NTA

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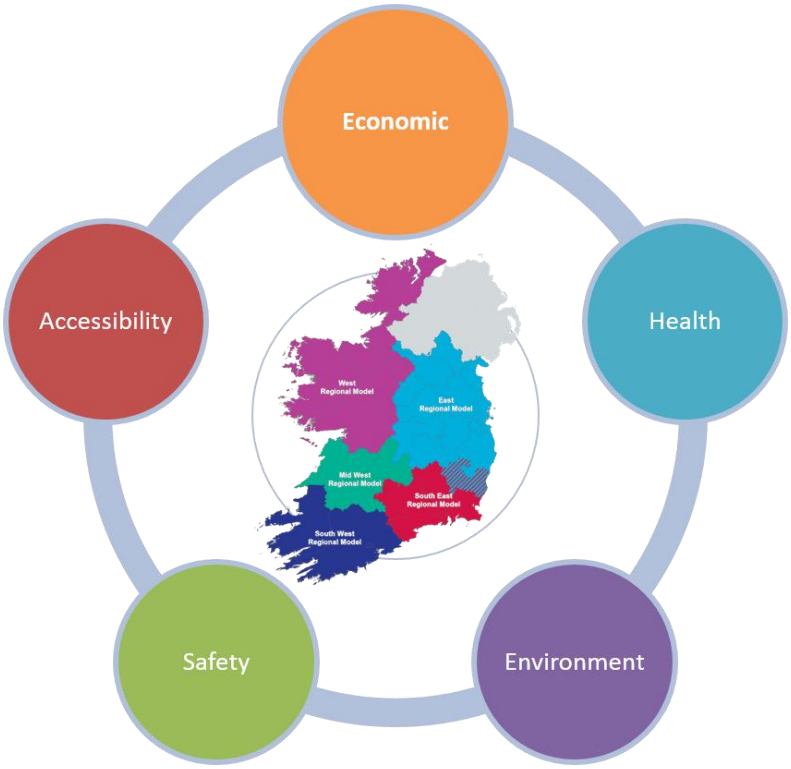
National Transport Authority



Economic Module

Development Report

March 2021 (v3.1.1)

National Transport Authority,
Dun Scéine,
Harcourt Lane,
Dublin

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	Name	Position	Date
Originated by	Shoham Vaich-Shkolnik	Graduate Transport Modeller	March 2021
Checked by	Jevgenija Guliajeva	Transport Modeller	March 2021
Approved by	Chris Bushell	Associate Director	March 2021
NTA Reviewer	Stylianos Papailiou	Transport Modelling PM	March 2021

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1 Introduction

1.1 Introduction to the Task

Jacobs/SYSTRA were commissioned by the National Transport Authority to develop a set of Appraisal Modules linking to the outputs of its Regional Modelling System. Appraisal modules were developed for each of the following aspects of standard transport scheme assessment and appraisal:

- Safety Appraisal
- Economic Appraisal
- Environmental Appraisal
- Health Appraisal; and
- Accessibility and Social Inclusion Appraisal.

This report describes the technical implementation of Economy Appraisal Module.

1.2 Economic Appraisal Module Overview

For the Economic Module, it was agreed during the scoping and specification stage that an Irish version of the UK DfT TUBA[1] program would be used for the economic cost-benefit calculations. The Economic Module also includes interfaces and processes for obtaining the relevant model data (from a full run of any of the regional models), for storage and formatting of user parameters as input, and reporting and analyses of the TUBA calculations. Scheme information required for the TUBA assessment, such as costs by year, are defined within the user parameters. The Irish version of TUBA is defined by the set of values in the Economic Parameters file, which are consistent with the Common Appraisal Framework and Project Appraisal Guidelines.

The full Economic Module process is presented schematically in Figure 1.1 below. Note, the latest version of the tool has been updated to work with 3 forecast years as well.

[1] TUBA is transport economic appraisal software developed by Atkins Limited on behalf of the Department for Transport. TUBA stands for transport user benefit appraisal. The purpose of TUBA is to carry out transport scheme economic appraisal in accordance with the DfT's published guidance in units A.1 of the WebTAG guidance. It implements a 'willingness to pay' approach to economic appraisal for multi-modal schemes with fixed or variable demand. TUBA is used by practically all transport consultants in the UK, undertaking scheme appraisal, and a number of others abroad. The current version of TUBA is 1.9.14 as of March 2021.

