can be utilised to construct O/D matrices. This is based on identifying paths followed by trips from each origin to each destination. To estimate missing parts of a trip matrix, four main inputs are required. First, an unloaded road network. Second, an initial O/D matrix. The initial O/D matrix used in this stage can be an empty or a partially filled matrix with the missing cells set at unity. Third, a set of observed/recorded traffic counts. Fourth, trip end constraints

The maximum number of unknown O/D pairs is equal Z^2 where Z is the number of traffic zones. The proportion of trips travelling a particular link can be obtained using a form of trip assignment techniques. Given such proportions and observed traffic counts, there will be a number of simultaneous linear equations equal to L, where L is the number of link traffic counts. In practice, where the number of equations are less than the unknowns, a number of constraints can be imposed through trip ends so as to obtain a feasible solution. Such technique can be mathematically represented as follows:

$$F_{(RL)}^{(P)} = \sum_{ij} T_{(ij)}^{(P)} Prop_{(ij,RL)}^{L(P)} \quad 0 \leq Prop_{(ij)}^{RL} \leq 1 \tag{10}$$

Where: $F_{(RL)}$ = Traffic flows in a particular road link
$T_{(ij)}$ = Number of trips generated from zone (i) and attracted to zone (j)
$Prop_{(ij)}^{RL}$ = proportion of trips travelling from zone (i) to zone (j) using road link (RL)

3.15. Assigning current O/D matrices as flows onto current road network

The basic objective of an assignment technique is to assign current O/D pairs within the 24 hour matrices and load these as flows onto current unloaded road networks, thus producing a road network loaded with current traffic flows. The choice and application of appropriate assignment models is vitally important. Several methods exist and can be classified in accordance with their consideration of congestion and stochasticity effects. At one end, the simplest of these is the all-or-nothing assignment, while at the other end the most sophisticated is the stochastic user equilibrium assignment. For BOT intercity road projects, being tolled roads passing through relatively uncongested areas, pure stochastic cost based assignment methods seem appropriate. Such methods are sometimes referred to as simulation based methods. These use Monte Carlo simulation to represent variability in drivers' perception to link costs. Such assignment techniques assume that a driver route choice is based on perception and trade off of a generalized cost function over alternative possible routes.

3.16. Validation of traffic model

As stated, base year 24 hour O/D matrices are initially assigned to the network using cost-based equilibrium assignment. Several runs are performed on the computer. For each computer run the assigned (estimated) flows are compared against the observed traffic counts. This process is known as traffic model validation. It should be noted that an intensification of traffic counting stations is contemplated specifically on competitive and surrounding routes to the intended BOT road project. If the comparison shows a low tolerable discrepancy, then the already calibrated O/D matrices representing current traffic flow patterns can be further utilised. On the other hand, if the comparison shows a high unacceptable discrepancy, this can be attributed either to errors in network representation or to inaccuracies in calibrated matrices.

3.17. Validation of base year network

All efforts are undertaken to correct any errors or inaccuracies in network representation. The network is checked for any logical errors, locations of high discrepancies in the network are determined and a better network representation is attempted. This process is known as network validation. Once the network is validated, assignment re-runs are undertaken to re-assign the calibrated matrices onto the newly validated network. Once more, a comparison of assigned flows versus observed flows is conducted. If still a high discrepancy exists, it is probable to deduce that these discrepancies are due to inaccuracies in developed matrices.

3.18. Re-estimation of base year matrices from traffic counts

Using matrix estimation techniques, attempts are made to modify O/D pairs in accordance with actual traffic volumes, especially those traffic counts taken in the vicinity of the location of the intended BOT road project. Sometimes, it might be necessary to support this step with more traffic and travel surveys. Runs are reiterated until a satisfactory matching between estimated and observed flows is reached i.e. an acceptable root mean square error is computed.

3.19. Corridor analysis of new BOT road projects

An initial step in the construction of a road is to make site investigations and consider a corridors location envelope that is meant to link trip origins and destinations and generally satisfy desire traffic lines. Within such an envelope, several alternative corridors can be identified. These are further investigated in accordance with a set of corridor analysis criteria such as, minimisation of excavation works, gradients and curves, avoiding crossing flooding lines, avoiding passing through important man made or natural environments, etc.

3.20. EIA of alternative corridors

The previous corridor analysis should be supported by conducting an EIA of alternative corridors. Such assessment would judge the environmental feasibility of alternative corridors with reference to their effects on components of baseline environmental contexts including physical, biological, ecological, cultural, social, and man made environments, etc. Based on conventional corridor analysis procedure as well as on conducted EIA, a final selection is made of preferred corridor.

