AXON

Excellence in Business

Development of the Danish LRAIC model for fixed networks

User Manual

[Version for 1st consultation]

Axon Partners Group

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Contents

1. Introduction

Since 2003, the DBA has annually regulated the wholesale prices for several fixed-network services through a Long Run Average Incremental Cost (LRAIC) model. As presented in the Model Reference Paper (hereinafter, 'the MRP') from October 2019[1], the relevant changes that occurred in the fixed Danish market since the last major update of the model in 2013, merited a new update of the fixed LRAIC model (hereinafter, 'the model') to make sure it is representative of the current situation and can fulfil DBA's regulatory needs.

The draft model submitted to consultation has been developed following the methodological principles laid out in the MRP from October 2019, which was subject to consultation with the industry between 1st July to 30th August 2019.

This document provides a user manual for the R and Excel models. While the former is used to perform a geographical assessment of the access and transmission networks in Denmark, the latter is used to calculate services' costs. This document has been split in two sections as follows:

- Excel model
- R model

[1] Link: https://erhvervsstyrelsen.dk/sites/default/files/2019-10/Final%20MRP.pdf

2. Excel model guidelines

This section, which provides guidelines on how to use the Excel model, is divided among the following sub-sections:

- **Getting started**, providing a set of high-level specs related to the hardware required to run the model.
- **General overview of the model**, describing the structure and worksheets of the Excel model.
- **Understanding the control panel,** presenting the Control Panel of the Excel model, which is the main user interface where the main options and scenarios are selected. Additionally, this worksheet contains a 'RUN' button to execute the Excel model.
- **Description of checks**, explaining the meaning of the checks included in the model.

2.1. Getting started

To run the Excel model, a computer with at least 1 GB of RAM memory and with Microsoft Excel version 2010 (or a newer version) is required. For enhanced performance, it is recommended to run the model on computers with at least 2 GB of RAM memory.

2.2. General overview of the model

The Excel model is comprised of worksheets that are grouped in the following blocks or calculation steps:

- Support and control worksheets
- Step 0: Parameters
- Step 1: Main inputs
- Step 2: Advanced inputs
- Step 3: Mapping
- Step 4: Drivers and demand factors
- Step 5: Dimensioning of the network
- Step 6: Resource Costing

- Step 7: Allocation of costs
- Step 8: Results

The Excel model has been developed based on a linear architecture in order to improve the execution performance and to ease the understanding of its calculation flow. The exhibit below shows the model calculation flow:

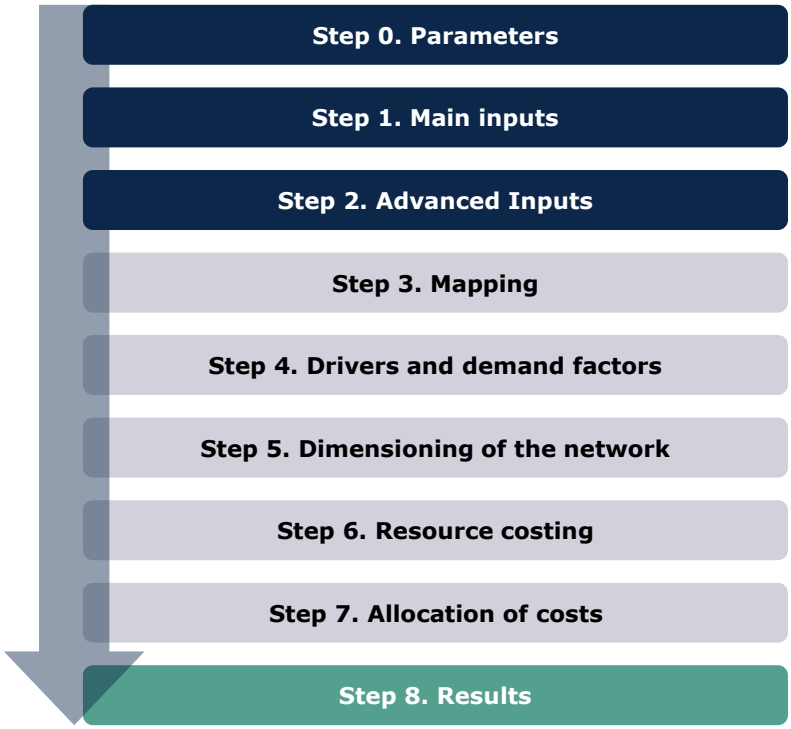

Exhibit 2.1: Calculation flow of the model [Source: Axon Consulting]

The block "Support and Control Worksheets" has not been represented in the previous exhibit for clarity purposes.

The worksheets contained in the blocks or calculation steps have been labelled according to the following structure (except for the "Support and Control Worksheets" block):

- Step number and ordinal: It is composed of the number of the step (i.e. 0, 1, 2…) and the order in letter format (i.e. A, B …).
- Type of worksheet indicators:
  - PAR: Definition of parameters
  - INP: Input worksheet

- MAT: Matrix obtaining the relationship between two dimensions
- MAP: Mapping between two dimensions
- DIM: Dimensioning of network elements
- RES: Summary of the number and costs of the resources in the network
- GEO: Summary of costs disaggregated at geotype level
- RESULTS: Results worksheets

- Name of the worksheet

As an example, the worksheet '1A INP DEMAND' is the first (A) worksheet of the Step 1. It represents an input (INP) related with the demand (DEMAND).

The following sections describe the calculation blocks, including a detailed description of the worksheets contained in each block. It should be pointed out that sub-section '2.2.1- Support and control worksheets' does not strictly describe a block of the calculation flow, but the supporting and control worksheets used within the model.

2.2.1 Support and control worksheets

The support and control worksheets provide general information to understand and run the model, as well as a number of checks to verify that the model is working properly.

Sheet name	Description
CONTENTS	▶ Provides high-level information about the model file (i.e. version, status and contacts) ▶ Provides a list and description of the model's worksheets
COVER	▶ This worksheet includes the main modelling options that may be adjusted to execute the model (e.g. WACC, execution mode, annualization methodology). At the same time, it includes the controls for the execution of the model.
MAP	▶ Map that represents the relationship between the model's worksheet blocks as well as the overall calculation flow. ▶ Colours have no meaning and have been selected to ease the identification of the blocks.
COLOUR CODE	▶ It contains the colour code used throughout the model.
CHECKS	▶ Multiple checks are performed in this worksheet to ensure that the model is working properly. Further details on these are provided in section '2.4 - Description of checks' of this document.

Exhibit 2.2: Support and control worksheets. [Source: Axon Consulting]

2.2.2 Step 0: Parameters

The worksheets concerning the parameterisations defined in the Excel model are described in the table below:

Sheet name	Description
0A PAR SERVICES	▶ The list of services (recurring and non-recurring) considered in the model is introduced in this worksheet. ▶ Services are defined by the type of service, the customer segment, the allocation rules that should be applied to the service, the unit and the period of costing (yearly or monthly).
0B PAR RESOURCES	▶ Network resources are listed in this worksheet. Other parameters related to the resources and cost items are also defined here.
0C PAR KPIS	▶ The Key Performance Indicators (KPIs) used to load data from the R Model are parametrized in this worksheet. The KPIs are defined differently for each access network.
0D PAR DRIVERS	▶ The drivers are the variables used for the dimensioning of the network (e.g. Connections, Mbps). The list of drivers considered is included in this worksheet. ▶ The rationale of the dimensioning drivers is to present traffic and demand (at service level) in a way that facilitates the dimensioning of network resources.
0E PAR LEVELS	▶ The levels of disaggregation for the results of the services are parametrized in this worksheet. The disaggregation takes into account: • Region • Geotype • Dwelling Unit • Regulation
0D PAR OTHER	▶ Other parameters needed in the model are defined in this worksheet.

Exhibit 2.3: Parameters worksheets. [Source: Axon Consulting]

2.2.3 Step 1: Main inputs

The main inputs are those that need to be regularly updated to better represent the current characteristics of the operator under study. The worksheets defined in this block are described in the following table.