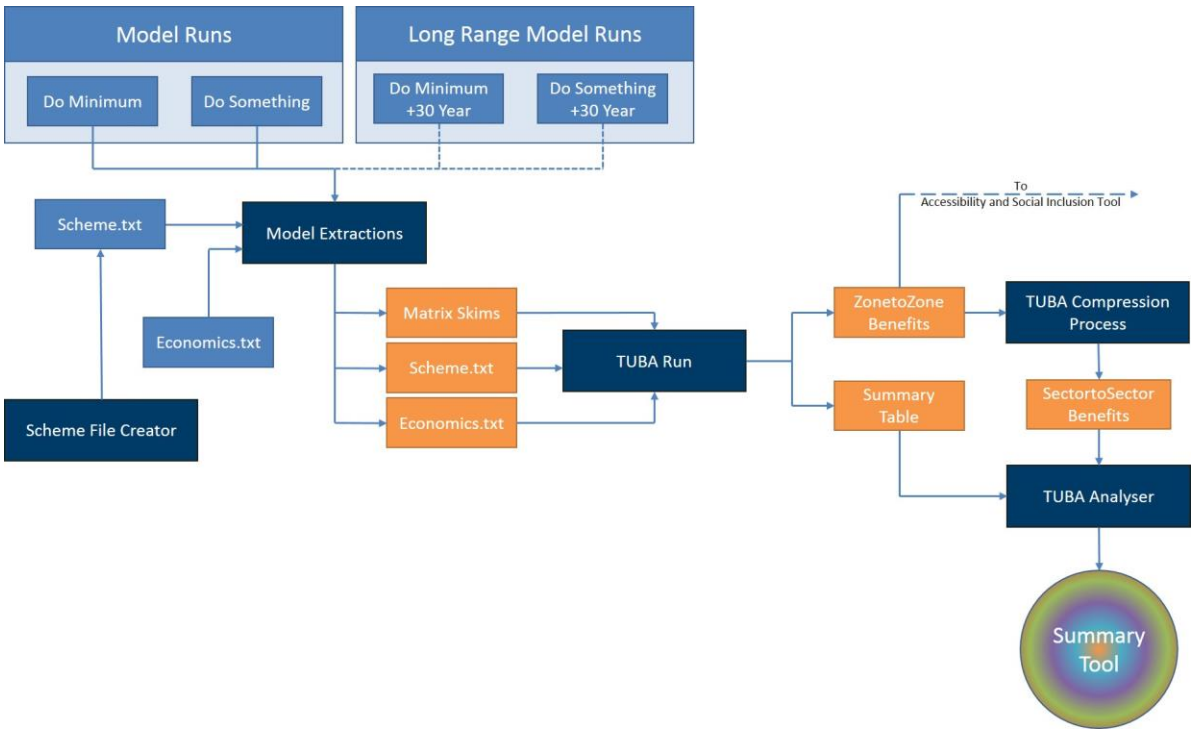


Figure 1.1 Economy Appraisal Module Process

1.3 This Report

The remaining chapters of this report describe the Economic Module according its respective components set out by the functionalities of model extraction, inputs and parameters definition, and outputs processing. In describing each of these stages it also serves as the user guide. The chapters are set out as follows:

- Chapter 2 provides an overview of the operation and service of the Economic Module. Further details are then set out in the remaining chapters.
- Chapter 3 describes the relevant model extractions required to run the Economic Module on a regional model.
- Chapter 4 describes the main inputs to the Economic Module, i.e., the TUBA Costs Workbook and the Irish economics file.
- Chapter 5 describes the TUBA Output Workbook and the functions it provides to interrogate the results produced by the TUBA module.
- Chapter 6 describes the tests that were undertaken on the Economy Module to confirm correct functioning of its procedures.

2 Model Extractions and TUBA Run

2.1 Overview

A Cube application was developed to extract the relevant data from any one of the regional models for use in the Economy Appraisal Module and to launch TUBA. Demand and cost skim matrices are extracted in a format compatible with TUBA. The process comprises four main stages as follows:

- Required inputs;
- Public Transport model extractions;
- Road model extractions;
- Outputs

This section describes the process employed in developing the application and extracting the matrix skims from the models.

2.2 Inputs Required

The TUBA program requires matrix skims for each user class, time-period and modelled scenario for the following outputs of the regional model:

- Demand;
- Distance;
- Time;
- Fares; and
- Charges (e.g. tolls).

Two processes extract skims for public transport and road by time period, respectively. The input files required are outlined in table 2.1.

Table 2.1 Format of matrix skim input files

Type of input	Input name	Location
PT demand	PT_{Time Period}_{Scenario Name}{Growth}{Year}.PTM	{CATALOG_DIR}\RUNS\{Regional Model}\{Model Year}\{Run ID} \4_Outputs_{Regional Model}_{Model Year}_{Run ID}__Input_v{Version number}\PT\{Time Period}
PT skims	SKIM_{Time Period}_PT_FTR.MAT	
	SKIM_{Time Period}_PT_GEN.MAT	
	SKIM_{Time Period}_PT_SCH.MAT	
Road Demand	Road_{Time Period}_{Run ID}{Growth}{Model Year}.HWM	{CATALOG_DIR}\RUNS\{Regional Model}\{Model Year}\{Run ID} \4_Outputs_{Regional Model}_{Model Year}_{Run ID}__Input_v{Version number}\Road\{Time Period}
Road Skims	Road_Skims_{Time Period}_{Run ID}{Growth}{Model Year}.MAT	

The inputs files are produced at the PT or Road assignment stages. The file name is followed by a "_{DemLoops}", which indicates the demand loop number.

Usage Tip

The Cube application requires that a model relevant seq_2_hier.exe file in the {Catalog_Dir}\Params\ folder. For each RMS model, there is an appropriate dat file. This dat file converts from between the different zonal systems and can be edited by the user if necessary.

2.3 Catalog Keys

Key	Required Data	Notes
Model	RMS Model	ERM, WRM, SWRM, SERM, MWRM
Zones	Number of Zones	Entering a number higher than the number of zones in the model will cause the module to crash.
User Program Folder	Location of working folder	Default C:\ST
Program_Directory	SATURN Directory	Default C:\SATWIN\XEXES
SkimOnly	Run skims only	Useful if multiple TUBA runs are required.
SchemeFile	Directory and name of Scheme File	Will rename file paths in Scheme File.
EconomicFile	Directory and name of Economic File	Will make a copy of economic file for use in the TUBA run.
TubaFile	Directory and name of TUBA .exe Note: Currently version v1.9.14.3 is used for the tool.	Default C:\Program Files\DfT\TUBA v1.9.14 64bit\tuba_g.exe
RunTuba	Run TUBA after skims	Manual TUBA run recommended if doing multiple runs.
The below keys are repeated for DoMin and DoSome tests for the three forecast years allowing for 4 Scenarios.		
RunDM(DS)F1(F2)(F3)	Run the scenario – Yes/No?	If not selected the Scenario will not be run.
DM(DS)F1(F2)(F3)_Net	Run the scenario from NetCatDM location defined by user.	Select if running from somewhere on the network.

