REHABILITATION OF CAST IRON TOOL
GUIDANCE MANUAL

GETTING STARTED

The Rehabilitation of Cast Iron Tool (RoCIT) is a decision support tool (DST) designed to assist asset managers to make rehabilitation decisions for small diameter cast iron pipes. This is achieved through six modules that help the user decide whether to renovate or replace the pipe(s). Before installing RoCIT, please check the minimum system requirements. The following provides a brief overview of the tool.

System Requirements

The software has the following requirements:

1. Windows operating system running Microsoft .NET Framework 4.0
   http://www.microsoft.com/download/en/details.aspx?displaylang=en&id=17113

Installation

The software is provided ready to install. Double click the installer [Setup] and then follow the instructions given. Please note the installation requires administrative rights.

OVERVIEW OF ROCIT NAVIGATION

Upon loading RoCIT, the user is presented with a screen that has a top navigation bar (which enables the user to set-up the tool, reset the analysis and save changes) and a side navigation column (which enables the user to navigate through the modules within the tool). RoCIT opens onto module 1, so a series of screening questions will also be seen. See Figure 1 for more details.

To navigate through the RoCIT, the user can either select the tab on the left navigation pane or use the "Next" and "Back" buttons at the bottom of the screen. In addition, the user can save the current settings and exit the tool by selecting the "Save and Exit" button. Alternatively, the user can exit the tool without saving by selecting the "Exit" button. The tool can be rest by selecting the "Reset" button on the top navigation bar, resetting the tool will restore the tool to default settings. Selecting "Save Changes" enables all changes to be saved as the new tool default settings.
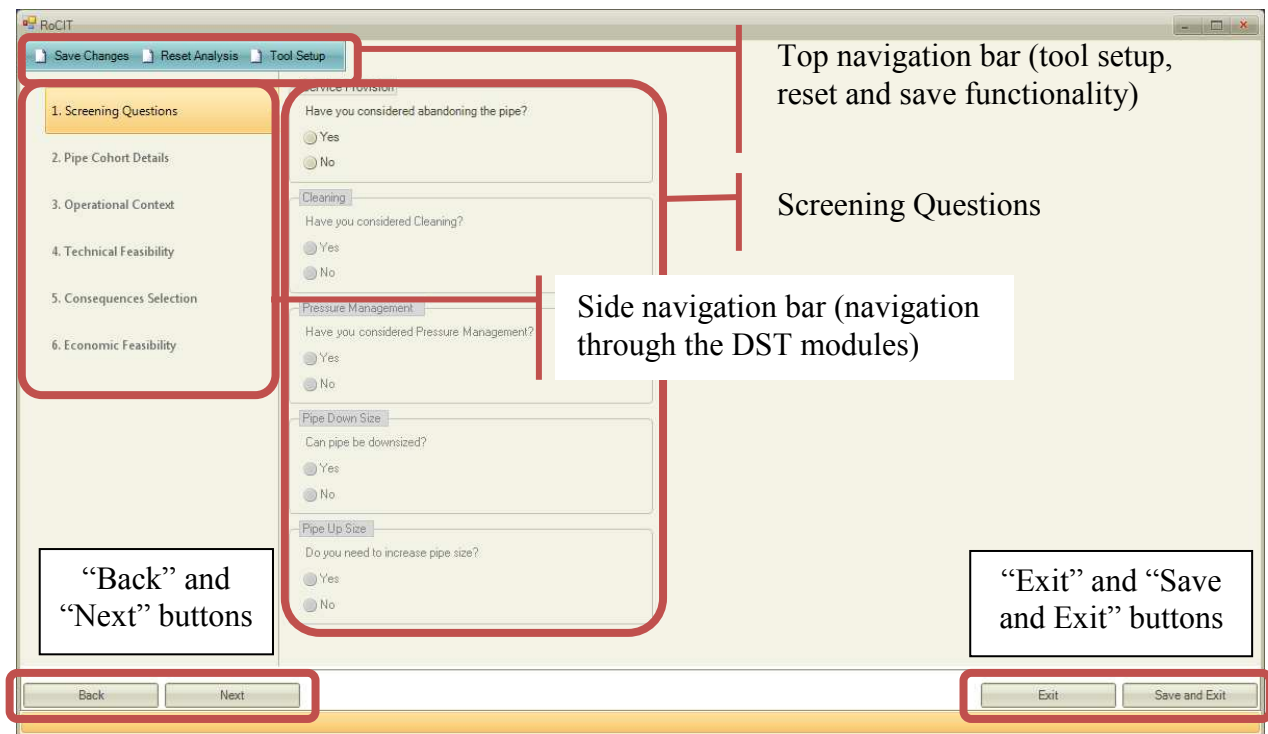
Figure 1 RoCIT features

TOOL SETUP

Before the tool is used, the user should confirm that the tool is setup to reflect utility preferences and context. This is done by selecting the "Tool Setup" tab on the top navigation bar. Within the tool settings tab, the user is presented with eleven setting fields. The settings fields are presented in the left navigation column, and comprise the following components.

Consequence Settings

The consequence setting module allows notional monetary values to be assigned to potential failure consequences via a pairwise comparison process, as discussed in the main report. The number of consequences is capped at twelve, but the descriptors are editable. The five tangible monetary values are used in the pairwise compassion process to assign values to the intangible factors. The values can be altered but the tool imposes a range between $1,000 and $500,000 dollars. Figure 2 illustrates the consequence settings screen. The user can adjust the tangible values used in the consequence pairwise comparison, edit the names of the consequence factors and undertake the pairwise compassion process. The later is achieved by clicking on the 'Calculate' button.

Figure 2 Consequence settings

In order to assign notional monetary values to the consequences, the user must first define the list of consequence factors and a suitable range of monetary values against which they will be assessed. The lower range should be set to $1000, reflecting the minimum additional failure consequence considered significant. The upper range should be set such that it exceeds the value of all other consequences. For example, say the maximum consequence you would expect from this type of asset would be $250,000, you would set the upper limit to this value. In setting the upper bound, it should be remembered that the research focuses only on small diameter CI pipes that are managed reactively.