3.21. Determining preliminary geometric and structural standards

In accordance with the Request for Proposals (RFP), preliminary geometric and structural specifications are outlined. These would probably include specifications relating to road class, cross-section, alignment, design speed, pavement type, etc. These ought to be considered as input until further analysis is conducted and such specifications are accordingly refined.

3.22. Building future road network

In this stage, a representation of the future road network is developed. This is mainly done by updating the base year validated network through the addition of nodes and links representing already committed and planned future road projects in the study area, as well as the considered BOT road projects. The development of the future road network is meant to provide a representation of expected capacities and levels of service that the future road network can accommodate. Ultimately, this step would result into the formation of an unloaded future road network within the study area.

3.23. Forecast of future trip ends

In this step, a forecast of future trip ends is undertaken. Four types of traffic are considered:

- Normal traffic which is expected to continue to use existing road network.
- Generated traffic expected of new developments & provision of new/improved accessibility.
- Diverted traffic reassigned from parallel roads and attracted to new BOT road projects as a result of better levels of service offered by BOT roads.
- Released traffic being suppressed due to unfavourable travelling conditions being improved by the implementation of the new BOT road project.

Forecast of future trip ends can either rely on a simple technique such as growth rate modelling, where future trips attracted to or generated from a particular zone is a product of current trips attracted to or generated from that zone multiplied by a growth rate. This growth rate is estimated as representing the future values of factors affecting the zonal trip making patterns such as population, income, and car owner ship as related to their present values. The general form of such trip generation/attraction models can be represented as follows:

$T_{(i)}^{F} = T_{(i)}^{P} * GR_{(i)}$ (11) $T_{(i)}^{F} = T_{(i)}^{P} * GR_{(i)}$ (12)
Where: $T_{(i)}^{F}$, $T_{(i)}^{F}$ = Number of Future Trips generated from zone (i)/attracted to zone (j)
$T_{(i)}^{P}$, $T_{(i)}^{P}$ = Number of Present Trips generated from zone (i)/ attracted to zone (j)
$GR_{(i)}$, $GR_{(i)}$ = Growth Rate in factors affecting generation of trips from zone (i) / attraction of trips to zone (j) - these can take any of the following forms:
$GR_{(i)} = Pop_{(i)}^{(F)} / Pop_{(i)}^{(P)}$ or $GR_{(i)} = Inc_{(i)}^{(F)} / Inc_{(i)}^{(P)}$ or $GR_{(i)} = CarO_{(i)}^{(F)} / CarO_{(i)}^{(P)}$ or
$GR_{(i)} = Pop_{(i)}^{(F)} * Inc_{(i)}^{(F)} * CarO_{(i)}^{(F)} / Pop_{(i)}^{(P)} * Inc_{(i)}^{(P)} * CarO_{(i)}^{(P)}$ (13)
Where: $Pop_{(i)}^{(F)}$ = Future Expected Population in Zone (i) $Pop_{(i)}^{(P)}$ = Present Population in Zone (i)
$Inc_{(i)}^{(F)}$ = Future Expected Income in Zone (i) $Inc_{(i)}^{(P)}$ = Present Income in Zone (i)
$CarO_{(i)}^{(F)}$ = Future Expected CarOwnership in Zone (i) $CarO_{(i)}^{(P)}$ = Present CarOwnership in Zone (i)

Alternatively, the calibrated trip generation/attraction regression based models can be utilised. These models are provided with expected values for future socio-economic parameters for each study zone, and future values of trip ends are then computed. The mathematical representation of such equations can take the following form:

$\text{Trips Generated}_{(i, VT)}^{(F)} = a_{(VT)} * \text{population}_{(i)}^{(F)} + b_{(VT)} * GRDP_{(i)}^{(F)} + \text{constant-G}$ (14)
$\text{Trips Attracted}_{(j, VT)}^{(F)} = c_{(VT)} * \text{employment}_{(j)}^{(F)} + d_{(VT)} * \text{working area}_{(j)}^{(F)} + \text{constant-A}$ (15)

3.24. Forecast/estimation of future O/D matrices

Forecasts of future expected interzonal trips is vital as these are meant to represent the demand expected to utilize the road network whether as it stands at its present condition (normal growth) or whether with the construction of the intended BOT road project as well as other committed projects (normal, generated, diverted and released demand). Short (5 years), medium (10-15 years) and long (15 -30 years) range combined with high (optimistic) and low (pessimistic) traffic forecast scenarios can be developed. A simplistic approach is to develop such scenarios based upon growth factors taking into account the future development in socio-economic parameters such as population, employment, GRDP, etc. Future matrices can be then produced each representing expected trips at the final year of the particular scenario. These matrices are obtained by multiplying all cells in the base year (current) matrices by respective growth factors for each scenario. The formulation of such computation is represented below.