NetCatDM(DS)	Directory of scenario files in form {Catalog_Dir}\Runs	A text entry is required even if not required.
Model Year	Current test year	In form XX
DM/DS Run ID	Run ID for current Scenario	
Growth	Growth for current Scenario	This is the same for the DoMin and DoSome for each year.

2.4 Parameter Files

Cube requires the user to define the economic and scheme file in the keys. The related files are described in the next chapter. Cube takes these files and copies them to the Appraisal_Modules\Economic folder renaming them to {DoSomethingRunID}_SchemeFile.txt and {DoSomethingRunID}_EconomicFile.txt.

If the Skims only option is selected this step is skipped. A user may wish to run skims only if setting up a TUBA run on a different machine or updating skims for an already established TUBA run.

2.5 Public Transport Assignment Data Extraction

2.5.1 PT Model User Classes

The PT user classes are defined in TUBA as:

Table 2.2 PT User Classes

No.	User Class	Veh/ submode	Purpose	Person_type
1	GEN business	Bus	Business	Passenger
2	GEN commute	Bus	Commuting	Passenger
3	GEN other	Bus	Other	Passenger
4	SCH (Primary and secondary educ.)	Bus	Other	Passenger
5	FTR (free travel, retired)	Bus	Other	Passenger

2.5.2 PT Skims

For each User Class, a distance, a time and a fare is calculated or extracted by running skimming procedures on the assigned Public Transport network.

Table 2.3 PT Skims Extracted for TUBA

Cost	Description	Voyager Script	PT assignment matrix
Distance	distance for all modes, average	DIST(0,ALLMODES)	*Done for NT (MW[12]) and T modes (MW[2]) separately*
Fare	Average fare, in monetary units for all modes	FAREA(0, all modes)	*MW[16]*

Walk Time	Actual walk/ride time for non-transit modes	TimeA(0,NTModes)	*MW[13]*
Waiting time	Initial wait time, actual, average	IWAITA(0)	*MW[29]*
Transfer time	Transfer wait time, actual, Average	XWAITA(0)	*MW[30]*
In-vehicle time	In-vehicle time for transit modes, actual, average	TimeA(0,TMODES)	*MW[3]*

According to WebTAG guidance that sets out appropriate data extraction for Cost-Benefit appraisal, walk time and waiting time should not be weighted for the case of business trips. The appropriate calculation for business trip time is therefore:

$$PT\_Time_{[EMP]} = WalkTime_{[GEN]} + WaitingTime_{[GEN]} + Transfer\_wait\_time_{[GEN]} + InVehicleTime_{[GEN]}$$

For other purposes, the PT walk time and waiting time need to be weighted. It is calculated as:

$$PT\_Time_{[UC]} = 2 \times WalkTime_{[UC]} + 2.5 \times WaitingTime_{[UC]} + Transfer\_wait\_time_{[UC]} + InVehicleTime_{[UC]}$$

The resulting time values are then converted into the appropriate units.

2.6 Road Assignment Data Extraction

2.6.1 Road User Classes

Within the regional models, there are 10 assigned User Classes for Road: EMP, COM, OTH,RET, EDU, TAXI, LGV, OGV1, OGV2_P, OGV2_NP.

The last two (OGV2_P and OGV2_NP) differ only by the type of permit needed and are aggregated for TUBA. Therefore, there are 9 road user classes for TUBA. The relevant time skims for OGV are calculated on the demand weighted average, shown in the formulae below.

$$TIME[OGV] = \sum_{UC \in \{OGV2\_P, OGV2\_NP\}} (TIME[UC].\ DEMAND[UC]) \ / \ \sum_{UC \in \{OGV2_P, OGV2_{NP}\}} DEMAND[UC]$$

$$TOLL[OGV] = \sum_{UC \in \{OGV2_P, OGV2_{NP}\}} (TOLL[UC].\ DEMAND[UC]) \ / \ \sum_{UC \in \{OGV2_P, OGV2_{NP}\}} DEMAND[UC]$$

$$HDIST[OGV] = \sum_{UC \in \{OGV2\_P, OGV2\_NP\}} (DIST[UC].\ DEMAND[UC]) \ / \ \sum_{UC \in \{OGV2_P, OGV2_{NP}\}} DEMAND[UC]$$

The Road user classes are defined in TUBA as:

Table 2.4 Road Model User Classes

No.	User Class	Veh/submode	Purpose	Person_type
7	Car Employer's Business	Car	Business	All
8	Car Commute	Car	Commuting	All
9	Car Other	Car	Other	All
10	Car Education	Car	Other	All

11	Car Retired	Car	Other	All
12	Taxi	Car	All	All
13	LGV	LGV	All	All
14	OGV1	OGV1	All	All
15	OGV2	OGV2	All	All

2.6.2 Road skims

Distance, Time, Toll charge for each UC are taken from skims created during the Road Model assignment stage within a standard run of a regional model. These get converted to suit the correct format needed for TUBA These factors can be seen below.