Sheet name	Description
1A INP DEMAND	▶ The demand (subscribers and traffic) that needs to be supported by the network is introduced in this worksheet. This demand is provided disaggregated based on the list of services defined in sheet "0A PAR SERVICES".
1B INP UNIT COSTS	▶ Unitary costs (differentiating CAPEX and OPEX) are defined in this worksheet for each resource introduced in sheet "0B PAR RESOURCES". In addition, the percentage of staff costs over OpEx is included along with the useful lives of the resources used to depreciate the different resources.
1C INP NW	▶ Network parameters needed for the dimensioning of the network (for instance, equipment's capacity, standard constants) are introduced in this worksheet.
1D INP NW EVO	▶ This worksheet presents several inputs related to the network that are expected to evolve over time.
1E INP ANCILLARY SERV	▶ The inputs required to calculate the costs of ancillary services are presented in this worksheet.
1F INP DEMAND DISTRIBUTION	▶ The distribution of lines per geotype and per technology is introduced in this worksheet. The sum for each technology and year must add up to 100%.

Exhibit 2.4: Main inputs worksheets. [Source: Axon Consulting]

2.2.4 Step 2: Advanced inputs

The second type of inputs, named as Advanced Inputs, mostly refers to inputs that have been extracted from the R model. As such, they are related to geographical information, technical parameters, etc, which is not expected to change significantly over time. The worksheets defined in this block are described in the table below:

Sheet name	Description
2A INP COVERAGE	▶ The percentage of dwellings passed for each geotype and network is introduced in this worksheet. ▶ The figures included in this worksheet are extracted from the R model.
2B INP NW INVENTORY	▶ This worksheet contains the number of network element required to properly characterise each access network throughout the modelling period. ▶ The figures included in this worksheet are extracted from the R model.
2C INP NW ELEMENT DIS	▶ This worksheet contains the distribution of the network elements per configuration. This disaggregation represents the percentage of elements introduced in worksheet 2B that uses each type of configuration. ▶ The figures included in this worksheet are extracted from the R model.
2D INP CORE & TX RINGS	▶ The information related to the transmission links is introduced in this worksheet. ▶ The information is introduced for each transmission network at ring/chain level. Specifically, it includes the number of nodes in the chain (without considering beginning and end nodes), the total road distances covered to connect all the nodes in the chain (including end and start nodes) and the percentage of total traffic handled by each ring/chain. ▶ This information is used to calculate the elements and cost of the transmission network. ▶ The figures included in this worksheet are extracted from the R model.
2E INP NW OTHER	▶ This worksheet contains additional inputs from the R model, such as the length of the drops and the number of buildings. These inputs are used in the dimensioning process to properly dimension and split elements and costs into geotypes. ▶ The figures included in this worksheet are extracted from the R model.

Exhibit 2.5: Advanced inputs worksheets. [Source: Axon Consulting]

2.2.5 Step 3: Mapping

The worksheets contained in this step are used to map the services with the drivers used for dimensioning and to define the routing factors used to allocate resources' costs to services. These worksheets are described in the table below:

Sheet name	Description
3A MAP DRIVERS	▶ Relationships between services and dimensioning drivers for the different networks. ▶ It must be noted that in order to obtain the drivers it is necessary to indicate which services are related to them. It should also be noted that a service is generally assigned to more than one driver as drivers represent traffic in a particular point of the network.
3B MAT DRIVERS	▶ This worksheet calculates a relationship matrix between services and drivers based on the mappings defined in worksheet "3A MAP DRIVERS".
3C MAP ROUTING FACTORS	▶ This worksheet defines the relationships between services and resources by means of the routing factors. ▶ A Routing Factor is a measure of how many times a resource is used by a specific service during its provision. Hence, the more traffic a service generates, the higher the cost will be charged from the asset considered; and the higher utilisation of the asset, the higher cost taken.
3D MAT ROUTING FACTORS	▶ This worksheet calculates a relationship matrix between services and resources based mappings defined in worksheet "3C MAP ROUTING FACTORS".
3E MAP WEIGHTS	▶ This worksheet includes the weights to be considered when converting the demand introduced in worksheet "1A INP DEMAND" into the drivers defined in worksheet "0D PAR DRIVERS".

Exhibit 2.6: Mapping worksheets [Source: Axon Consulting]

2.2.6 Step 4: Drivers and demand factors

The worksheets contained in this step are used to calculate the drivers that will be used for the dimensioning of the network and the demand factors used for the allocation of the resources costs to services. These worksheets are described in the table below:

Sheet name	Description
4A CALC COPPER SHUTDOWN	▶ This worksheet includes information related with the simulation of a copper shut down scenario. It is responsible for reallocating the unserved copper demand to fibre access networks.
4B CALC DRIVERS	▶ The total volume of the drivers over the whole country is calculated in this worksheet based on the matrix presented in the worksheet '3B MAT DRIVERS'.
4C CALC DEMAND FACTORS	▶ Demand factors are used to transform the demand of the service into different types of units (e.g. from lines to Mbps). These factors are needed in order to be able to allocate the costs of different types of network elements to services. ▶ This worksheet includes the relationships needed to transform the demand of the different services to the relevant types of demand.

Exhibit 2.7: Drivers and demand factors worksheets [Source: Axon Consulting]

2.2.7 Step 5: Dimensioning of the network

These worksheets are responsible for the dimensioning of the network and are described below:

Sheet name	Description
5A DIM TX & CORE	▶ In this worksheet the transmission and core networks are dimensioned, calculating the necessary equipment that supports the relevant demand for each increment. ▶ Calculations are presented for two different increments (shown when moving towards the right of the sheet). ▶ The dimensioning of the network takes as starting point the drivers obtained in block 4 as well as other inputs extracted from blocks 1 and 2 (for instance, network parameters, coverage, etc.)
5B DIM GEO	▶ In this worksheet the access network is dimensioned, calculating the necessary equipment that supports the relevant demand for each increment. ▶ Calculations are presented for two different increments (shown when moving towards the right of the sheet). ▶ The dimensioning of the network takes as starting point the drivers obtained in block 4 as well as other inputs extracted from block 1 and 2 (for instance, network parameters, coverage, etc.).
5C DIM GEO CONS	▶ This worksheet consolidates the results from the dimensioning performed in the worksheets "5A DIM TX & CORE" and "5B DIM GEO" per geotype. ▶ The results included in this worksheet appear as values, as they are controlled by the macro in charge of executing the model, which only copies them from the previous two worksheets and pastes them into this worksheet.

Exhibit 2.8: Network dimensioning worksheets [Source: Axon Consulting]

2.2.8 Step 6: Resource Costing

This step contains the worksheets related with the costing of resources. A description of these worksheets is provided in the following table:

Sheet name	Description
6A RES CONS	▶ This worksheet consolidates the total number of resources for the access and core networks at a national level.
6B RES UNIT COST	▶ This worksheet consolidates the unit costs of the resources and calculates the different unit cost (both CapEx and OpEx) of the resources throughout the modelling period, considering the unit costs and their trend.
6C RES OPEX	▶ This worksheet calculates the total OpEx associated to the different network elements included I the model, throughout the modelling period. ▶ Please note that if the "Economic depreciation" methodology is selected in the control panel, this worksheet will appear blank, as the OpEx costs will be considered within the calculation of the Economic Depreciation in worksheet '6D RES CAPEX'.
6D RES CAPEX	▶ This worksheet calculates the CapEx (depreciation + cost of capital) for each element of the network. Two methodologies are implemented in this worksheet: Tilted Annuities and Full Economic Depreciation.
6E RES INCR-COM COST	▶ This worksheet calculates the total Incremental and Common cost for each network element in the network. Additionally, the cost overheads of the network -such as G&A, IT or wholesale costs- are calculated in this worksheet
6F RES ANC SERV COST	▶ This worksheet calculates the costs of the activities from the ancillary services considering the salary and salary trends included in sheet '1E INP ANCILLARY SERV'.