$T_{(ij)}^{F} = T_{(ij)}^{P} * GF$ (16)
Where: $T_{(ij)}^{F}$ = Number of future trips generated from zone (i) and attracted to zone (j)
$T_{(ij)}^{P}$ = Number of present trips generated from zone (i) and attracted to zone (j)
GF = Growth factor reflecting future development in socio-economic parameters

Alternatively, and more accurately is to develop and utilise growth factor trip distribution models. Such models basically rely on computing growth factors relating the future trip ends resulting from forecasts of trip generation models to current trip ends. Cells in the present base year matrices are then multiplied by appropriate factors and future trip matrices are produced. Four growth factor methods are available, namely: constant factor, average factor, Fratar and Furness methods. All of these methods are based on iterative application until a convergence is reached between forecasted trip ends and estimated trip ends of the projected matrices. Mathematically, these are represented as follows:

$T_{(ij)}^{F} = T_{(ij)}^{P} * GF$	Constant Factor Model	(17)
$GF = \Sigma_{ij}T_{(ij)}^{F} / \Sigma_{ij}T_{(ij)}^{P}$		(18)
Where: $\Sigma_{ij}T_{(ij)}^{F}$ = Total future traffic flows generated from origins 1 to i and attracted to destinations 1 to j		
$\Sigma_{ij}T_{(ij)}^{P}$ = Total base year traffic flows generated from origins 1 to i and attracted to destinations 1 to j		
$T_{(ij)}^{F} = T_{(ij)}^{P} * [(GF_{(i)} + GF_{(j)})/2]$	Average Factor Model	(19)
$GF_{(i)} = GT_{(i)}^{F} / GT_{(i)}^{P}$ $GF_{(j)} = AT_{(j)}^{F} / AT_{(j)}^{P}$		(20)
$GT_{(i)}^{F}$ = Future number of trips expected to be generated from zone (i)		
$GT_{(i)}^{P}$ = Present number of trips generated from zone (i)		
$AT_{(j)}^{F}$ = Future number of trips expected to be attracted to zone (j)		
$AT_{(j)}^{P}$ = Present number of trips attracted to zone (j)		
$T_{(ij)}^{F} = T_{(ij)}^{P} * GF_{(i)} * GF_{(j)} * [\Sigma^{N}t_{iN}/\Sigma^{N}(AT_{(j)}^{F}/AT_{(j)}^{P})*t_{iN}]$	Fratar Model	(21)
$[\Sigma^{N}t_{iN}/\Sigma^{N}(AT_{(j)}^{F}/AT_{(j)}^{P})*t_{iN}]$ = balancing/normalising factor		
N = Total number of traffic zones		
$T_{(ij)}^{F} = T_{(ij)}^{P} * GF_{(i)} * GF_{(j)} * BF_{(i)} * BF_{(j)}$	Furness Model	(22)
$BF_{(i)}$ = Balancing/normalising factor dependent on generated trip ends applied through iterations		
$BF_{(j)}$ = Balancing/normalising factor dependent on attracted trip ends applied through iterations		

Another important alternative for the estimation of future O/D matrices is to use synthetic gravity models. As previously stated, this method relies on having forecasted trip ends in addition to a good matrix representation of future GC. This requires forecasting components of GC based on present base year GC and including initial and adjusted toll costs of proposed BOT road projects. This can be mathematically represented as follows:

$$T_{(ij)}^{(F)} = A_{(i)}^{(F)}O_{(i)}^{(F)} B_{(j)}^{(F)}D_{(j)}^{(F)}f(GC_{(ij)}^{(F)}) \qquad (23)$$

3.25. Adjustment of future matrices accounting for new/inadequately represented areas

This step is only carried out in case where considered BOT road projects are passing through newly developed areas or areas, which are not adequately represented in the current zoning system. In this case, an expansion of the zoning system is warranted. A specific trip generation model is developed to represent the expected trip patterns in relation to the expected socio-economic characteristics such as population, employment and GRDP of these new areas. The expansion of the zoning system is reflected in the size of the O/D matrices. In addition, certain cells in the already estimated future matrices would be adjusted using adjustment factors that are meant to reflect the share of the newly added zones in the trip patterns of these O/D cells.