Once the tangible costs have been set, the user then selects the "Calculate" button to initiate a pairwise comparison process. This presents the user with a series of questions (see Figure 3). For each question, the user is required to decide which factor/monetary value has the greater impact/importance to their business. To complete the comparison, the user selects the corresponding letter associated with the more important factor. The user also has the ability to cancel the comparison (noting, any factors that have been compared will be lost, and the analysis will need to be re-done). At the completion of the pairwise comparison, a monetary value is assigned to each intangible factor and a summary output of consequence costs is displayed/updated.
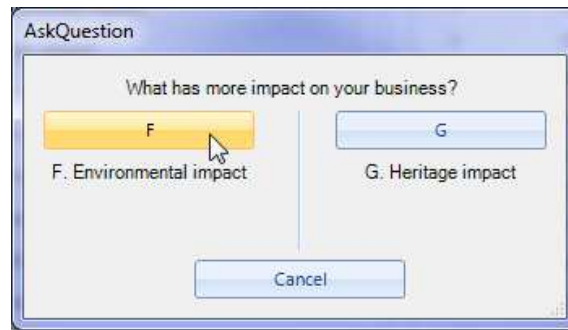
Figure 3 Pairwise comparisons of consequence factors

Tool exclusion criteria

The tool exclusion criteria allows the user to define the factors and operational context that mean a specific rehabilitation technique cannot be used (Figure 4).
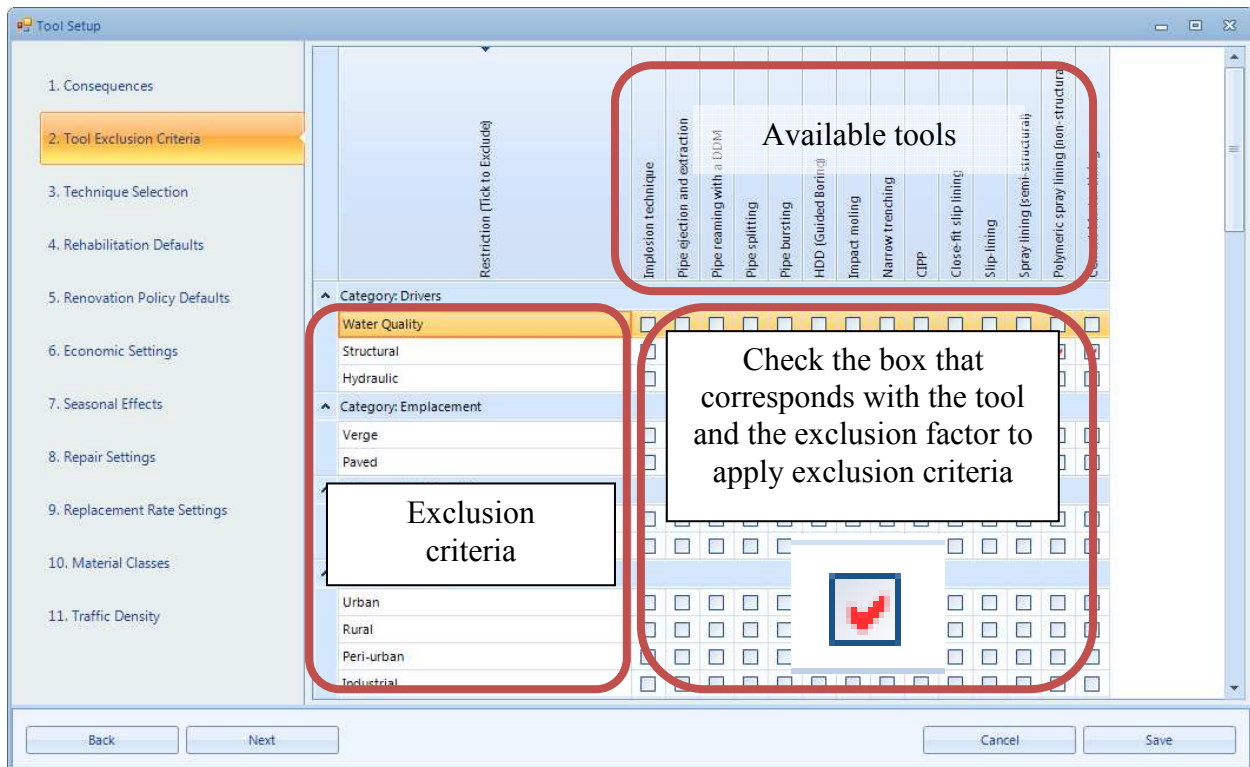

Figure 4 Tool exclusion criteria screen

The categories included in the tool exclusion criteria are:

- Drivers for rehabilitation
- Pipe emplacement
- Joint condition
- Pipe location

- Report Body Text
- Pipe condition
- Pipe depth
- Site soil class
- Soil corrosivity
- Surrounding infrastructure
- Valve type
- Water hardness
- Water table

To exclude a technique based on the factors listed above, the user simply checks the box that corresponds to each tool/technique and corresponding exclusion factor. The effect of this is to exclude any technique from consideration where the specified factor is present. For example, if 'Category driver' 'structural' is ticked for (say) non-structural polymeric lining, then this technique will not be available for any scheme for which the driver is specified as 'structural'. The tool is provided with defaults that exclude techniques based on information elicited during the research.

Technique selection

The RoCIT considers ten replacement techniques and five renovation techniques. However, not all these tools and techniques may be readily available to a given utility. The technique selection module allows the user to select techniques that are available to them. Only the selected techniques are used in any subsequent analysis.