Exhibit 2.9: Resource costing worksheets [Source: Axon Consulting]

2.2.9 Step 7: Allocation of costs

This step contains the worksheets that are responsible for allocating the costs from the resources to the services. They are described below:

Sheet name	Description
7A GEO RES COSTS	▶ This worksheet calculates the total incremental, common and total cost of the different resources of the network for each of the geotypes defined in the model.
7B GEO SERV DEMAND	▶ This worksheet calculates the percentage of the demand of each service that is associated to each geotype. The results of this worksheet are used to allocate the costs of the resources at geotype level (worksheet '7A GEO RES COSTS') to services (worksheet '7C GEO SERV COSTS').
7C GEO SERV COSTS	▶ This worksheet presents the costs of each service for each geotype. The calculation is performed by taking into consideration the relevant demand for each service (considering the demand factors from worksheet '4C CALC DEMAND FACTORS'), as well as the costs of the services and the relevant routing factors.

Exhibit 2.10: Allocation of costs worksheets [Source: Axon Consulting]

2.2.10 Step 8: Results

The worksheets contained in this step provide detailed information about the results of the Excel model. These worksheets are described below:

Sheet name	Description
8A RESULTS SERV	▶ This worksheet consolidates the service cost per line and year. The cells C8 to C11 allow the cost to be visualized at different levels, such as national, region or geotype level.
8B RESULTS ANC SERV	▶ This worksheet calculates the cost of the ancillary services for each modelled year.

Exhibit 2.11: Results worksheets [Source: Axon Consulting]

2.3. Understanding the control panel

The control panel represents the main interface between the user and the model and it is presented in the "COVER" page. It is used to select the model's key inputs and methodological options, to configure the execution mode and to run the model. The following figure shows a snapshot of the control panel.

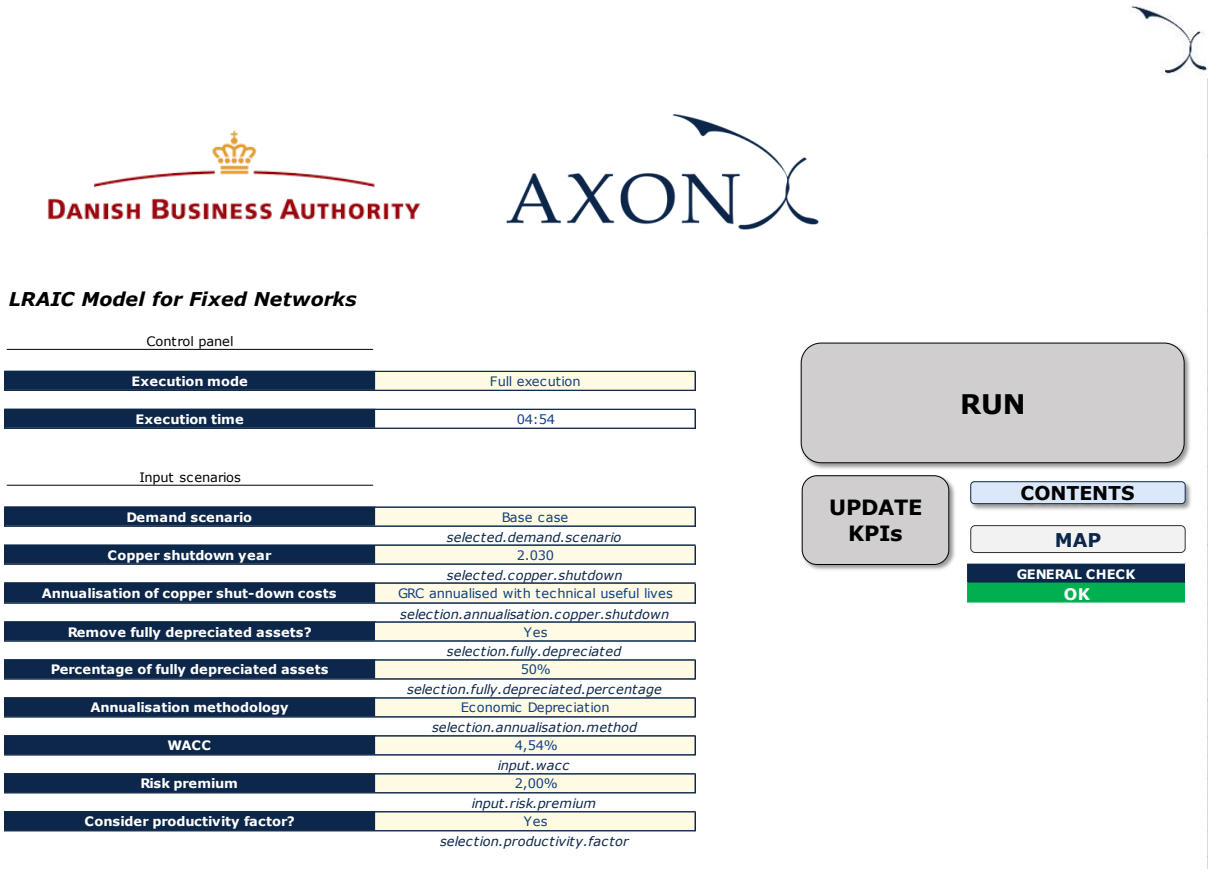

Exhibit 2.12: Snapshot of the control panel [Source: Axon Consulting]

The control panel is divided into the following blocks:

- Execution Panel
- Input scenario
- Results overview

These three blocks are described in the following paragraphs.

Important warning: the model needs to be run to see the impact on the results of any change made in the control panel.

2.3.1 Execution Panel

The Execution Panel displays information regarding the status and progress of the execution of the model. The following information is shown in this Panel:

- **Execution mode:** It displays the execution mode to be selected. The two options available are:

- Full execution: The model is completely executed. It takes roughly 4 minutes, depending on the computer.
- Costing only: The model is run from block 6 (included) onwards. This mode becomes handy to assess the impact of different costing scenarios when the number of resources is not expected to change. It takes roughly 2 minutes, depending on the computer.

- **Execution Time**: It displays the duration of the current (or last) model execution.

The execution panel also includes a number of buttons:

- **RUN**: Press this button to launch the execution of the model.
- **UPDATE KPIs**: Press this button to load the KPIs from the R model. When this button is pressed Excel will prompt a window where the user is requested to select the file generated by the R model *(in case a wrong file is selected the excel will display an error message).*
- **CONTENTS**: Quick link towards the "CONTENTS" worksheet
- **MAP**: Quick link towards the "MAP" worksheet
- **GENERAL CHECK**: It shows an "OK" when no errors are registered in the last execution and a "Review worksheets" when issues have been found.

2.3.2 Input scenarios

The input scenarios panel includes up to nine options that may be adjusted to tailor the execution of the model to the user's objectives. These options are:

- **Demand scenario:** Allows the user to select different demand scenarios that may be defined in worksheet '1A INP DEMAND'.
- **Copper shutdown year:** Allows the user to select the year of the copper shutdown. Please refer to the Model Description Document for further details on this option.
- **Annualization of copper shut-down costs:** This option allows the user to select how copper access costs should be annualized if the network is shut down before 2035.
- **Remove fully depreciated assets?:** This option allows the user to select whether the adjustment for fully depreciated assets should be considered.
- **Percentage of Fully depreciated Assets.** When "Yes" is selected in the option "**Remove fully depreciated assets?**" then the user may select what percentage of

the GBV for copper and coaxial networks of the modelled operator correspond to fully depreciated assets. Please refer to the Model Description Document for further details on this aspect.

- **Annualization methodology:** This parameter allows the user to select its desired annualization methodology (tilted annuities or economic depreciation). Please refer to the Model Description Document for further details on this aspect.
- **WACC (Weighted Average Cost of Capital):** This parameter represents the average minimum remuneration required for the capital employed. The WACC is employed for the calculation of the cost of capital associated to fixed investments. A percentage must be introduced by the user.
- **Risk premium**: This parameter allows the consideration of an additional risk premium for fibre access network elements.
- **Consider productivity factor?:** This option allows the user to select whether a productivity factor on human workforce should be considered.