2.7 Conversion factors

The conversion factors that are used between the HW/PT skims and TUBA can be seen in Table 2.5 below. A summary spreadsheet for the conversion factors can be found under "\working\test checks" folder. Time, Fare, Distance and Demand matrices are output into text files in the right format for TUBA.

Table 2.5 Unit converstion factors

Unit	Original Units	Conversion factor	TUBA units	Process location
HW Distance	Meters	1/1000	Kilometers	Car Distance extraction
HW Time	Seconds	1/3600	Hours	Car Time extraction
HW Toll	Euros	100	Cents	Car Toll extraction
PT Distance	Kilometers	None	Kilometers	PT Extraction skims
PT Time	Minutes	1/60	Hours	PT Extraction skims
PT Toll	Euros	100	Cents	PT Extraction skims

2.8 Cube Extraction Process Outputs

Final PT and Road skims are saved in: {CATALOG_DIR}\ RUNS\{Regional Model}\{Model Year}\{Run ID}\4_Outputs_{Regional Model}_{Model Year}_{Run ID}__Input_v{Version number}\ Appraisal_Modules\Economic

User Tip

Outputs are text files in "TUBA format 3":

I, J, User Class, Value AM, value LT, value SR, value PM. Fields are separated by a space.

2.9 .exe file and inputs.

An executable file (as mentioned above) is used in the tool to convert from the Saturn zone system to a hierarchical zone system created for TUBA. The file uses a lookup file located in the same folder as the file to replace the Saturn zones with their equivalent hierarchical zone number. The inputs

for the executables are the hierarchical conversion file and the input file with the Saturn zone system.

This executable was written in C# and the raw code can be found on the SharePoint site, under the Executables Code folder

3 User Defined Inputs

3.1 Introduction

User inputs to the Economic Module consist of:

- The Irish TUBA Economics File; and
- The input and parameters as defined in the TUBA Costs Workbook.

Both are described in detail in turn below.

3.2 TUBA (Irish) Economics File

The TUBA Economics File specifies the economic and transport parameters used in the cost-benefit calculations.

User Tip

The TUBA economics file should be updated when new guidance is released or if required by changes to the TUBA software package.

The version of the economics files provided with the module is the latest available from the Metrolink team at the time of module development (January 2021). The following guidelines/documents are used to inform the values for the file:

- PE-PAG-02030 Guidance
- Source Circular SRA01 2020
- TII PAG Unit 6.3

User Tip

Alternative versions of the TUBA economics file should not be used without approval from the NTA.

3.3 TUBA Costs Workbook

3.3.1 Overview

In the Economic Module, TUBA inputs are configured by a Workbook based procedure[2] (referred to as the TUBA Costs Workbook) that uses VBA scripts to output scheme files in the correct format for TUBA.

The main parts of the workbook are as follows:

- TUBA Run Worksheet, which defines where inputs and outputs are located and provides a user button that runs the macros to create the Scheme File from the data in the rest of the workbook;
- Scheme Input Worksheets, including the following:
  - Scheme Inputs –defines the main parameters of the TUBA run;
  - Matrix Inputs –defines where demand and skim matrices are located;
- Cost related worksheets, which comprise:

[2] SchemeFileCreator.xlsx

- Cost Main Parameters
- Capital Costs Inputs
- Annual Operation & Maintenance Cost Inputs
- Annual Road Maintenance Costs
- Segmented Maintenance
- Vehicle Fleet Requirements

- Outputs; these worksheets combine the cost inputs and format for output to TUBA
  - Full Cost Profile
  - NTA Standard Costs Workbook.

Each of these Workbook elements is described in turn below.

3.3.2 TUBA Run Worksheet

This sheet is where the locations of output files and inputs files are defined. For Scheme File creation, these definitions include:

- Sector File Location
- Skim Matrices Location
- Output Path for Scheme File

For running TUBA these definitions include:

- Scheme File Location
- Economic File Location
- Output Path for Run Batch File
- Output Path for Results
- Tuba Directory
- Tuba Analysis Location

User Tip

Under the Scheme File Details input box (in Cell B7) there is an option to select “Cube Defined Skim Path”. If set to “Yes” a place holder will replace the skim file paths in the scheme file which the Cube application will in turn replace with output location of the skims. If “Yes” is selected then no Skim Matrices path needs to be defined.

3.3.3 Matrix Inputs Worksheet

References to the location paths, filenames and definitions of the demand and cost skims extracted from the Regional Models.

3.3.4 Scheme Input Worksheet

This worksheet facilitates the entry of the main scheme specific parameters required for the TUBA scheme file plus the definition of time periods and user classes.

Scheme Parameters

Data in relation to the scheme opening year, first year of construction and scheme stage for each mode. The scheme stages refer to how TUBA handles the allocation of scheme costs. If no preparation or supervision costs are defined, TUBA calculates these as percentages of land and construction costs. The factors applied by TUBA depends on the stage of scheme development, which should be defined as one of the following:

- SI (Scheme Identification);
- PC (Public Consultation);
- PR (Preferred Route);
- OP (Order Publication); or
- WC (Works Commitment).

User Tip

Scheme stage can be set in Cells E45 and E46

Other parameters include:

- TUBA version number;
- TUBA run name;
- Do minimum and do something run names
- Scheme opening year;
- List of modelled years;
- Scheme appraisal horizon years
- Current year i.e. the year in which appraisal is being carried out. Also used to define the first year for the discount rate table;
- Set the print warning limits for the output file;
- The average speed of the car leg of park and ride trips; and
- Setting the program to use sectors or zones for the output of results.