To select techniques for inclusion, the user first selects the rehabilitation method (renovation or replacement), followed by the approach (trenched, trenchless, fully structural, semi-structural and non-structural). A list of available tools and techniques will then be displayed based on the method and approach selected. The user "double clicks" each tool/technique that is to be included. To clear the selected tools, the user "double clicks" on the tool to be omitted. In addition, selecting the "Reset" button will clear all tools selected (see Figure 5). Open Cut is always considered to be available.
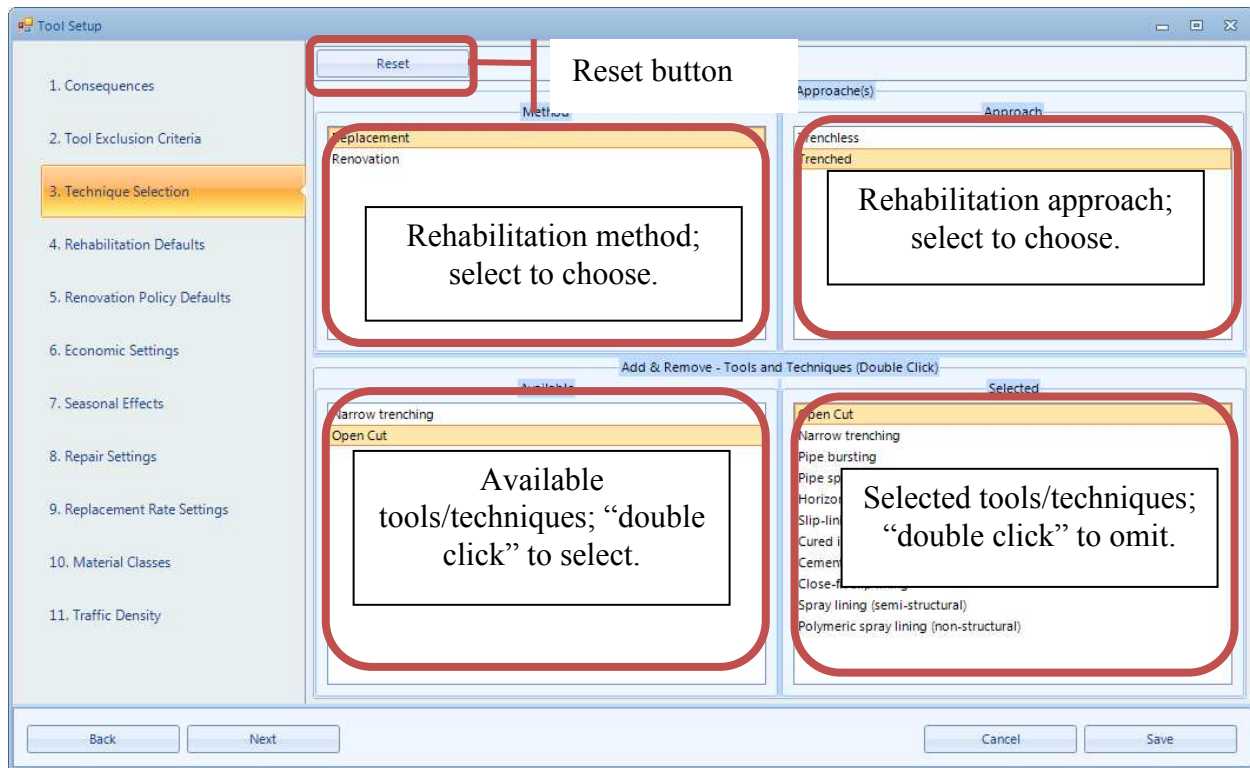
Figure 5 Technique selection screen

Rehabilitation defaults

The rehabilitation defaults enables the user to provide unit cost data for the selected rehabilitation techniques, in addition to details on work rates, mobilization costs, relative expected performance, impact on traffic disruption, impact to customers and whether a trenched replacement is required for the given renovation technique at the end of its useful life. The inputs are disaggregated across two tabs: one for replacement and one for renovation. Note: it is assumed that a replaced pipe removes all performance issues. As such, the performance of a replaced pipe is not an input parameter (Figure 6 illustrates the rehabilitation default screen).

The first three inputs for the renovation and replacement defaults are relatively self explanatory, noting that a unit cost rate is required ($/m), an installation rate (m/day) as well as a mobilization cost ($/scheme, which may be zero in many cases). For renovation defaults, the following parameters need to be set:

- Relative expected performance: set for bursts, leakage, water quality and pressure. 100% indicates the performance of the host pipe is unchanged. By default, for non-structural renovation, the performance of the renovated pipe is considered to be the same as the host pipe, so the defaults are set to 100%.
- Relative impact on traffic and customers: this represents the impact of the technique on customers and traffic. If set to 100% then the technique has the same impact as open cut.
- Proportion of time causing disruption: this is the percentage of the capital works that customers loose water supply. This may be set to zero if temporary supplies are used.

- Trenched end of life replacement required: this box should be ticked if the renovated pipe MUST be subsequently replaced using open cut techniques. If it is not checked, then the model will select the cheapest replacement option available.
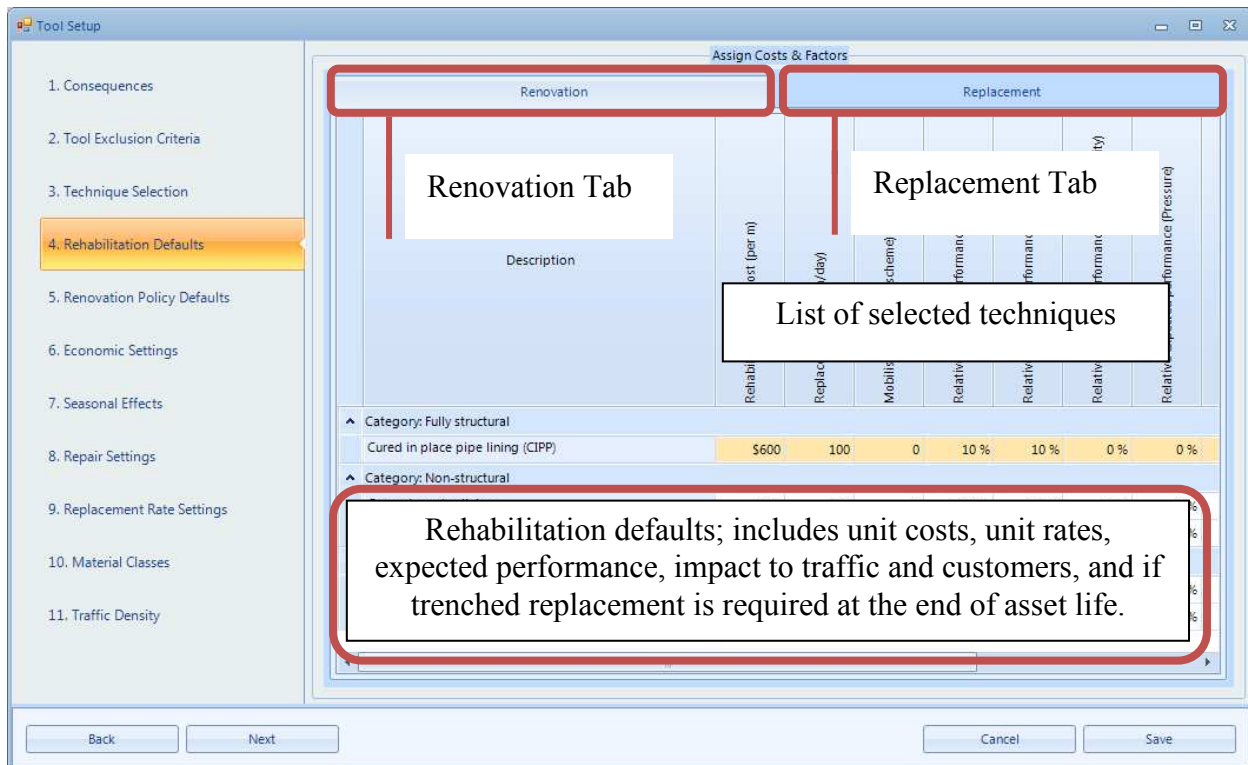
Reviewing and setting these defaults is a key requirement for successful use of the tool