2.3.3 Results overview

This panel allows the user to display the results of three different services, based on his selection of the following items:

- **Service**: Select a service from the list of services introduced in the model.
- **Geotype:**
  - Region: Hovedstaden, Sjælland, Syddanmark, Midtjylland, Nordjylland or all
  - Degree or Urbanisation: URBAN, SUBURBAN, RURAL or all
  - Type of building: Single-Dwelling, Multi-Dwelling or all
  - Regulated areas: Regulated, Not-Regulated or all

Result overview

	Scenario 1	Scenario 2	Scenario 3
Selected service:	Access.Copper.Wholesale.Raw Copper	Access.Fibre.Wholesale.Raw access (POI1)	Access.Coaxial.Wholesale.BSA Access (POI2/POI3)
Units	DKK / Lines / Year	DKK / Lines / Year	DKK / Lines / Year
Region	All	All	All
Degree of Urbanisation	All	All	All
Type of building	All	All	All
Regulated areas	All	All	All

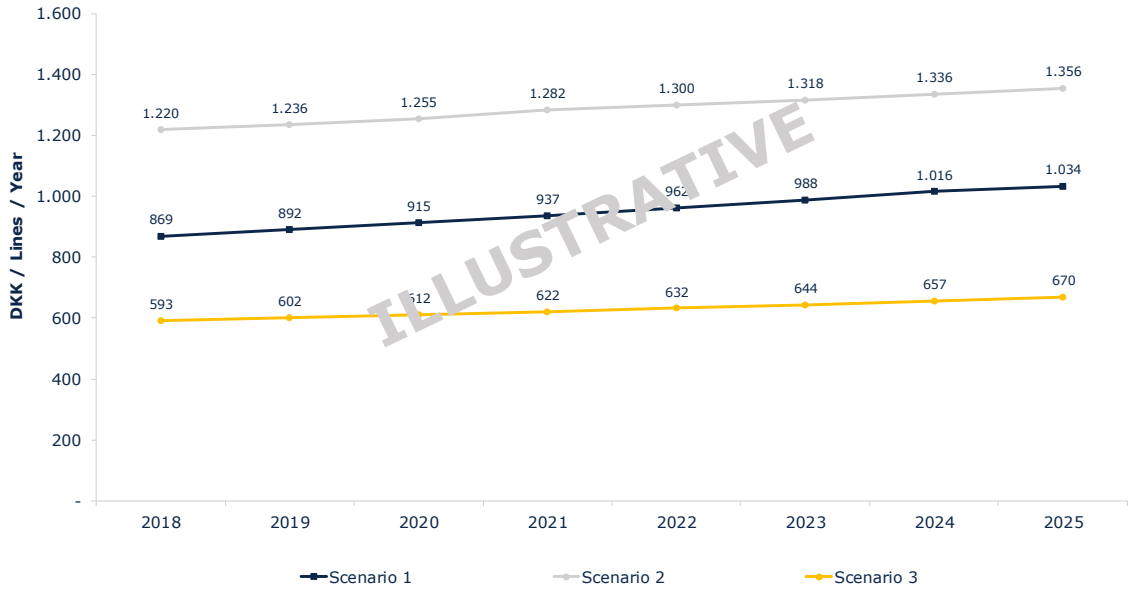

Exhibit 2.13: Result overview [Source: Axon Consulting]

2.4. Description of checks

This section describes the list of checks included in the worksheet "CHECKS" to guarantee the correct performance of the Excel model:

- **GENERAL CHECK:** This check indicates if the model is working properly or if it is necessary to review any of its worksheets and calculations.
- **Duplicity of resources unitary cost input:** This check indicates that there are duplicated resources in the worksheet "1B INP UNIT COSTS". The duplicated resource shall be removed.
- **Resources unitary cost input:** This check indicates that some resources are missing in the worksheet "1B INP UNIT COSTS". These missing resources should be included in this worksheet.

- **Invalid name of resource:** This check indicates that the name of a resource included in the worksheet "1B INP UNIT COSTS" is not correct and therefore, it should be adjusted.
- **Time Period:** This check indicates that the time period used in the model fits into the excel tables considered and thus allows a correct calculation.
- **Implementation of Economic Depreciation:** This check verifies that the sum of the depreciation and cost of capital charges obtained after calculating the economic depreciation is equal to the NPV of the resources depreciated.
- **Calculation of resource costs at geotype level:** This check indicates if there is any mistake in the allocations performed in the worksheet '7A GEO RES COSTS'.
- **Calculation of service costs at geotype level:** This check indicates if there is any mistake in the allocations performed in the worksheet '7C GEO SERV COSTS'.

3. R model guidelines

This section, which provides guidelines on how to use the R model, is divided among the following sub-sections:

- **Getting started**, detailing the main considerations and specifications to run the model.
- **Understanding the control panel**, describing the Control Panel of the model, which is the main user interface where the main options and scenarios are selected.
- **Expert access to execution scripts,** describes the main structure of the app and the folders to find the main scripts of the model.

3.1. Getting started

Important note: The model submitted for consultation includes only a sample dataset. The complete dataset has not been shared for confidentiality reasons. Nonetheless, please note that the algorithms and calculations included in the model shared for consultation are identical to the ones considered in the internal version with the complete dataset handled by DBA to ensure a full review is possible.

Computer requirements

The R model is provided as an application, and thus does not require the installation of R in the computer. However, to run the model, a computer with at least 8 GB of RAM memory is required. For enhanced performance, a computer with 32 GB of RAM memory is recommended.

In addition, at least 5 GB of free space (2 GB in the version with the sample dataset) in the computer's hard drive are required to open the app.

Execution Time

It must be noted that the R model comes pre-executed, which means that results may be extracted upon opening the app. As the model is computationally intensive, section '3.2.2 Execution control panel' provides estimated execution times for the different calculations included in the model.

The app is completely self-contained program that has everything necessary to be executed.

The first step that the user should follow is to un-zip the app into a local folder.

Then, to start the app, the user must click on the file named "LRAIC_Rmodel.bat" on the app folder. Note that the opening process of the app takes between 1-5 minutes, as it loads the dataset. Upon complete loading, the R model pops-up a window letting the user know that the process has been completed.

3.2. Understanding the control panel

The application represents the main interface user-model. The application uses a web interface that opens in the predefined web browser of the user. The interface is used to select the model's main available options, configure the execution mode and run the model. The following figure shows a snapshot of the control panel.