Input matrices

File paths for skim matrices are generated based on the file path defined in the TUBA Run Worksheet. If Cube Defined file paths were selected the file paths will appear as placeholders

In some cases, the user may wish to carry out an appraisal but may only have one future year test, for example, 2030. TUBA allows this future year test to be factored up to represent a second future year, for example, 2060. This is done by changing the “Future Year Factor” value. If the “Future Year Factor” is greater than 1.00, the TUBA Costs Workbook will assume no future year test is available and apply the factor to the first future year to allow TUBA to simulate a future year. If the “Future Year Factor” is set to 1.00 then the TUBA Costs Workbook will include the path and filenames for a second future year test in the scheme file.

Time Slices

The modelled time slices should be defined along with their duration (e.g. 60 minutes) and the annualisation factors. Standard appraisal annualisation factors will be specified for each regional model.

Ultimately, these will be automatically populated following a user specification of which regional model is being used for the appraisal.

Do Minimum Costs and Cost Profiles

Do Minimum costs represent costs for construction, operation and maintenance (O&M) of the Do Minimum scenario. Do Minimum costs can be assumed to be zero where the appraisal typically only considers the additional cost of providing a scheme.

In certain circumstances, the provision of a scheme may involve a change in Do Minimum costs e.g. if a new public transport service involved a rationalisation of existing services and therefore a change in O&M costs from the Do Minimum scenario. It is up to the user as to how this is handled in the TUBA assessment. These cost differences can be incorporated into the Do Something cost estimates, or input as Do Minimum costs.

The scheme input worksheet facilitates manual entry of Do Minimum costs and profiles if required.

Delay Costs

Values of the delays to road and/or public transport users as a result of scheme construction can be incorporated into the appraisal. These can be specified by year and mode and split between business, commuting, other and freight travel.

Benefit Changes

Any changes to the value of scheme benefits, beyond the final modelled year can be specified. These are over and above the value of time growth specified in the standard economics file, and the standard extrapolation of benefits beyond the final modelled year.

Sector File References

This defines the sector system to be used for the analysis of TUBA outputs. Each regional model has its own system of sectors defined in separate csv files. Sectors files can be omitted if detailed results are required at a zonal level. Note that this increases TUBA run times and results in large output files.

3.3.5 Cost Input Worksheets

Details relating to scheme costs are input into a series of worksheets as follows:

- Main Costs;
- Capital Cost Inputs;
- Annual O&M PT Costs;
- Annual O&M Road Costs;
- Segmented Maintenance Costs;
- Vehicle Fleet Requirements & Renewals; and

These are described in further detail below. The preparation of scheme costs for input into TUBA should be undertaken in consultation with the NTA.

3.3.6 Main Costs

This worksheet includes high level inputs relating to the stage of cost estimate, the price base year, the appraisal period and the residual value period assumed.

It also requires inputs in terms of assumed inflation rates for construction, land and O&M with inputs for inflation factors where appropriate. The assumed percentage risk allowance is also included in this worksheet.

3.3.7 Capital Cost Inputs

This worksheet takes user inputs in relation to total scheme capital costs, the breakdown of costs into the various stages of scheme development and the proposed profile of expenditure over time. It allows for input of Consumer Price Index data to bring all costs to the price base year (currently 2009).

Scheme costs are generally prepared as part of scheme development and approved by the NTA at the following stages:

- Outline Cost Estimate;
- Base Cost;
- Total Scheme Budget.

For further details on preparation of scheme costs, please refer to the NTA *Guidelines for the Management of Public Transport Investment Projects* or the TII *Project Appraisal Guidelines*.

Typically, scheme costs are prepared for the current year at market prices (i.e. inclusive of VAT). The Capital Cost Input worksheet includes the relevant calculations to convert to base year prices at factor cost (i.e. exclusive of VAT) for input into TUBA.

The worksheet also incorporates the application of shadow prices, in line with the DPER *Public Spending Code*. The user must specify the proportion of expenditure for each stage of scheme development that will be delivered by public funds. This impacts on the application of the shadow price of public funds. In addition a set of assumptions regarding the percentage labour content of each stage of scheme development can be edited as required, which impacts on the application of the shadow price of labour.

The final input in relation to capital costs is the proposed annual profile of expenditure. The totals (over multiple years) for each stage of scheme development must equal the values specified in the breakdown of scheme costs.

The remaining section of the worksheet, takes the cost inputs, applies the relevant discounting and shadow pricing calculations, strips out the allowances for risk and inflation and generates the total costs and cost profiles for input into TUBA for the price base year, at factor costs.

3.3.8 Annual O&M Costs (Public Transport)

Annual O&M costs for public transport schemes can be input for the following elements of ongoing expenditure on public transport schemes:

- Operations (staff, traction, insurance etc.);
- Vehicles; and
- Infrastructure.

All costs should be entered in factor costs (i.e. exclusive of VAT) in current year prices. The assumed proportions for labour content and public funds should also be specified in order to apply shadow pricing to the total O&M costs. An appropriate contingency can also be specified. The worksheet then applies shadow pricing and rebases the costs to the price base year (currently set at 2009).

3.3.9 Annual O&M Costs (Road)

Annual O&M costs for road schemes typically consist of non-traffic related road maintenance costs. Standard per kilometre road maintenance costs are available from the TII PAG Unit 6.11 and are incorporated into the worksheet. The user specifies the road length for each type of carriageway cross section as appropriate and the maintenance costs are calculated.