3.26. Estimation of toll rates for considered BOT roads

The estimation of toll rates to be applied for the considered BOT road projects is a difficult task. If this matter is not handled with care, it could lead to financial losses for the concessionaire. This could be attributed either due to toll rates being set lower than those rates covering expected costs and inducing an acceptable net revenue or to high toll rates causing the reassignment of drivers to alternative routes. In all cases, the objective is to achieve optimum or semi-optimum toll rates that eventually lead to acceptable rates of return. In deciding on accepted toll rates, several factors are taken into consideration. A good start is to adapt computed representative average network toll rates. These rates could be adjusted taking into consideration:

- studies showing user benefits expected in terms of savings in VOC and time costs.
- studies using methods such as stated preference techniques to determine willingness to pay tolls of potential BOT road users so as to save time, VOC and enjoy better riding quality and service levels.
- type of toll system operation i.e. flat rates for open toll collection system and vehicle kilometer based rates for closed toll collection systems
- review of international toll rates of similar road standards

3.27. Adjustment of toll rates

An index needs to be established as a basis to adjust toll rates in the future so as to be in line and harmony with expected future changes. Several indexes can be used such as inflation rates, Gross Domestic Product Changes, Consumer Prices Indexes denoted (CPI), .. etc. CPI is thought to be more appropriate to use than other indexes, as it reflects in a better way the ability of the potential road users to pay, and at the same time the changes in the cost of maintenance and operation. A proposed toll indexation formula can take the following form:

$$\text{Toll Rate}_{(VT)}^{(F)} = \text{Toll Rate}_{(VT)}^{(P)} * (CPI^{(F)} / CPI^{(P)}) \qquad (24)$$

3.28. Estimation of expected future GCF

Expected future GCF are used to simulate future deterrence factors faced by drivers in making their route choice decisions. These are necessary for running traffic assignment models and predicting extent of traffic expected to use the various routes constituting the road network. Taking into account the effect of changes in inflation rates and CPI, current VOC and VOT can be updated to reflect expected future scenarios. Expected future GCF per vehicle type are then computed as the summation of adjusted VOC multiplied by travelled distance, adjusted VOT multiplied by travel time, and adjusted future toll rate (if applicable i.e. road is tolled) of this vehicle type. The following is a representation of future GCF computation on the road network taking into consideration variations in accordance with vehicle and road classifications.

$$GCF_{(VT,RL)}^{(F)} = VOC_{(VT)}^{(F)} * TD_{(RL)} + VOT_{(VT)}^{(F)} * TT_{(VT,RL)} + [\text{Toll Rate}_{(VT,RL)}^{(F)} \text{ if applicable}] \qquad (25)$$

3.29. Assigning future O/D matrices as flows onto future road network

Using proper traffic assignment techniques, future O/D matrices would be assigned onto the developed representation of future road network. As stated earlier, for the BOT road projects, being tolled roads in a rural relatively uncongested areas and networks, a pure stochastic cost based assignment method seems appropriate. This assignment technique assumes that a driver route choice is based on his/her perception and trade off of estimated future GCF over all alternative possible routes. In order to model the effects of possible congestion that will develop during the later forecast years, capacity-restraint equilibrium assignment can be used. Such assignment techniques assume that a driver route choice is based on his/her perception and trade off of congestion costs mainly represented by the cost of in vehicle time. The development of proper speed - flow curves for each link is crucial for the utilisation of these methods. As a result of this step, future demand would be loaded as traffic flows onto expected future network. Traffic flows by vehicle type for each considered BOT road are identified. For each year of the evaluation period (concession period), annual traffic flows using the BOT roads are forecasted or estimated using ratio and proportional between future and present matrices.

3.30. Capacity analysis for BOT roads

A capacity analysis need to be conducted so as to evaluate and demonstrate the expected levels of service on the BOT road projects. Such analysis comprises several steps, which differ in accordance with the road type and classification. Several countries have standards and procedures for conducting such analysis. These standards and procedures are results of many years of research concerning the relation between geometric and traffic conditions, see for example USDOT (2000).

It would be expected that BOT roads would be classed as freeways or highways. In both cases, capacity of the road is determined in accordance with its geometric features, such as number of lanes, widths of lane, shoulder and median, slopes, gradients, access control, etc. Such information would have been already specified in accordance with the RFP. In addition, knowledge of traffic composition i.e. percentages of different types of heavy vehicles is crucial for the computation of capacity. The computed capacity is meant to be used as a reference to determine the degree of utilisation of the road by the forecasted traffic flows. In accordance with the HCM, five levels of services are included spanning from A to F. Levels A and B are considered favourable, while most roads run at level C which is acceptable. Starting from level D, intervention measures have to be considered. For BOT roads, accepted LOS are specified by the sponsoring agency. If during appraisal stages, the selected geometric standards were not sufficient, these should be upgraded so that the consequent costs can be estimated.

3.31. Estimation of ESAL

In order to conduct the structural design of the pavement in terms of thickness and material composition of road layers, it is crucial to determine the expected ESAL over the appraisal (concession) period. An important input to ESAL computation is the forecasts of future traffic by type of vehicle. Actually, it is the HGV that cause most of the expected road deterioration that pavements have to endure. Other important considerations in the computation of ESAL include type of pavement (flexible, rigid, composite), assumed terminal serviceability, assumed structural number in case of flexible pavement or slab thickness in case of rigid pavement, axle configuration by type of vehicle and axle load by type of vehicle.