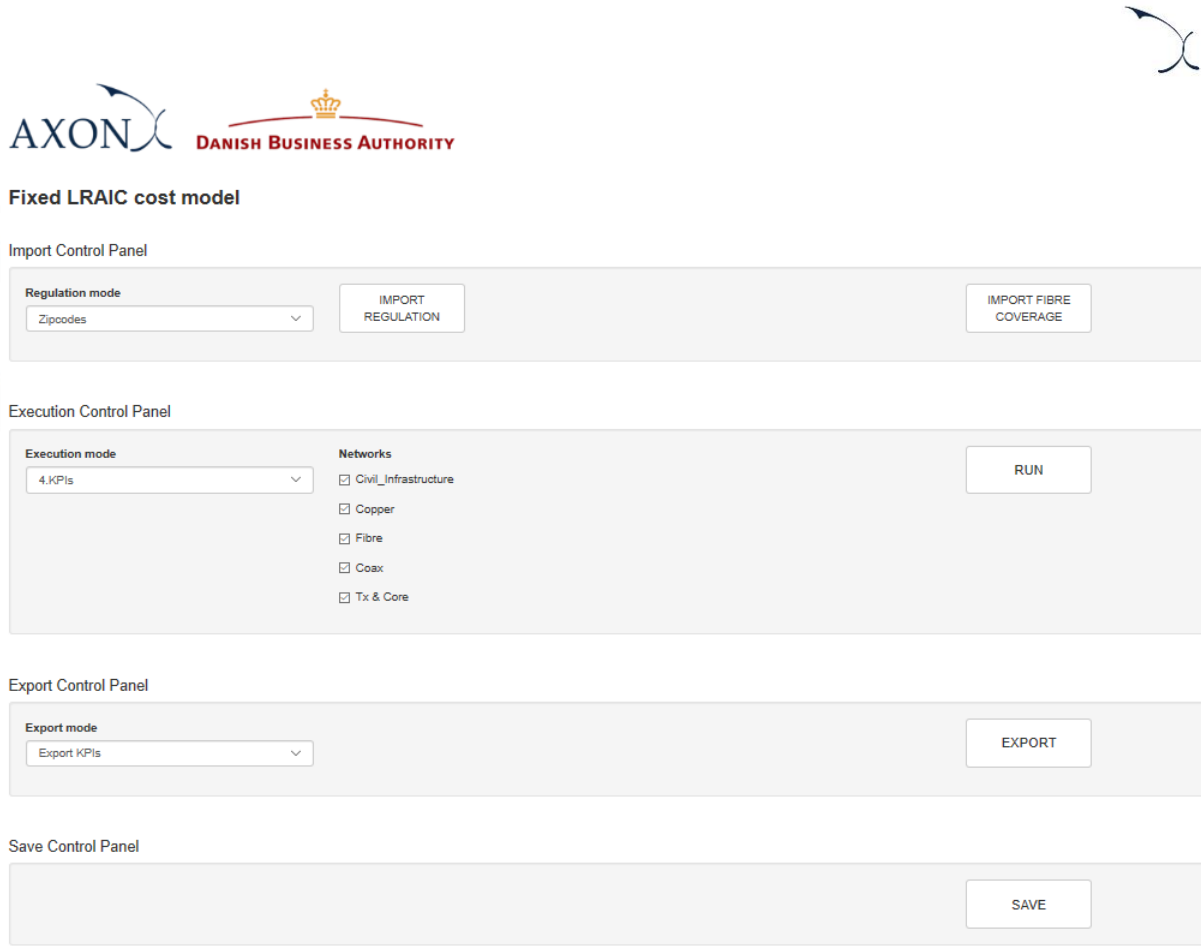

Exhibit 3.1: Control Panel of the R Model [Source: Axon Consulting]

As the exhibit shows the control panel consists of 4 main blocks:

- Import control
- Execution control
- Export control
- Save control

3.2.1 Import control panel

The objective of the import control panel is to allow the user to update some parameters and inputs relevant to the calculations performed in the model. Currently, the model allows the update of the following inputs:

- Regulatory status

- Fibre

The process to update each of these inputs is presented below.

Regulatory status

This part of the panel is responsible for the loading of the data related to the regulation areas. To do that, it has different options that shall be selected by the user. There are two different modes to load this input:

- By postal code
- By home

Once the option of loading selected, the "IMPORT REGULATION" button must be pressed to import the data of the option selected.

A pop-up window will open to choose the Excel file to import from the computer.

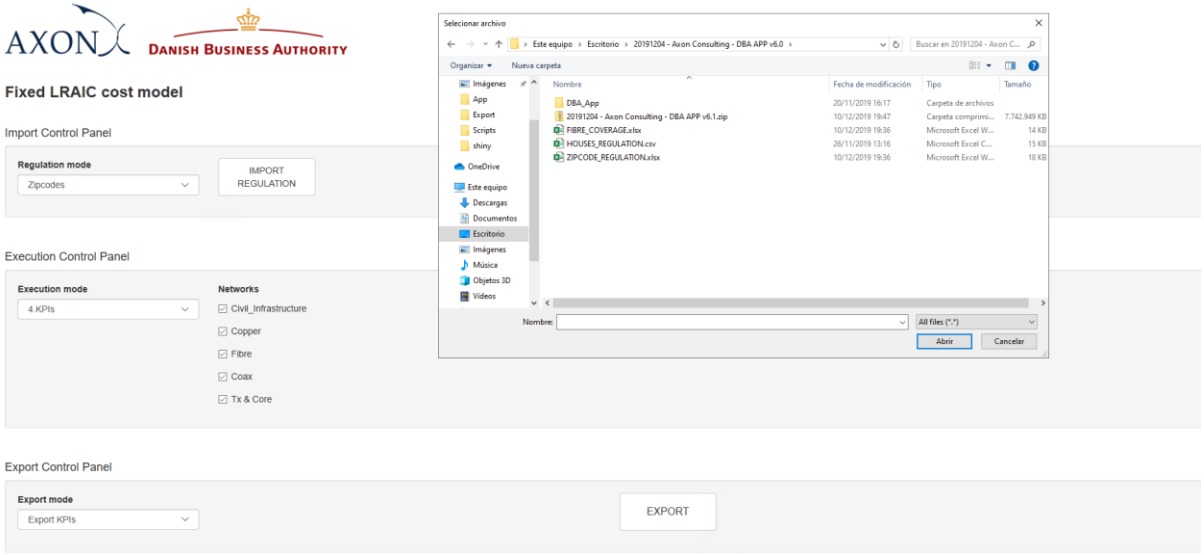

Exhibit 3.2: Pop-Up to import file from computer for the R model [Source: Axon Consulting]

The app comes with built in templates that shall be used for the purpose of updating the regulatory status of the postal codes or the homes. These templates are located in the provided app folder with the following names:

- 'ZIPCODE_REGULATION.xlsx', to be used to load the regulatory status at postal code level.
- 'HOUSES_REGULATION.xlsx', to be used to load the regulatory status at home level.

Please note that the templates provided are filled only with sample data and do not contain an exhaustive list of the regulated houses or zip codes. The regulatory status of the buildings included in the current version of the model are based on the results of the current DBA's market review.

Warning: if the selected file does not correspond to the right template the model will not proceed to calculate.

Fibre coverage

This part of the panel can be used to update the number of homes passed with fibre networks. The model allows the introduction of multiple figures, which can be used to determine network requirements throughout the modelling period.

Once the "IMPORT FIBRE COVERAGE" button is pressed. A pop-up window will open to choose the Excel file to import from the computer.

The template that shall be used for this purpose are located in in the provided app folder with name 'FIBRE_COVERAGE.xlsx'

Please note that in the case of the model with the sample dataset, the figures included in this template are only illustrative and not representative of those used in the complete dataset.

Warning: if the selected file does not correspond to the right template the model will not proceed to calculate.

3.2.2 Execution control panel

While the model comes complete pre-executed, the user can decide to update part of the calculations. This should only be done in the case that some of the inputs have been changed (for instance, to update figures in a yearly update or to model a new operator).

Notably, the Execution Control Panel allows to run the execution of the calculations selecting several parameters:

- Execution Mode
- Networks

The options under each alternative are presented below.

Execution Mode

The panel displays five options of execution:

Execution Mode	Description	Execution Time	Execution need
KPIs	This mode calculates the KPIS associated to each network. The different modelled networks can be selected. More than one option can be selected at the same time.	The execution time depends on the selected network options and the source dataset: ▶ Full dataset: • Civil Infrastructure (1-5 mins) • Copper (5-10 mins) • Fibre (15-30 mins) • Coax (1-5 mins) • Transmission (40-70 mins) ▶ Sample: • Civil Infrastructure (<30 seconds) • Copper (<30 seconds) • Fibre (2-3 mins) • Coax (<30 seconds) • Transmission (4-6 mins)	KPIs should be executed in the event that any of the inputs of the R model are updated. *(e.g. to be performed upon annual update of pricing decisions or when modelling a new operator)*
Building treatment	This mode prepares the address database to easily extract the KPIs. Some of the calculations performed in this mode involve the calculation of coverage, geotype definition and assigning SDP information to buildings	▶ Full dataset: 0,5-2h ▶ Sample: <30 seconds	This mode should be executed in the case that new inputs are loaded into the model *(e.g. when modelling a new operator or if updating the source coverage database in the annual update process)*

Execution Mode	Description	Execution Time	Execution need
Node Splitting	This mode performs the node splitting and the location of SDPs in the different networks.	▶ Full dataset: 4-10h ▶ Sample: <30 seconds	This mode should be used only in the case that different network nodes are updated in the model. *(e.g. to be performed when modelling a new operator)*
Section treatment	This execution mode converts the generated routes and divides it into sections so the KPIs can calculate the results using a section level of detail.	▶ Full dataset: 1-3h ▶ Sample: <30 seconds	This mode should be used only in the case that different network nodes are updated in the model. *(e.g. to be performed when modelling a new operator)*
Generate routes	This execution mode recalculates all routes nationwide.	▶ Full dataset: approx. 24h ▶ Sample: 4-5 mins	This mode should be used only in the case that different network nodes are updated in the model. *(e.g. to be performed when modelling a new operator)*