Additional values for annual maintenance costs can also be incorporated where necessary, such as bridge or tunnel related maintenance costs. Again, the assumed overall proportions for labour content and public funds should also be specified in order to apply shadow pricing to the total O&M costs. The worksheet then applies shadow pricing and rebases the costs to the price base year (currently set at 2009).

3.3.10 Staggered Maintenance Costs

For some projects it is necessary to have maintenance costs implemented in intervals, for example a cost can be required every 10 years as is common for Public Transport Schemes. It is important that these costs not be spread out into annual costs as this can alter the TUBA result.

Costs can be entered for both Road and Public Transport Costs. If the case arises that two Public Transport schemes require different staggered costs these values can be entered in the Road column. This is also applicable for two road schemes that require staggered maintenance. In the calculation of costs the Annual O&M Costs for both Public Transport and Road are still included regardless on data entered in the Staggered Maintenance tab.

3.3.11 Vehicle Fleet Requirements & Renewals

This worksheet allows the input of capital costs associated with a new public transport fleet required for a scheme. Values should be specified in factor costs at current prices with the overall proportions for labour content and public funds also specified to apply shadow pricing. The initial year of purchase should be specified along with the assumed renewal frequency.

The initial capital costs associated with new rolling stock/vehicles plus the renewal requirements over the appraisal period will be incorporated into annual O&M costs in the TUBA scheme file.

3.4 Output Worksheets

3.4.1 Full Cost Profile

The Full Cost Profile is developed from the various cost input worksheets and scheme input details.

Rounding Error Correction

The Costs Spread profile, a percentage of costs spend each year, is passed through an error correcting process to correct errors that can occur due to percentage rounding.

This process adds or removes the error difference from the year with the highest cost. The largest expenditure year was chosen as to not entirely remove or create small costs in other years. In the case that the maximum expenditure is present in two or more years the error correction is applied to each year, with the first years having the proportional error correction rounded down to the nearest one tenth applied and the final year having a rounded-up error correction applied.

3.4.2 NTA Standard Cost Workbook

This worksheet uses formatting functions to correctly format the full cost profile for output to a TUBA compatible text file.

3.5 Running TUBA

The process is set up so that when the relevant skim processes complete, CUBE will launch TUBA using the parameter files defined in the keys (and created from the Scheme File Creator Workbook).

3.5.1 TUBA distance reference files.

As part of the update in V3 of the model, TUBA was updated from version 1.9.4 to version 1.9.14. In the newer versions of TUBA, a reference distance matrix needs to be used for a run to take place. This is advised by the TUBA guidance to be a weighted base distance matrix. Therefore, a reference distance matrix was created for each user class for each regional model, based on the latest release of the relevant Base runs. The Base models used to create these files were:

- For the ERM - E7R08
- For the WRM - W16R02
- For the SWRM – SW10R03
- For the MWRM - MW13R01
- For the SERM - SE10R04

The matrices were created using a two-part process written in VBA. The first stage of the process was to align the demand matrix with the distance matrix. This was done as there were more entries in the distance matrix compared to the demand matrix. Therefore, a new matrix was created using all the entries from the distance matrix. If the demand matrix had data for the OD pair, it was used, if not, the demand was set to zero for this temporary demand matrix.

The second step was creating the base distance reference matrix. This was done by stepping through the distance matrix line by line and using the temporary demand matrix to weight the distance data. If there was no demand, the average of the distance data was taken. If there was demand, this was multiplied for each time-period and then averaged followed by division by the total demand to yield a weighted distance average.

Table 3.1 Example of the data structure for a distance matrix.

1	1	0.572	0.851	0.750	0.199
1	2	0.718	0.028	0.787	0.664
1	3	0.843	0.865	0.267	0.268

As can be seen, by the table above, there were entries for each one of the four time periods. In the final reference distance matrix, these were combined to a single average per user class.

4 TUBA Output Workbook

4.1 Overview

This section outlines the development of the TUBA Output Workbook of the Economy Appraisal Module.

The purpose of the output Workbook it to provide a clear display of the results of a TUBA appraisal in a consistent way between different models runs. The Workbook takes in the .OUT and .CSV files produced by the TUBA appraisal and sorts the data into a presentable form, allowing for interrogation of detailed TUBA benefits results. Sector to sector benefits can easily be viewed in matrix format, split by time period, mode and user type, assisting with overall model understanding and sense checking.

Furthermore the output Workbook is capable of recreating full output Transport Economic Efficiency[3] tables given a particular set of benefits adjustment rules, such as removing benefits associated with specific sector to sector movements.

The sections below provide an overview of the main tab groups within the Workbook. These regard rule specification, input files, output TEE tables and benefits summary tables.

4.2 Filtering Rule Specification

The Workbook can generate output TEE tables (including BCR values) with three rule types applied:

- unfiltered,
- filtered – discarding negligible sector to sector benefits, and/or
- filtered – disregarding specified sector to sector benefits.

The rule to be applied is set on the 'README' sheet, in the region highlighted in the figure below. The magnitude of sector to sector benefits to be ignored is also set in this region.