Figure 6 Rehabilitation defaults screen

Renovation policy defaults

The renovation policy default setting allows the user to assign safety factor limits to each of the categories of renovation, namely: fullly structural, semi-structural and non-structural. The safety factors limits are used in the RoCIT to assess whether a renovation option is technically feasible based on the pipe/cohort attributes. Figure 7 illustrates the renovation policy default settings and the safety factor bands that are applied to fully structural, semi-structural and non-structural renovation techniques. Note: these bands are user definable.

Economic settings

The economic settings screen, shown in Figure 8, allows a series of factors, rates and uplifts to be set that are used in the economic model. These comprise:

- o Utility perception of unplanned disruptions (uplift factor: e.g. if set to 200%, then the perceived cost of unplanned disruption to traffic and customers is double the cost of planned disruption)

- o Road management efficiency (factor: e.g. if set to 50% then the amount of traffic disruption caused during a planned intervention is half that during an unplanned repair; if set to 100%, disruption is assumed to be unchanged)
- Rates
    - o Discount rate (%)
    - o Rate of rise factors (%/year) for bursts, leakage and complaints
- General costs
    - o Traffic disruption costs ($/vehicle/hour)
    - o Social costs per interruption ($/customer/hour)
    - o Cost of non revenue water ($/m^3)
- Water quality complaint costs
- Pressure complaint costs
- Renovation compared to replacement
    - o Include: consider renovation technique economically feasible if the minimum required service life (MRSL) of the renovation is less than this value
    - o Exclude: consider renovation technique economically unfeasible if the MRSL is greater than this value
- Consequence occurrence frequency
    - o Specifies linguistic descriptors (high, medium, low) used later to indicate the frequency with which consequences are expected to occur.

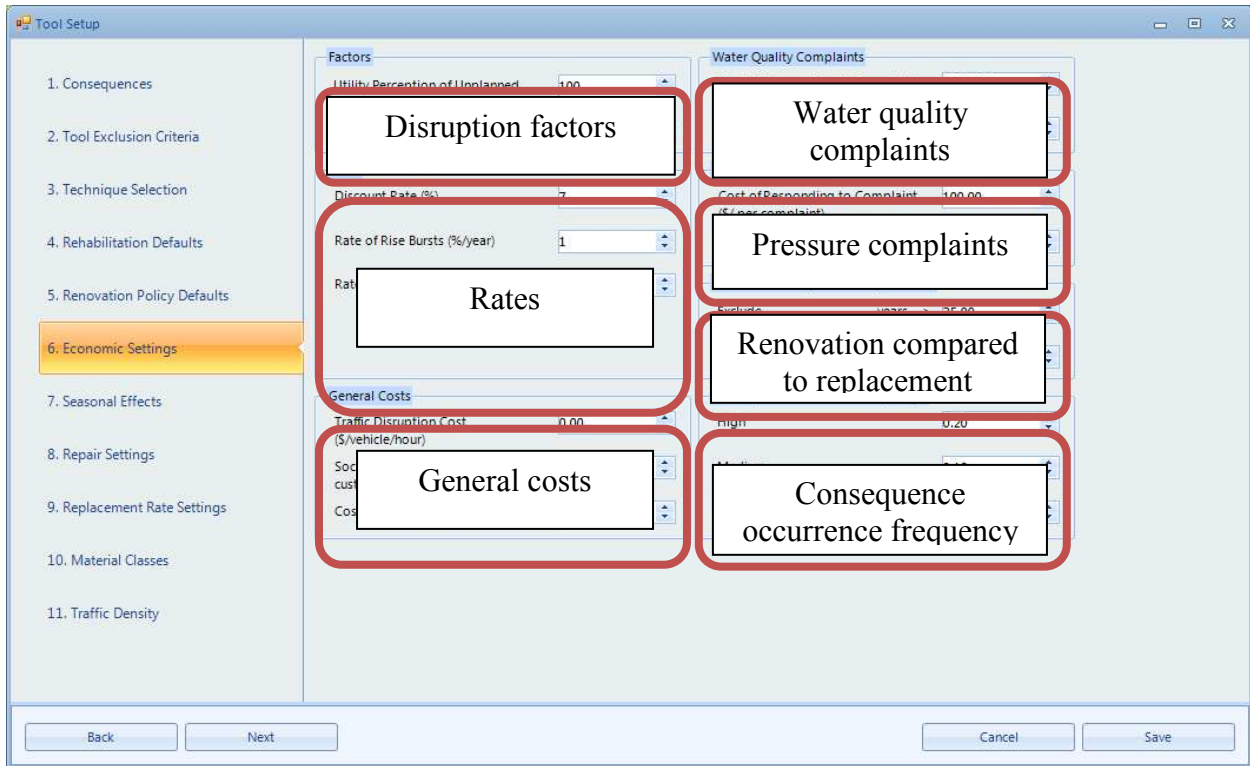**Figure 7 Renovation policy defaults screen**

Figure 8 Economics settings screen

Seasonal effects

The seasonal effects of winter (frost heave) are used in the technical feasibility module of the RoCIT. They are captured by the use of linguistic descriptors (see Figure 9); the descriptors used are:

- For winter: severe, hard, moderate and mild.