4. Estimation of revenues expected of BOT road project

For each year of the evaluation (concession) period, toll revenues are estimated. Toll revenues are computed as the multiplication of traffic flows for each type of vehicle by the respective toll rate. Such computation can be mathematically represented as follows:

$$TRev_{(RL)}^{(F)} = AADT_{(VT,RL)}^{(F)} * 365 * \text{Toll Rate}_{(VT,RL)}^{(F)} \quad (26)$$

where: TRev = Toll Revenue at a particular point of time in the future (F)
AADT = Annual Average Daily Traffic (Forecasted) 365 = Number of Days within a year

Several other sources of revenue can be obtained by the concessionaire. These include publicity and advertisement rates along the road, fees collected for services provided along the road such as petrol stations, rest houses, hotels/motels, etc. For each year of the evaluation (concession) period, such sources of revenue are estimated. For each year of the evaluation period (concession period), total revenues are estimated. These are computed as the summation of toll revenues and other sources of revenue. Such computation can be mathematically represented as follows:

$$TotRev_{(R)}^{(F)} = TRev_{(R)}^{(F)} + ORS_{(R)}^{(F)} \quad (27)$$

where: TotRev = Total Revenue at a particular point of time in the future (F)
OSR = Other Sources of Revenue at a particular point of time in the future (F)

5. Conducting EIA

In accordance with outcomes of the capacity analysis and estimation of ESAL, fine tuning and refinement of preliminary geometric and structural standards is undertaken. Another EIA ought to be carried out to assess the environmental consequences of refined geometric and structural standards. Such EIA would judge the environmental feasibility of such standards in relation to other standards. Based on capacity analysis, ESAL computation and conducted EIA, a final refinement is made of preliminary geometric and structural design standards. All construction, operation and maintenance components of the BOT road project ought to be designed in accordance with standards, specifications, and practices set in the RFP or known to be approved by the sponsoring authority. Examples of international standards that can be followed include AASHTO, ASTM.

Plans and programs should be devised to address issues such as detailed time schedule of all construction stages and considered maintenance types indicating start and completion date of each activity. Also, proposed methods for undertaking construction, maintenance in terms of mobilisation, location of contractors' yards, construction crew allotments, fabrication yards, equipment and material supply depots, equipment fleet, quarries, etc. should be thought of. In addition, traffic management issues at construction and maintenance sites, quality assurance procedures, toll facilities and equipment and methods for toll collection and enforcement, all should be discussed.

Finally, a full fledged EIA ought to be carried out to assess the environmental feasibility of BOT road phases. These include pre-construction, construction, operation and maintenance phases. For each of these phases, detailed activities are identified. In addition a baseline context is drawn of all components constituting the natural and man made environments. The objective of this EIA is to assess the magnitude and significance of impacts of these activities on components of the environment. This is followed by identifying the most significant impacts, and analysing these with the objective of suggesting a set of mitigation measures to relieve such impacts. The costs of these measures is then estimated and included in the costing exercise of the BOT road project.

6. Estimation of costs expected of BOT road project

The cost of a road scheme consists mainly of initial design and capital construction costs as well as the subsequent running maintenance and operation costs. The following is a brief discussion of these cost types.

Consultancy and design costs are costs incurred as a result of hiring reputable consultants to conduct various different studies, i.e. legal, technical, traffic, environmental, financial, etc. This eventually leads to the final design of components and details of road construction, maintenance and operation. "Preliminary design and feasibility are often simultaneous, but detailed design which can be very costly usually follows commitment to the project", TRRL (1988).

Construction costs are normally derived using item rates from comparable schemes previously quoted by contractors. It is necessary for original estimates to be updated at different stages in the scheme development. Construction costs need also to be allocated to each year during which construction takes place. This period constitutes the years before opening the road to traffic, where only capital construction costs are incurred and no revenues are materialized.

Maintenance costs are normally regarded as a stream of costs arising each year of the assessment (concession) period. Maintenance costs can be divided into two broad categories i.e. non-traffic related costs and traffic related costs. Non traffic related costs (referred to as routine maintenance) comprise expenditures which are not mainly due to traffic such as maintenance of safety barriers and fences, remedial earthworks, road sweeping and gully emptying, traffic signals and signs, road lighting, roadstuds and markings. These maintenance costs are generally described as annual costs per unit length of road or as annual percentage of construction costs.

Traffic related maintenance costs comprise expenditures that result from traffic flows. These are considered as periodic interventions to prevent the road from further deterioration to fair or poor condition and bring the road status back to good condition. Typical examples of this type of cost are overlays to strengthen road structure; surface treatment, resealing of joints, resurfacing of hard shoulders, local patching, etc. Such maintenance activities can be generally grouped under the heading periodic maintenance. Periodic maintenance costs can be computed either as a cost per unit length of road or as a percentage of construction costs. Another traffic related maintenance type is known as rehabilitation/overhaul. This is also applied at long time intervals. This is meant to prevent the road from deterioration to poor condition, thus bringing the road back to fair or good condition.