[3] TEE table is the output table at the end of the .out file. Includes BCR, Cost and Benefits summaries

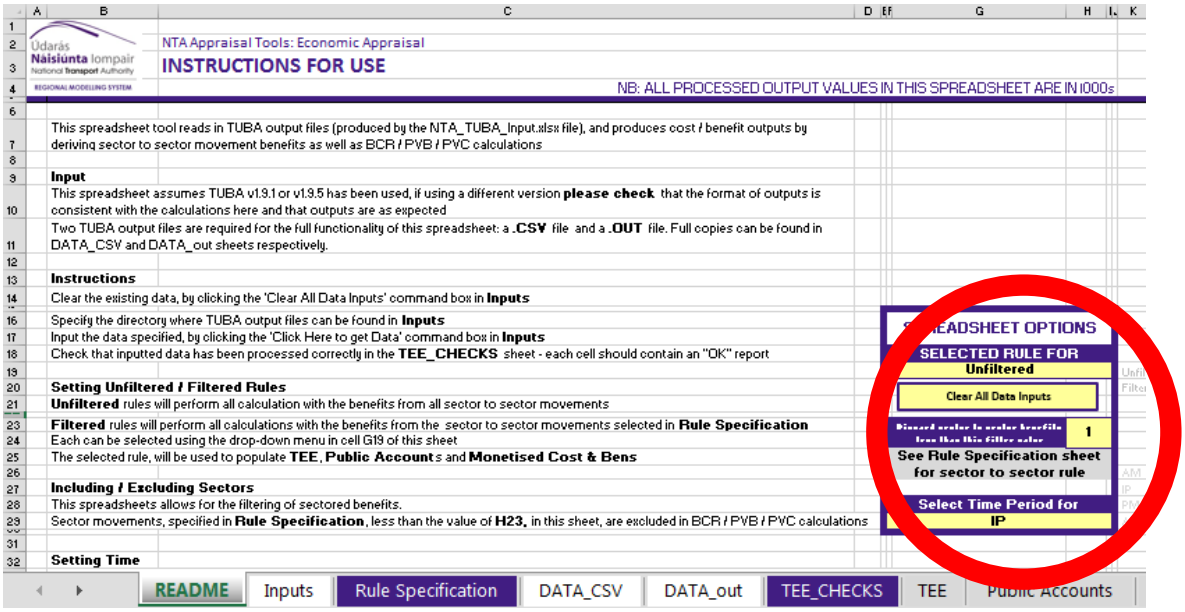


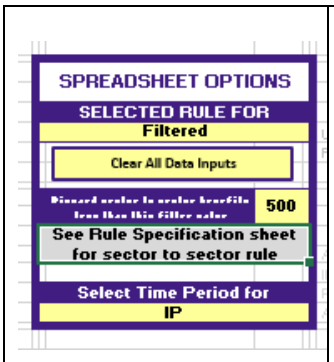
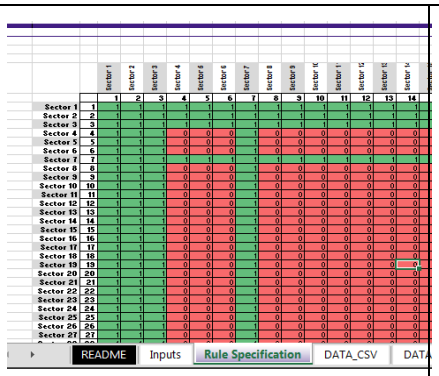
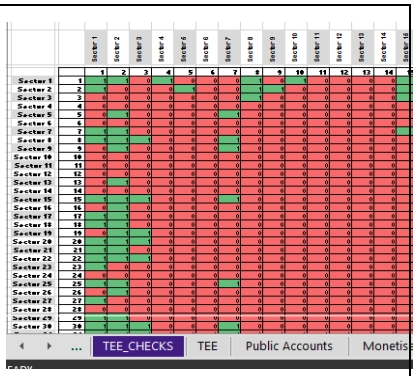
Figure 4.1 TUBA Output Workbook Options

The filtering of specific sector to sector movements is defined in the 'Rule Specification' sheet. A value of 1 in the input matrix indicates that full benefits are taken for this movement, and a value of 0 indicates that benefits for this movement are excluded.

The outcome of all applied filtering rules is shown in the matrix on the 'Rule_Processing' tab. As with the input specification, a value of 1 indicates that benefits are being used and a value of 0 indicates that benefits are not.

It should be noted that although benefits can be filtered by sector to sector movement, since TUBA provides this detailed information in the output csv file, `greenhouse gases' cannot be filtered in such a manner as the detailed information is not produced. To account for this, the greenhouse gases value is instead scaled by the change in fuel Vehicle Operating Costs given the selected filtering schemes.

A worked example of the application of filtering is provided below:

		
'README' tab specifying rules to apply	'Rule Specification' tab providing a sector to sector filter	'Rule_Processing' tab showing the result of combining the two rules

4.3 Input Files

Input files to be read in by the Workbook should be specified on the 'Inputs' sheet. When the `Click here to get data' button is clicked, a macro will run and the appropriate tabs will be automatically populated in the proper manner.

The two input files are:

- The .OUT file produced automatically by a completed TUBA run. This is read in to the 'DATA_OUT' tab, where the full file is stored in column J and just the final TEE table economics data is sorted in to columns B to F. The benefits data from this table is used to check the accuracy of recreated unfiltered TEE table benefits (in the 'TEE_CHECKS' tab) and the cost data is used directly in the recreated TEE tables.
- The detailed benefits .csv file produced by the user pressing through the 'Analysis' tab within TUBA. This is read in to the 'DATA_CSV' tab, where each row is allocated to a TEE table benefit type (in column T) and the outcome of filtering rules is applied.

After importing the input files, the user should check the 'TEE_CHECKS' tab and ensure that all cells report as 'OK' and none report as 'ERROR'. This tab checks that each of the TEE values reported in the .OUT file can be reconstructed from the supplied CSV disaggregate benefits within a tolerance specified on rows 2 and 3. A tolerance is required because TUBA outputs the CSV benefits to a different level of accuracy to that which it works internally, thus the summation of multiple CSV values may not equal the .OUT file value. This is particularly noticeable in TUBA runs containing high numbers of sectors.