Tables 1 provides additional information on the meaning of each linguistic term used in the safety factor calculations. Note: the attributes for each linguistic description for winter and summer conditions are not editable.

Table 1
Winter seasonal effect linguistic descriptor definition

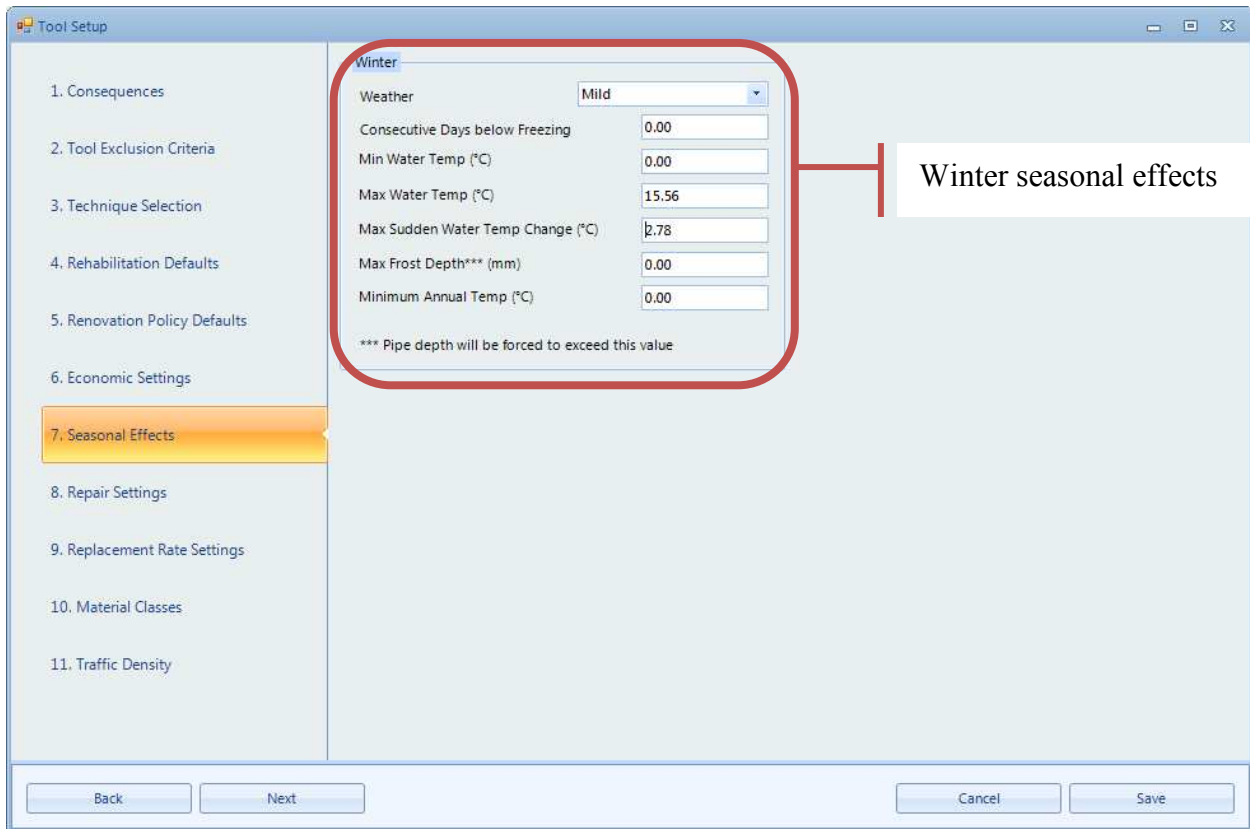| Description	Consecutive Days Below Freezing	Min Water Temp (ºC)	Max Water Temp (ºC)	Max Water Temp Drop (ºC)	Min Annual Temp (ºC)	Max Frost Depth (mm)
Severe	60	0	15.6	-14.4	-30	1524
Hard	40	0	15.6	-14.4	-20	1016
Moderate	20	0	15.6	-14.4	-10	381
Mild	0	0	15.6	-14.4	0	0

Figure 9 Seasonal effects settings screen

Repair settings

Repair settings are used in economic module of the RoCIT in conjunction with failure rate data to project future costs of the host pipe and the renovated pipe. The repair settings comprise repair costs and times for pipes laid under a road, paved surface (i.e. sidewalk, driveway, car park, etc) or unpaved surface (grass verge, nature strip, etc.) for a variety of locations, namely:

- CBD (central business district)
- Urban
- Peri urban (in between rural and urban; e.g. suburbia)
- Rural
- Industrial (e.g. area with factories)
- Commercial (e.g. area with shops etc.)