Exhibit 3.3: Execution modes in the R Model [Source: Axon Consulting]

Networks

This part of the panel is only to be used when execution mode "KPIs" is selected. The following networks can be chosen:

- Civil Infrastructure
- Access Copper Network
- Access Fibre Network
- Access Coax Network
- Core and Transmission Network

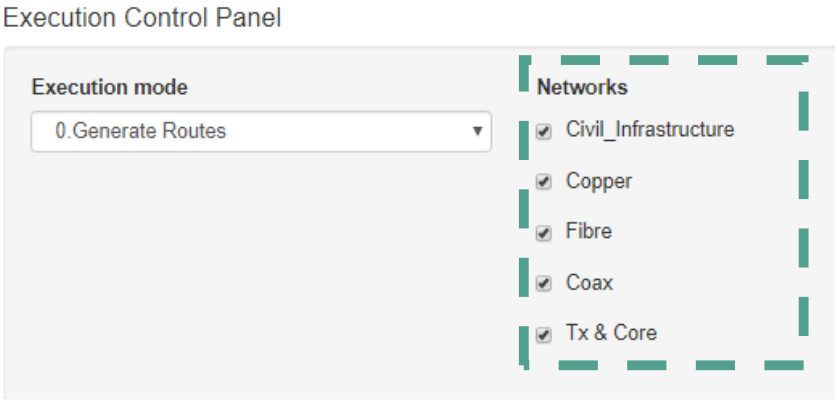

Exhibit 3.4: Execution Control Panel, selection of networks [Source: Axon Consulting]

3.2.3 Export control panel

The Export Control Panel creates Excel files containing the latest results of the calculations performed in R. Results are exported to the following folder: APP_FOLDER/DBA_App/app/shiny/Export

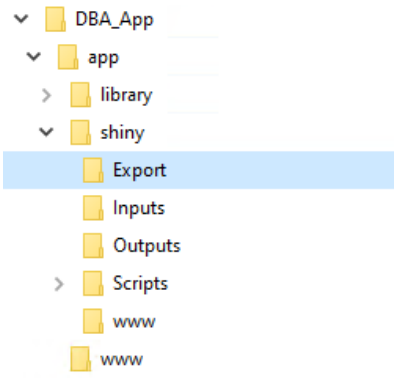

Exhibit 3.5: Folder Tree where to find the exported data [Source: Axon Consulting]

The results of this export can be loaded in the excel model (please see section '2.3.1- Execution Panel' of this document)

3.2.4 Save control panel

Finally, this panel allows to save the results of the latest execution into a dataset pressing on the "SAVE" button. This action is only required when executing some of the algorithms presented in section '3.2.2 - Execution control panel'. Results can be exported without saving the dataset.

Please note that this action takes roughly 30 minutes for the full set and around 10 minutes for the sample set and that it cannot either be cancelled or reversed.

Warning: if this option is stopped through command line, task administrator or other administration tools may corrupt the existing dataset and may cause to lose data.

3.3. Expert access to execution scripts

In addition to the app, the user can access the scripts that hold the specific algorithms included in the model. In order to access these scripts, it is necessary to install a distribution of R. We recommend installing RStudio[2].

In order to clarify the steps that need to be followed to access and review the scripts, the following sections are presented:

- Setting up R for the LRAIC model
- Description of the scripts included in the R model

3.3.1 Setting up R for the LRAIC model

The process to set up RStudio to access and review the scripts involves the following steps:

- **Step 1. Installing RStudio**. To install RStudio, please download 'RStudio desktop' from the following link: https://rstudio.com/products/rstudio/. After the file has been downloaded, please follow the set-up guide to install the program.
- **Step 2. Installing the required packages.** After installing R, and before opening the app, you will be required to install the packages included in the scripts. To do so, click on the 'Tools' tab in RStudio, then on 'Install packages'. A window will pop-up where the user shall list the necessary packages. Please copy and paste the following packages in the 'Packages' section of the pop-up window:

[2] https://rstudio.com/

Shinyalert shiny tidyr zoo sos data.table sp rgdal maptools XML plotKML plyr dplyr igraph operators sf matlib LearnGeom spatstat writexl BAMMtools splitstackshape aspace readxl stringr numbers TSP

Then, press on the 'Install' button from the pop-up window.

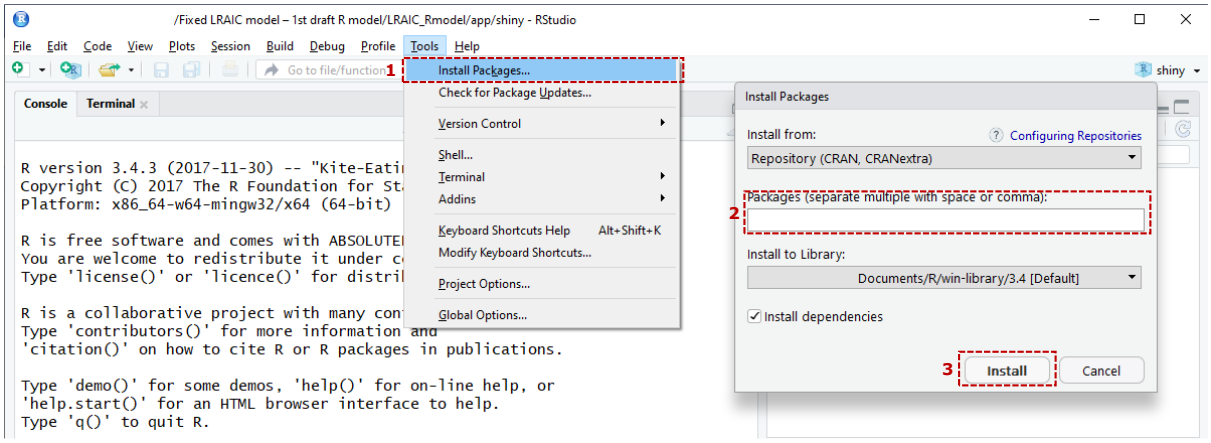

Exhibit 3.6: Overview of the process to install necessary packages [Source: Axon Consulting]

- **Step 3. Create a new project.** In order to ensure the scripts work properly, a new project shall be created in RStudio. To do so, click on the 'File' tab in RStudio, then on 'New Project…'. After this, in the new window will pop-up, click on the 'Existing Directory' option.

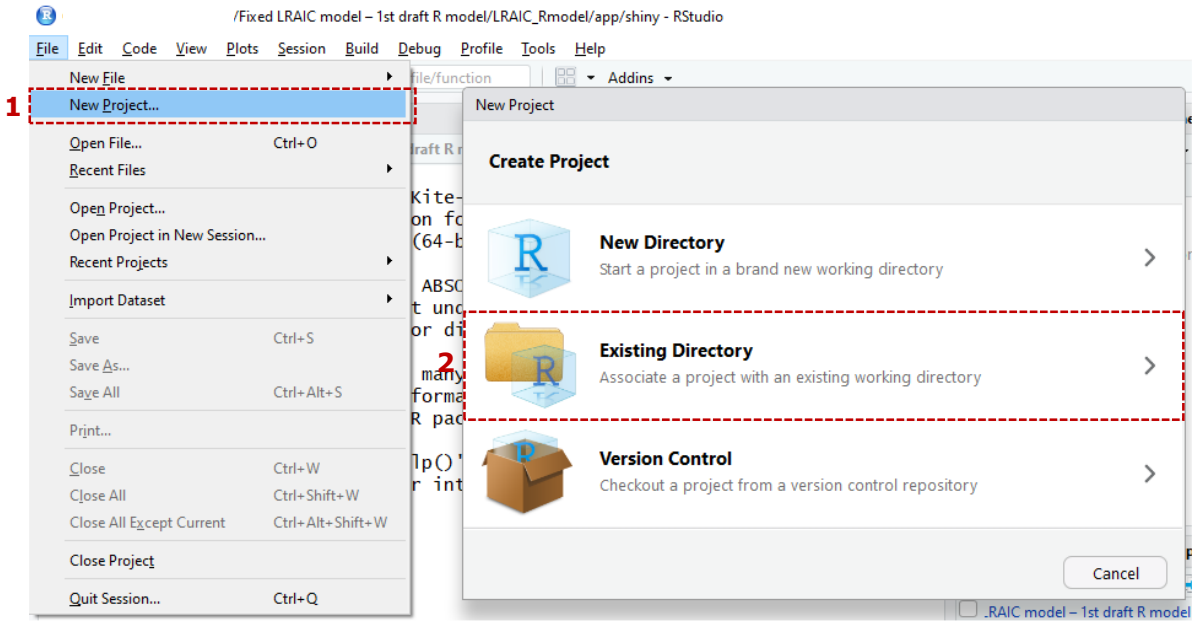

Exhibit 3.7: Overview of the process to create a new project [Source: Axon Consulting]