4.4 Output TEE tables

The sheets 'TEE', 'Public Accounts' and 'Monetised Costs & Bens' contain the Transport Economic Efficiency, Public Accounts and Analysis of Monetised Costs and Benefits tables respectively. These three sheets are the primary output of the Workbook, and provide a full summary of scheme impacts including derivation of the key values: Present Value of Benefits (PVB), Present Value of Costs (PVC), Net Present Value (NPV) and Benefit to Cost Ratio (BCR).

Cost information is linked directly to the DATA_OUT sheet, and benefits information is constructed from the DATA_CSV sheet given the specified filtering structure.

4.5 Benefits Summary Tables

These sheets are designed to assist with the interrogation and understanding of detailed benefits information produced by TUBA and the model outputs.

The sheet 'Filtered_SecBens' provides full post-filtering sector to sector benefits for any time period (specified in the 'README' sheet). This includes user benefits on each mode, operator revenue and tax benefits. It also includes full sector to sector benefits for the specified time period.

The sheet 'SectSummary' contains the benefits totals broken down by type and time period, both before and after filtering.

5 Testing the Economic Module

5.1 Introduction

This section describes some of the final tests on the Economy module. The purpose of testing the Economy Module with these two scenarios was to confirm the correct functioning of the full process and to present a detailed process here. A full table of the tests can be found in Appendix A below.

5.2 Steps in the Testing Process

The Economy Module is comprised of several components which were tested in sequence; they are:

1) Scheme File Creator Test;
2) Cube Process Tests
   a) Copying and formatting TUBA Scheme and Economic Files
   b) Extraction and formatting of Road and PT data;
   c) Running TUBA;

The remainder of this section describes these tests for the ERM and WRM scenarios respectively.

5.3 ERM Test

For the ERM Test, the first step was to check and confirm the correct operation of the scheme file creator Workbook.

5.3.1 Step 1: Scheme File Creator Test

The result of these tests was the successful production of a TUBA compatible Scheme file for input into the Cube processing part of the Economic Module.

5.3.2 Step 2: Cube Processes Test

This testing step involved running the CUBE and TUBA process for DoStrat21 using the scheme file created in Phase 1, according to the steps outlined above in Section 5.2.

Step 1: Scheme File Creator Test

This completed successfully with the specified economic and scheme files copied to the output folder. Matrix file paths in the scheme file were correctly updated to reflect the output folder.

Step 2: Cube Process

The Extraction and formatting of Road and PT data completed successfully with the required matrices being created for the TUBA assignment.

Step 3: Running TUBA

This completed successfully with the batch file to launch TUBA being created and run by CUBE. The TUBA assignment then completed successfully. All the TUBA output files were created, and the.OUT file underwent checks as described by the check's spreadsheet. These tests included checking matrix totals and checking the amount of benefit/dis-benefit obtained from the different user classes.

Test Outcome

Each stage of testing was successful and confirmed the correct operation of the set of procedures.

5.4 WRM Test

To ensure the scheme file creator Workbook is fit for purpose costs for the schemes were applied to the sheet and scheme files created.

Step 1: Scheme File Creator Test

The result of these test was the successful production of a TUBA compatible Scheme file for input into the second element of the Economic Module.

Step 2: Cube Process

The second part of the testing involved running the CUBE and TUBA process using the scheme file created in Phase 1.

This completed successfully with the specified economic and scheme files copied to the output folder. Matrix file paths in the scheme file were correctly updated to reflect the output folder.

Extraction and formatting of Road and PT data completed successfully with the required matrices being created for the TUBA assignment.

Step 3: Running TUBA

This completed successfully with the batch file to launch TUBA being created and run by CUBE. The TUBA assignment then completed successfully. All the TUBA output files were created, and the .OUT file underwent checks as described by the check's spreadsheet. These tests included checking matrix totals and checking the amount of benefit/dis-benefit obtained from the different user classes.

Test Outcome

Each stage of testing was successful and confirmed the correct operation of the set of procedures.

5.5 Conclusion

The tests undertaken confirmed the correct operation of the Economic Module's procedures, automated components, and use of the TUBA software for economic analysis.

6 Appendix A – Full economic module tests

Table 6.1 List of test runs carried out testing the Economic module.

Module version	Test Type	Regional model used	Testing location
V3.0.0	Single year skim only	ERM	Jacobs machine
	Single year Full TUBA	ERM	Jacobs machine
	Two years skim only	ERM	Jacobs machine
	Two years full TUBA	ERM	Jacobs machine
	Single Year Multiple DS	ERM	Jacobs machine
	Single Year Manual TUBA 1	ERM	Jacobs machine
	Single Year Manual TUBA 2	ERM	Jacobs machine
	TUBA Analyser Checks	ERM	Jacobs machine
V3.1.0	Two years full TUBA run	ERM	Jacobs machine
	Three years full TUBA run	ERM	Jacobs machine
	Three years Skim Only	ERM	Jacobs machine
	Three years Manual TUBA	ERM	Jacobs machine
	Three years Full run	ERM	NTA Server
V3.1.1	Three years new TUBA Version	ERM	Jacobs machine
	Three years new TUBA Version	SWRM	Jacobs machine
	Three years new TUBA Version	MWRM	Jacobs machine
	Three years new TUBA Version	SERM	Jacobs machine
	Three years new TUBA Version	WRM	Jacobs machine