Figure 10 illustrates the repair settings screen, with the costs and time data disaggregated based on location.
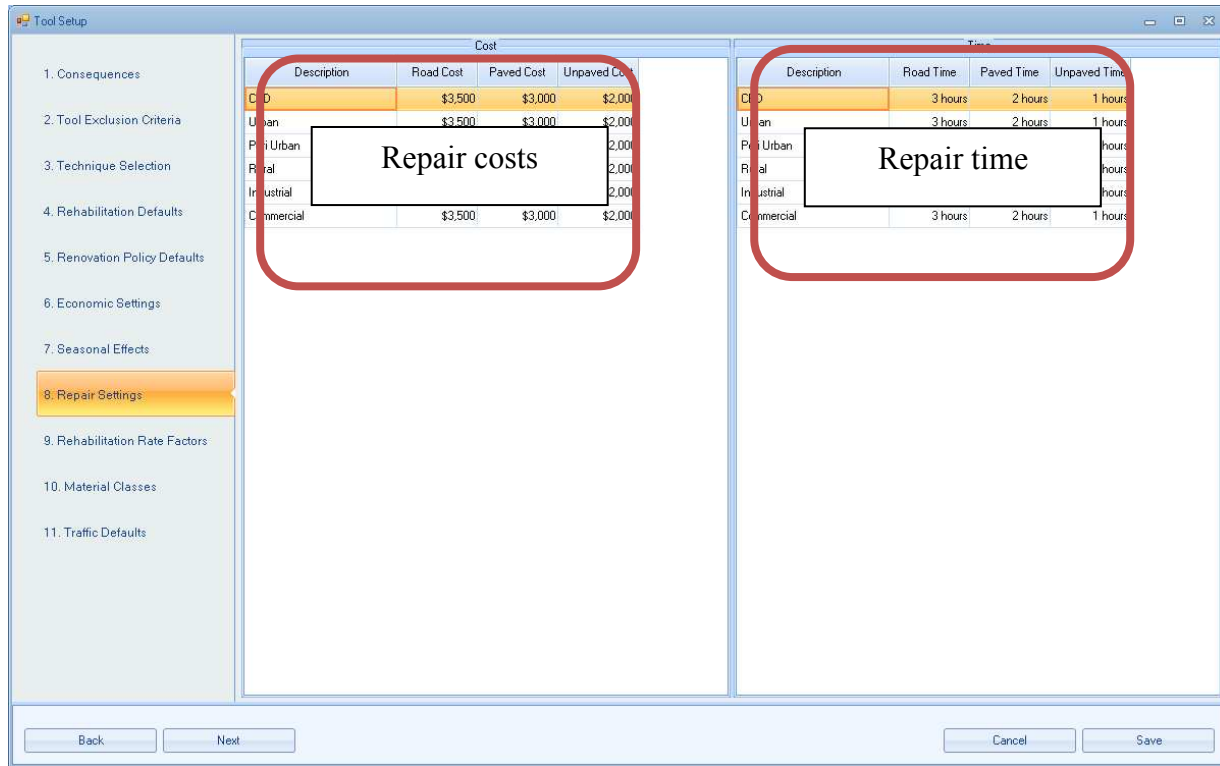
Figure 10 Repair settings screen

Rehabilitation rate factors

This screen allows the user to provide additional information on the relative installation efficiencies of rehabilitation techniques based on the assets location (this setting is used to reflect increases or decreases in installation rates). The rates are disaggregated by surface type (i.e. pipes laid under a road, paved or unpaved surface for a variety of locations, as per the repair settings above. Figure 11 illustrates the replacement rate settings screen.
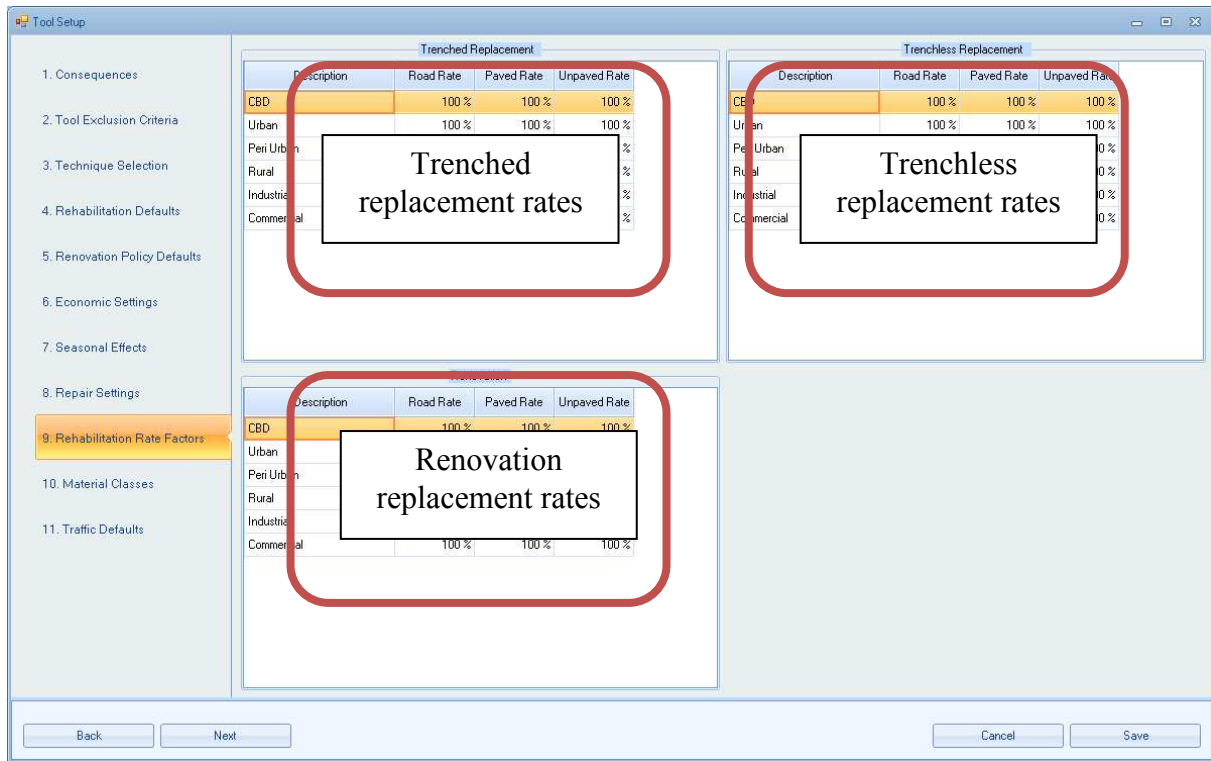
Figure 11 Replacement rate settings screen

Material classes

The type of CI varies depending upon the installation year of the pipe and the availability of each material class specific to the users' utility. As such, the user has the ability to adjust the material class information based on the installation decade. Figure 12 illustrates the material class screen. The material class information is used to assign original pipe wall thicknesses and inner pipe diameters within the pipe cohort details in RoCIT. The types of cast iron material are:

- Horizontal pit cast iron
- Vertical pit cast iron
- Spun cast iron (1st generation)
- Spun cast ion (2nd generation)
- Spun ductile cast iron