After this, a new window will request the existing address of the project. In this case, the user shall select in the 'Project working directory' the following address:

APP_FOLDER/LRAIC_Rmodel/app/shiny

Where 'APP_FOLDER' represents the location of the folder where the .zip file of the app has been unzipped. After this folder has been selected, click on the 'Create Project' button.

- **Step 4. Opening the app (optional).** After the project has been created, the user may interact with the scripts included (please see section '3.3.2 - Description of the scripts included in the R model' for further details on the scripts). In addition, the user may open the app within RStudio to interact with it. To do so, the user shall open the 'global.R' script in the main working folder (double click). Then the user shall press the 'Run App' included in the main RStudio screen.

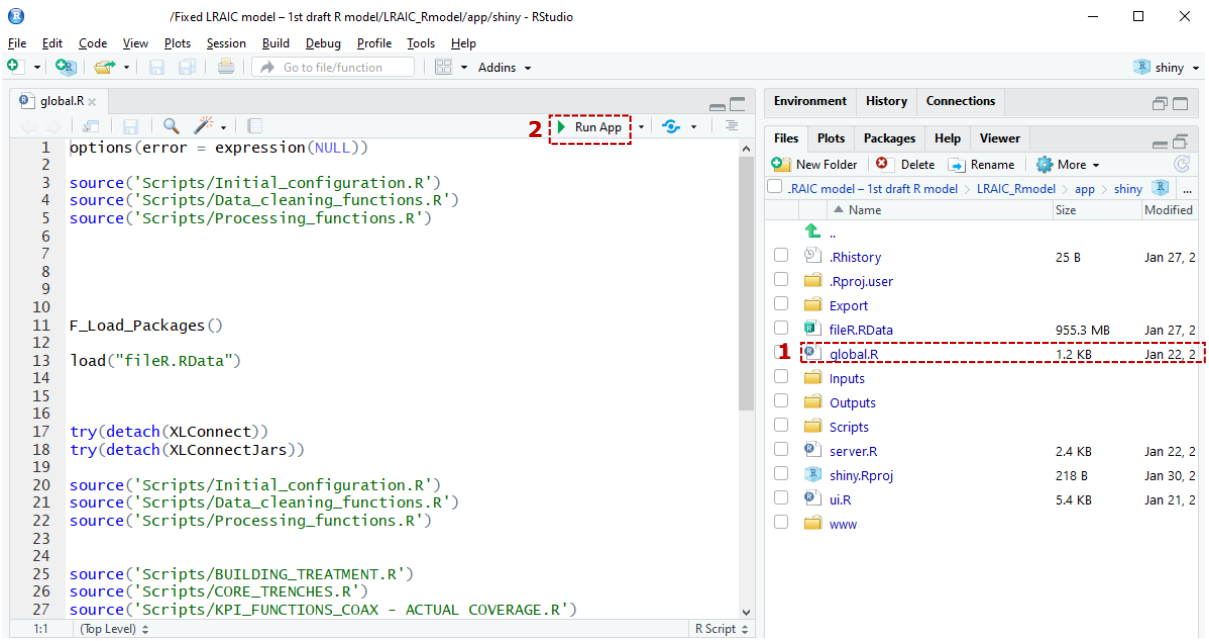

Exhibit 3.8: Opening the app from RStudio [Source: Axon Consulting]

3.3.2 Description of the scripts included in the R model

The scripts included in the R model are distributed into three main groups:

- Interface scripts
- Link scripts
- Backend scripts

The functions and scripts included in each group are presented below.

3.3.3 Interface scripts

These scripts are responsible of building the app interface. The scripts are included in the following folder:

APP_FOLDER/LRAIC_Rmodel/app/shiny

Where 'APP_FOLDER' represents the location of the folder where the .zip file of the app has been unzipped.

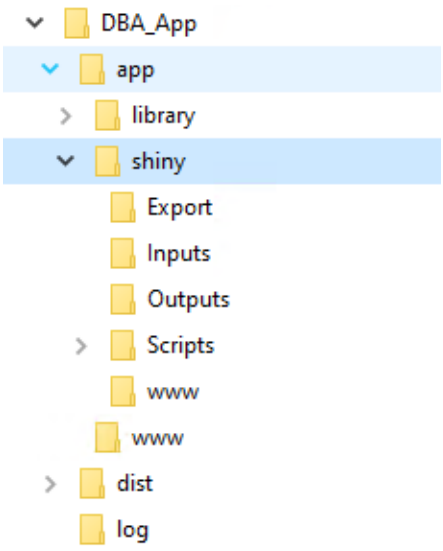

Exhibit 3.9: Folder tree where to find the interface scripts [Source: Axon Consulting]

The scripts included in this group are described below:

Script name	Description
global.R	This script loads the datasets and functions into the R model.
Server.R	This script is used to link the R Model interface, the user actions and the backend scripts (see section '3.3.5 – Backend scripts')

Script name	Description
ui.R	This script defines the layout of the R Model Interface.

Exhibit 3.10: Script summary from the Interface Scripts [Source: Axon Consulting]

3.3.4 Link scripts

The scripts included in this group are responsible for grouping the main functions executed when using the interface and linking them with the underlying functions they involve (please, see '3.3.5– Backend scripts', for further details). Each of the scripts in this is related to one of the execution options of the interface.

The scripts are included in the following folder:

APP_FOLDER/LRAIC_Rmodel/app/shiny/Scripts/Blocks

Where 'APP_FOLDER' represents the location of the folder where the .zip file of the app has been unzipped.

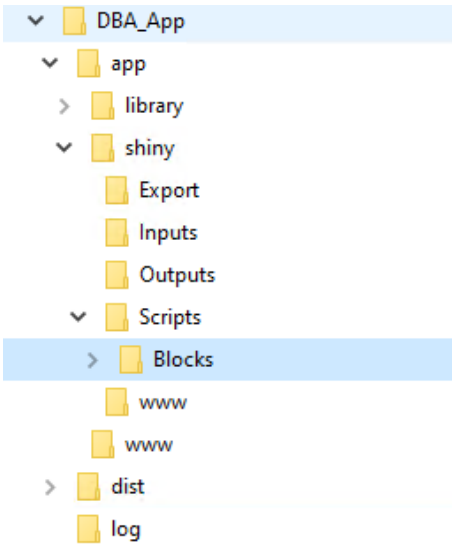

Exhibit 3.11: Folder tree where to find the link scripts [Source: Axon Consulting]

The scripts included in this group are described below:

Script name	Description
IMPORT_COVERAGE_FIBRE.R	Calls backend script in charge of loading the file with the covered houses per year into the model.