A detailed itemization of expected BOT road related costs allocated, in generic matrix format, into the key stakeholders interacting in a BOT road project is presented in table 2. For each of these costs, appropriate contingency factors ought to be applied to represent contingency allowances that are adequate to cover unexpected cost escalation. Taking into consideration such contingency factors as well as appropriate inflation rates to account for differential price changes across time, these costs are annualised over the assessment (concession) period. Finally, such annualised costs are summed together. The mathematical representation of such computation is detailed below.

$$TotCos_{(RL)}^{(F)} = \Sigma_{(C=1)}^{(c=N)} [C_{(RL)}^{(F)} * CCF_{(C,RL)}^{(F)} * IR_{(C)}^{(F)}] \quad (28)$$

Where: TotCos = Total Annualised Cost for a particular road (R)
C = Specific Type of Cost N = Number of Specific Costs Considered
CCF = Specific Cost Contingency Factors IR = Inflation rate

Table 2: A Generic cost allocation matrix for a BOT road project

Main Stakeholders **Itemisation of Costs**	**Government**	**Sponsor**	**Concessionaire**	**Financier**	**Users**
Building Public Support	(*)				
Conceptual Studies		(*)			
Legal Studies		(*)	(*)	(*)	
Technical Studies		(*)	(*)	(*)	
Environmental Studies		(*)	(*)	(*)	
Financial Feasibility Studies		(*)	(*)	(*)	
Economic Feasibility Studies		(*)			
Prequalification Process		(*)	(*)		
Request for Proposals		(*)	(*)		
Bidding			(*)		
Selection Procedure		(*)			
Loan Request Procedure			(*)		
Loan Approval Procedure			(*)	(*)	
Right of Way Land Acquisition		(*)	(*)		
Environmental Approval Procedure	(*)		(*)		
Design			(*)		
Construction			(*)		
Operation			(*)		
Environmental Mitigation			(*)		
Environmental Monitoring	(*)				
Maintenance			(*)		
Regulation		(*)			
Tolls					(*)
Cost of Capital			(*)		
Other costs (royalties, taxes, etc.)			(*)		
Handover		(*)	(*)		

(*) = Party Incurring Cost

6.1. Risk assessment and estimation of costs of potential risks

In this step different risk types related to the BOT road project are identified. Generally, risks related to BOT road projects can be categorised into political, financial, construction, operation and commercial risks, see OECD (1987). A detailed itemization of expected risks allocated, in a generic matrix format, into the key stakeholders interacting in a BOT road project is presented in Table 3. For each of the risks incurred by the concessionaire, the potential likelihood and timing of occurrence is estimated. This is followed by estimation of expected costs in case of occurrence. The following is a mathematical representation of computation of risk costs

$$TotRC_{(RL)}^{(F)} = \sum_{(Risk=1)}^{(Risk=N)} LOR_{(RL,\ Risk)}^{(F)} * RC_{(RL,\ Risk)}^{(F)} \qquad (29)$$

Where: TotRC = Total Risk Costs Risk = Specific Type of Risk
N = Number of Specific Risks Considered LOR = Likelihood of Occurrence of Risk RC = Risk Cost

Table 3: A generic risk allocation matrix for a BOT road project

Main Stakeholders **Itemisation of Risks**	**Government**	**Sponsor**	**Concessionaire**	**Financiers**	**Users**
Development of Non-Bankable Project	(S)	(C, I)			
Unsuccessful Bidding			(C, I)		
Project Cancellation		(C)	(C, I)		
Design Cost Overruns			(C, I)		
Design Time Overruns			(C, I)		
Inadequate Design		(S)	(C)		(I)
Unsuccessful Credit Raising			(C, I)	(C)	
Credit Raising Time Overruns			(C, I)	(C)	
Transfer Delays		(C)	(I)		
Construction Cost Overruns			(C, I)		
Construction Time Overruns			(C, I)		
Inadequate Construction		(S)	(C)		(I)
Opposition of Public Opinion	(S)	(S)	(I)		
Operation Cost Overruns			(C, I)		
Over-prediction of Traffic			(C, I)		
Revenue Shortfall			(C, I)		
Maintenance Cost Overruns			(C, I)		
Maintenance Time Overruns			(C, I)		
Inadequate Maintenance		(S)	(C)		(I)
Inability to Service Debt			(C, I)		
Inability to pay Debt			(C, I)		
Concessionaire Insolvency			(C, I)		
Difficulties in Settlement of Disputes	(C, S)	(S)	(I)		
Interference in Toll Structure		(C)	(I)		
Withdrawal of guarantees	(C)		(I)	(I)	
Expropriation (nationalisation)	(C, S)	(C, S)	(I)		
Repatriation	(C)	(S)	(I)		
Termination		(C, S)	(I)		
Local Currency Transfer (Instability)	(C)	(S)	(I)		
New Fiscal/Economic Legislation & Policies (Taxation, Import Duty, etc)	(C)	(S)	(I)		
New Specific Legislation (Const., Maint., Environmental Standards)	(C)	(S)	(I)		
Tort (accident) Liability	(C)	(S)	(I)		
Environmental Liability	(C)	(S)	(I)		
War, riots, hostilities, insurrection			(I)		
Force Majeure (e.g. Earthquakes)	(S)	(S)	(I)	(S)	