Traffic defaults

This screen is used to set traffic defaults. Traffic density data and the average disruption time per vehicle are both used in the economic module of the RoCIT. As such, the user has the ability to define traffic densities and disruption times for a variety of road types. Figure 13 illustrates the traffic density settings screen. The user can input estimates of traffic densities (average number of vehicles per hour) for each location and street type.
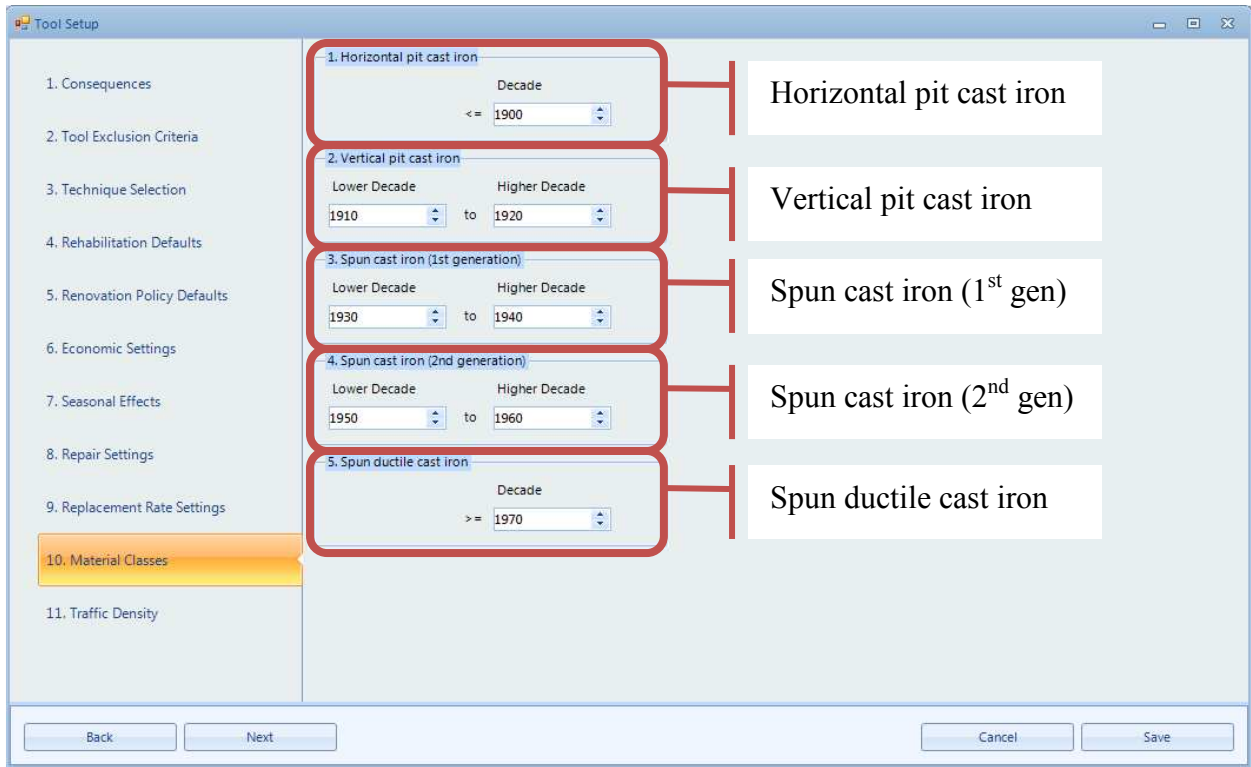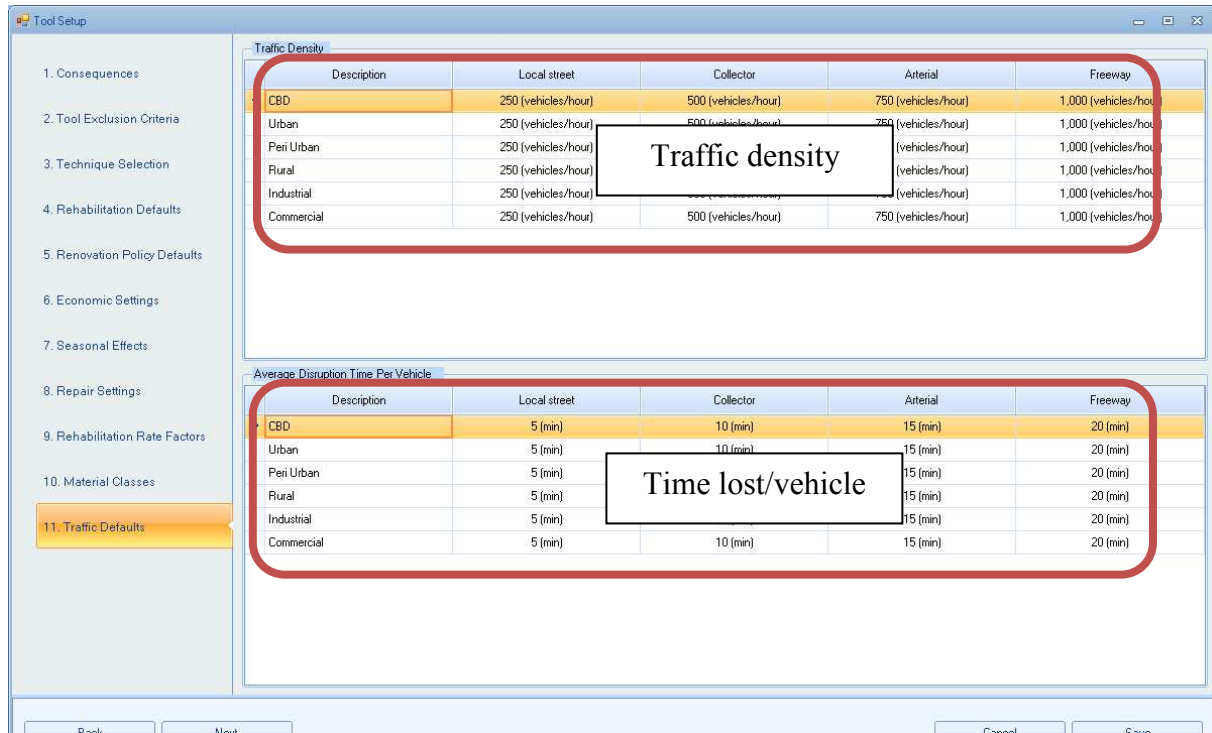
Figure 12 Material class screen