Script name	Description
IMPORT_REGULATION_HOUSES.R	Calls the backend script in charge of loading the file with the regulated homes into the model.
IMPORT_REGULATION_ZIPCODES.R	Calls the backend script in charge of loading the file with the regulated postal codes into the model.
Pre-KPI Building treatment.R	Calls the backend script in charge of performing the data treatment of the buildings prior to extracting the KPIs.
Pre-KPI Generate routes.R	Calls the backend script in charge of calculating the routes between houses and the different level of nodes.
Pre-KPI Node Splitting Calculation.R	Calls the backend scripts in charge of calculating the new nodes added in the Coax (CMC), Copper and Fibre (SDP) networks.
Pre-KPI Section treatment.R	Calls the backend script in charge of performing the section treatment.
KPIs_Coax.R	Calls the backend script in charge of calculating the KPIs for coax access networks.
KPIs_Copper.R	Calls the backend scripts in charge of calculating the KPIs for copper access networks.
KPIs_Fibre.R	Calls the backend script in charge of calculating the KPIs for fibre access networks.
KPIs_Passive.R	Calls the backend script in charge of calculating all KPIs that are not network related (such as number of per building, number of buildings and average last drop per building).
KPIs_General.R	This script gathers into a single table all the KPIs calculated from copper, coax, fibre and passive KPIs.
TX_&_Core_Calculations.R	Calls the backend scripts in charge of calculating the transmission and core networks. Please, note that in the case of the 'Sample dataset' the script called is a simplified version to calculate distances. Nonetheless the script used in the case of the full dataset is also included in the model included the ' Sample dataset'.
Outputs_Script.R	This script loads the excel template into the model, fills it with the KPIs calculated in previous steps, and then exports the result into an excel file in the export folder.

Exhibit 3.12: Script summary from the Link Scripts [Source: Axon Consulting]

3.3.5 Backend scripts

This group of scripts gather all other functions and scripts used in the R model.

The scripts are included in the following folder:

APP_FOLDER/LRAIC_Rmodel/app/shiny/Scripts

Where 'APP_FOLDER' represents the location of the folder where the .zip file of the app has been unzipped.

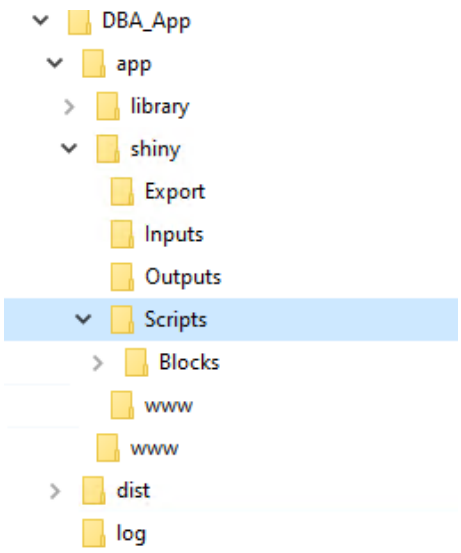

Exhibit 3.13: Folder tree where to find the backend scripts [Source: Axon Consulting]

The scripts included in this group are described below:

Script name	Description
Additional data processing.R	This script ensures that all the sections of the dataset are complete and thus, will not generate any error during the generation of routes between network nodes.
ADDITIONAL INPUTS_LOADING.R	This script loads a set of additional inputs that are required after the calculation of the routes is performed. Some of the inputs loaded are: ▶ Backbone nodes ▶ Network assets ▶ Coverage database
BUILDING_TREATMENT.R	This script contains a function used to assign the degree of urbanisation and the dwelling type to each building that is used in the 'BUILDINGS_PROCESSING.R' script.
BUILDINGS_PROCESSING.R	This script prepares the buildings and the network node tables that will be used in the calculation of the KPIs. Some of the actions done are: ▶ Assigning a geotype to each building, ▶ Assigning the coverage for copper and coax networks ▶ Calculating a coverage order for the fibre networks ▶ Joining the information calculated during the node splitting into the network node tables.
CLEANING.R	This script removes several unnecessary data generated in the execution of the route calculation to enhance performance in the model.
CMC Treatment.R	This script performs the node splitting for the CMC nodes in the coax network.

Script name	Description
CMC_TREATMENT_functions.R	This script contains several functions used by the 'CMC Treatment.R' script. Some of the functions are: ▶ Calculation of CMC node splitting locations ▶ Route modification to account for the CMC splitting
CORE_CALCULATIONS.R	This script calculates all the KPIs related to the core and transmission networks for the full dataset.
CORE_CALCULATIONS_SAMPLE.R	This script in charge of calculating all the KPIs related to the core and transmission networks for the sample dataset.
CORE_TRENCHES.R	This script contains the functions related to the calculation of trenches and civil infrastructure KPIs for the core and transmission networks.
COVERAGE_KPI.R	This script calculates the coverage KPIs of the model for the three access networks (copper, fibre and coax).
COVERAGE_SCRIPT_FIBRE.R	This script is used to calculate some additional parameters required in the calculation of the coverage for the fibre network, such as the order of the deployment of the areas.
Data_cleaning_functions.R	This script contains functions used to clean and process the inputs (such as access nodes and nodes coverage areas) loaded into the R Model.
FIBRE_KPIS_PER_YEAR.R	This script calculates the KPIs for fibre network for each year modelled.
IMPORT_COVERAGE_FIBRE.R	This script is used to update the coverage of fibre access networks (in terms of houses covered per year) into the model.
IMPORT_REGULATION_HOUSES.R	This script is used to update the regulatory status of the houses included in the model.
IMPORT_REGULATION_ZIPCODES.R	This script is used to update the regulatory status of the postal codes included in the model.
Initial_configuration.R	This script contains several functions that allows the R Model to self configurate to work properly. Some of the functions are: ▶ Loading of inputs and outputs folder path ▶ Loading the distributed R packages into the model.
KPI_FUNCTIONS_COAX - ACTUAL COVERAGE.R	This script contains the function used to calculate the KPIs for coax networks not related to the civil infrastructure.
KPI_FUNCTIONS_COAX_PASSIVE - ACTUAL COVERAGE.R	This script contains the function used to calculate the KPIs for coax networks related to the civil infrastructure.
KPI_FUNCTIONS_COPPER - ACTUAL COVERAGE.R	This script contains the function used to calculate the KPIs for copper networks not related to the civil infrastructure.
KPI_FUNCTIONS_FIBRE.R	This script contains the function used to calculate the KPIs for fibre networks not related to the civil infrastructure.
KPI_FUNCTIONS_PASSIVE - ACTUAL COVERAGE.R	This script contains the function used to calculate the KPIs for copper networks related to the civil infrastructure.
KPI_FUNCTIONS_PASSIVE_FIBRE_2.R	This script contains the function used to calculate the KPIs for fibre networks related to the civil infrastructure.

Script name	Description
KPI_FUNCTIONS_SUBFUNCTIONS.R	This script contains several functions that are used to calculate the KPIs. Some of these functions include: ▶ Calculation of cable asset requirements per section ▶ Dimensioning the different distribution points ▶ Calculation of the asset's distribution
Node_Assignation_Sample.R	This script a function that is used solely in the sample model and in the full dataset model. This function assigns each network node to the closest intersection defined in the sample dataset.
Processing_functions.R	This script contains several functions used during the route calculation, such as: ▶ Calculation of distance building to road ▶ Calculation of distance between two intersections ▶ Disaggregation of access nodes into different hierarchy categories
SDP_CALCULATION.R	This script calculates the location of the SDP nodes.
SDP_TREATMENT.R	This script contains some additional functions used for the calculation of the SDPs and in the integration of the SDP calculation results into the network node tables.
SECTION_TREATMENT.R	This script treats the route paths for the access network calculated so they are usable during the calculation of the KPIs.
SECTION_TREATMENT_CORE.R	This script treats the route paths for the core and transmission networks network calculated so they are usable during the calculation of the KPIs.
TEMPLATE_SCRIPT.R	This script contains a function that modifies the results of the R model to be exported in the same order as the excel model, to ensure the correct treatment of the R model data.
Tx&CORE.R	This script contains some functions involved in the calculation of the KPIs for core networks, such as: ▶ Calculation of route distance between two nodes ▶ Disaggregation of ring information into links ▶ Node treatment for KPI calculation

Exhibit 3.14: Script summary from the backend Scripts [Source: Axon Consulting]

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