(C) = Party **C**ausing Risk (I) = Party **I**ncurring Risk (S) = Party **S**haring Risk

7. Determination of financial viability of BOT road project

In order to compare the costs and revenues of a proposed BOT road scheme, the change in monetary values as a result of time change has to be eliminated. This is achieved by discounting the annual costs and revenues of the project to current year. This is done using a discount rate which is considered acceptable and reflects such scale of projects that involve such high capital costs and risks and where sufficient revenues materialize over a long period of time. Such discount rate should also take into account the opportunity cost of resources employed by the project. Once a discount rate is determined, a discount formula is used. The basic discount formula, used in such projects, is known as Present Worth Factor. The following represents the mathematical computation followed in order to discount total revenues and costs.

$$PVR_{(RL)}^{(F)} = TotRev_{(RL)}^{(F)} * (1 / (1 + DR)^{F-P}) \quad (30)$$

Where: PVR = Present Value of Revenues
$(1 / (1 + DR)^{F-P})$ = Discount formula known as Present Worth Factor
DR = Discount rate used to reflect preference of present value
F-P = Time difference between future year of materialisation of revenue and present year

$$PVC_{(RL)}^{(F)} = (TotCos_{(RL)}^{(F)} + TotRC_{(RL)}^{(F)})* (1 / (1 + DR)^{F-P}) \quad (31)$$

$$PVCC_{(RL)}^{(F)} = CC_{(RL)}^{(F)} * (1 / (1 + DR)^{F-P}) \quad (32)$$

Where: PVC= Present Value of Costs including risk costs
CC = capital costs spread over construction period PVCC = Present value of capital costs

A set of financial indicators are available through which judgment can be made regarding the financial viability of the BOT road project. Typical indicators reported in the literature; see Beltrandi (1995) and Gannon & Brown (1995); include Value of Net Present Profit (VNPP), Project Rate of Return (PROR), Project First Year Rate of Return (PFYRR), Capital Rate of Return (CROR), Equity Rate of Return (EROR), Operating Ratio (OR), Cover Ratios (CR), Pay Back Period (PPB), etc. VNPP is considered as one of the most appropriate yardsticks for comparing the worthiness of projects. VNPP is measured as the present value of revenues less the present value of costs. The following is a representation of the computation of key financial indicators for a BOT road project.

$$VNPP_{(RL)} = \sum_{1}^{AP} PVR_{(RL)}^{(F)} - (PVCC_{(RL)}^{(F)} + PVC_{(RL)}^{(F)}) \quad (33)$$

where: AP = Assessment (concession) period

$$OR_{(RL)} = \sum_{1}^{AP} PVR_{(RL)}^{(F)} / (PVCC_{(RL)}^{(F)} + PVC_{(RL)}^{(F)}) \quad (34)$$

$$PROR_{(RL)} = \sum_{P}^{F-P} [(TotRev_{(RL)}^{(F)} - (CC_{(RL)}^{(F)} + TotCos_{(RL)}^{(F)} + TotRC_{(RL)}^{(F)})) * (1/(1 + DR)^{F-P})] = 0 \quad (35)$$

PROR is equal to DR that satisfies the above formulation

$$PFYRR_{(RL)} = \sum_{P}^{F-P} [TotRev_{(RL)}^{(F)} / (TotCos_{(RL)}^{(F)} + TotRC_{(RL)}^{(F)} + CC_{(RL)}^{(F)})] \quad (36)$$

The maximum value of F would be the first year traffic is expected to run on a BOT road project

The determination of financial viability of a BOT road project relies mainly on the comparison of expected versus targeted financial indicators. Two possible outcomes can result, the first is the favourable where expected indicators are equal to or higher than targeted ones, and hence the project is considered viable. The other outcome is where expected indicators are less than targeted ones, hence the project might be considered not viable. Break-even values as well as minimum targeted values for the key financial criteria are detailed in table 4. The table also shows the logical interpretation of achieving such minimum targeted values.

Table 4: Summary of cost-revenue criteria used for financial appraisal of BOT road project

Financial Criteria	Break-even Values	Minimum Targeted Values	Judgment
VNPP	zero	Positive	Positive net profit
Revenue/Cost Ratio	1	≥ 1	Efficient investment
PROR	DR	≥ DR	OK
PFYRR		Approaching DR	High short term return

In case expected indicators are lower than targeted ones, a number of adjustments can be made, namely: adjustments to the structure of toll rates as well as to the concession period (i.e. time over which revenue is materialised).

8. Summary and conclusions

The eligibility of a BOT road project depends on meeting several criteria, including economic, financial, environmental, technical, and legal criteria. This paper was concerned with developing a detailed generic algorithm to assist in conducting a comprehensive and structured financial feasibility assessment of private investment in road projects. The developed approach encompasses a number of generic stages, procedures, steps and models envisaged to assist sponsors, concessionaires as well as financiers in identifying bankable road projects. The structure of the developed approach constitutes eight stages. The first is concerned with defining the objectives of the project to provide the necessary background against which appraisal of alternatives is performed. The traffic analysis presents the core of the second stage. The third stage involves conducting an EIA. The fourth stage is concerned with the estimation of potential costs expected, taking into consideration the cost of environmental mitigation measures. In the fifth stage project revenues are forecasted. Stages six and seven are concerned with the estimation of key financial criteria and comparing these with project financial objectives so as to determine project viability. Finally, the eighth stage is concerned with minimising uncertainties and risk through a three level procedure of conducting scenario analysis, followed by sensitivity tests and then risk analysis. In the course of developing, the following conclusions were deduced.

1. In a BOT road project, the sponsoring highway agency is expected to conduct an economic feasibility study to verify the project worthiness from the society point of view, as well as a financial feasibility study to justify its choice of a bankable project and to assist in negotiating the concessionaire during bidding and contracting phases.

2. In addition, both the concessionaire and the financier are expected to undertake a financial assessment aimed at demonstrating the project financial viability. The concessionaire wants to make sure that his investments would be worthwhile. On the other hand, the financier wants to guarantee project success and hence ability of concessionaire to repay and service his debts.

3. Identification of BOT road project objectives and representing these into several expected quantifiable financial indicators is a crucial initial step towards any financial assessment.

4. It is of vital importance to forecast and analyse the development of traffic flows over the life of a BOT road project. Such forecasts should particularly run over the time period considered for evaluating the proposed BOT scheme. In order to accurately forecast traffic flows for a BOT road project, a computer-based simulation model ought to be developed. A traffic model is mainly expected to serve the following analytical purposes:

- It allows the simulation of current and future traffic conditions on existing network and especially on parallel roads to expected BOT road scheme. This is done both for the do nothing and do something scenarios.
- It provides necessary comparative traffic estimates and network utilisation statistics required for conducting feasibility assessments. Network statistics include vehicle kilometers and vehicle hours for current and future networks and their associated traffic conditions.
- It acts as a quick test vehicle for exploring alternative scenarios. A scenario can be composed of alternative network configuration, traffic growth rate, toll rate, …etc.

5. Disaggregate traffic demand forecasting models are warranted for BOT road projects. Such quality models are meant to forecast demand for different types of vehicles throughout the operation period of the project rather than at peak periods only. This is crucial for the rigorous required in the forecasting of revenue, which is detrimental for establishing project's viability.

6. For a BOT road project it is necessary to conduct EIAs to serve three purposes, first for corridor analysis, second for selection of environmentally friendly geometric and structural standards, and finally to environmentally assess the pre-construction, construction, operation and maintenance phases. For each of these EIAs a number of significant impacts are identified, mitigation measures are suggested and their costs estimated.

7. Estimation of costs for a BOT road project should take account the life of the concession, inflation rates and shadow pricing. The main types of expected costs are those incurred during design, construction, operation, maintenance, and implementation of environmental mitigation measures as well as debt repayment and service costs. Such costs are estimated on a year by year basis over the concession period of the BOT road project.

8. Estimation of revenue for a BOT road project is dependent on traffic forecasts, proposed toll rates and toll rate indexation. In addition, revenue expected as a result of fees collected for providing other types of road services such as publicity, petrol stations should be estimated. Such revenue estimations are done on an annual basis over concession period of the BOT road project.

9. Costs and revenues should be annualised and discounted across the concession period using an appropriate discount rate that reflects expected opportunity costs and risks.

10. Judgment of project viability is based on a comparison between expected and output values of identified financial indicators. These are utilised to judge project feasibility and effectiveness.

11. Parameters identified as critical to the financial success of a BOT road project include: length of the concession period, toll categories and rates, traffic growth rates, discount rate, etc. Scenario analysis, sensitivity tests and risk analysis ought to be conducted taking into account the effect of variations in such factors on projects viability.

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