Figure 13 Traffic density settings screen

THE DECISION SUPPORT PROCESS

After completing the tool setup, the tool is now ready to use. To facilitate ease of use, the tool is divided into six modules, namely:

1. Screening questions
2. Pipe cohort details
3. Operational context
4. Technical feasibility
5. Consequence selection
6. Economic feasibility

Step 1: Screening questions

The screening questions ensure the user has considered alternatives to pipe rehabilitation prior to using the tool (see Figure 14). The alternatives that are screened include:

- Abandoning the asset
- Undertake water mains cleaning
- Undertake pressure management
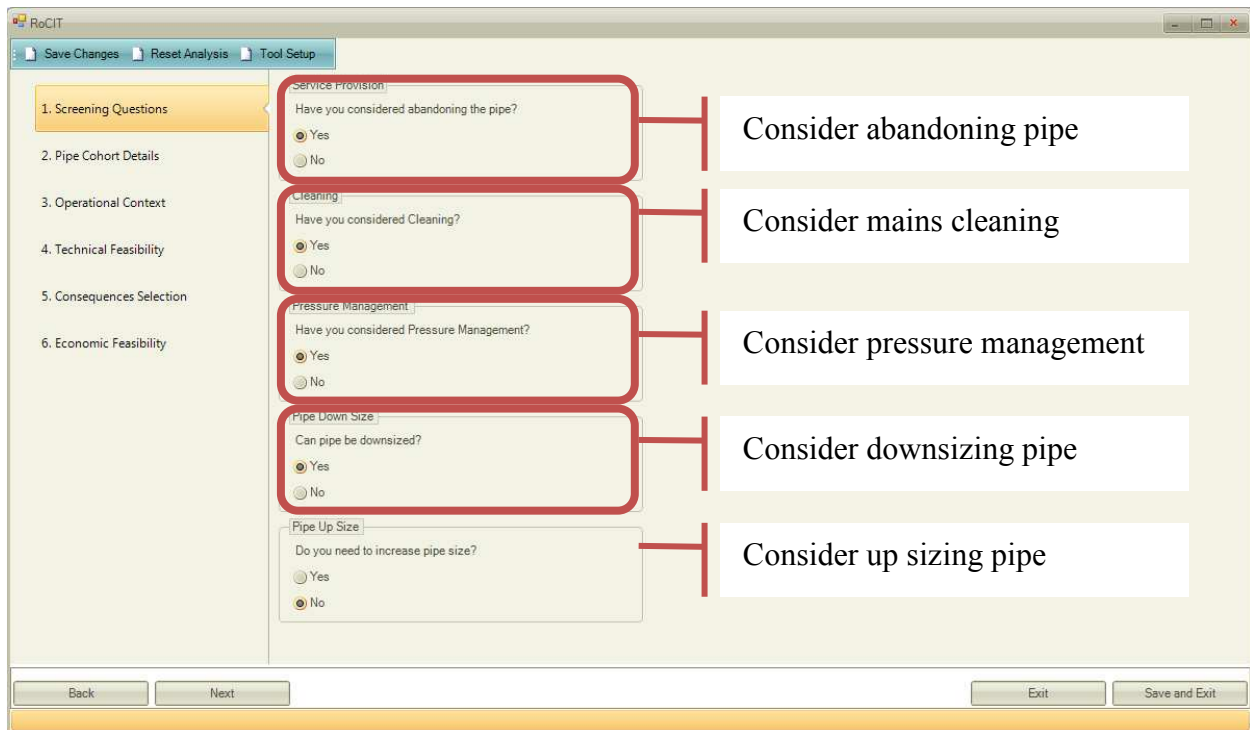- Downsizing the pipe
- Upsizing the pipe

Figure 14 Step 1 – Screening Questions

Depending on the answer provided by the user, the screening questions provide automated response suggesting alternative strategies be considered or allowing the user to continue to Step 2 (with caveats on the use of the tool, i.e., the inclusion or exclusion of certain techniques). Table 2 lists the screening questions and the limiting comments based on user responses.

Table 2
Screening question limiting responses

Question	Response	Comment
Have you considered abandoning the pipe?	No	Review needed
Have you considered cleaning?	No	Please consider cleaning
Have you considered pressure management?	No	Please consider pressure management
Can pipe be downsized?	No	Rehabilitation options: slip-lining and close fit slip lining will not be available
Do you need to increase the pipe size?	Yes	All renovation options are excluded; tool can be used to consider trenchless and trenched replacement.

The user can not progress to the next step of the tool unless all the screening questions have been answered.

Step 2: Pipe cohort details

After completing the screening questions, the user is now presented with a user input screen that captures information pertinent to the pipe or pipe cohort being analyzed. Figure 15 illustrates the pipe cohort details screen. Tables 4 and 5 display the pipe condition and joint condition linguistic definitions. As illustrated, the user is requested to provide details on the driver for rehabilitation and the pipe/cohort being considered, namely:

- Main drivers
    - Water quality
    - Hydraulic
    - Structural
- Condition
    - Pipe condition (good, reasonable or poor; see Table 3).
    - Joint condition (sound or leaking)
    - User defined pipe condition
        - Pit depth
- Cross section dimensions
    - Nominal pipe diameter
    - User defined pipe diameter
        - Inner pipe diameter
        - Pipe thickness

- General pipe characteristics
  - o Number of assets in cohort
  - o Pipe installation decade
  - o Pipe material (for selected decade)
  - o Pipe pressure class
    - ▪ Class A (30 m Head)
    - ▪ Class B (60 m Head)
    - ▪ Class C (90 m Head)
    - ▪ Class D (120 m Head)
  - o Type of isolation valve
  - o Max depth
  - o Cohort length
  - o Operating pressure
- Pipe performance
  - o Number of bursts
  - o Observation period
  - o Water loss (average water lost in a burst in cubic meters)
  - o User defined burst rate
    - ▪ Burst rate (failures/100km/year)
  - o Non revenue water (Leakage rate)
  - o Number of water quality complaints per year
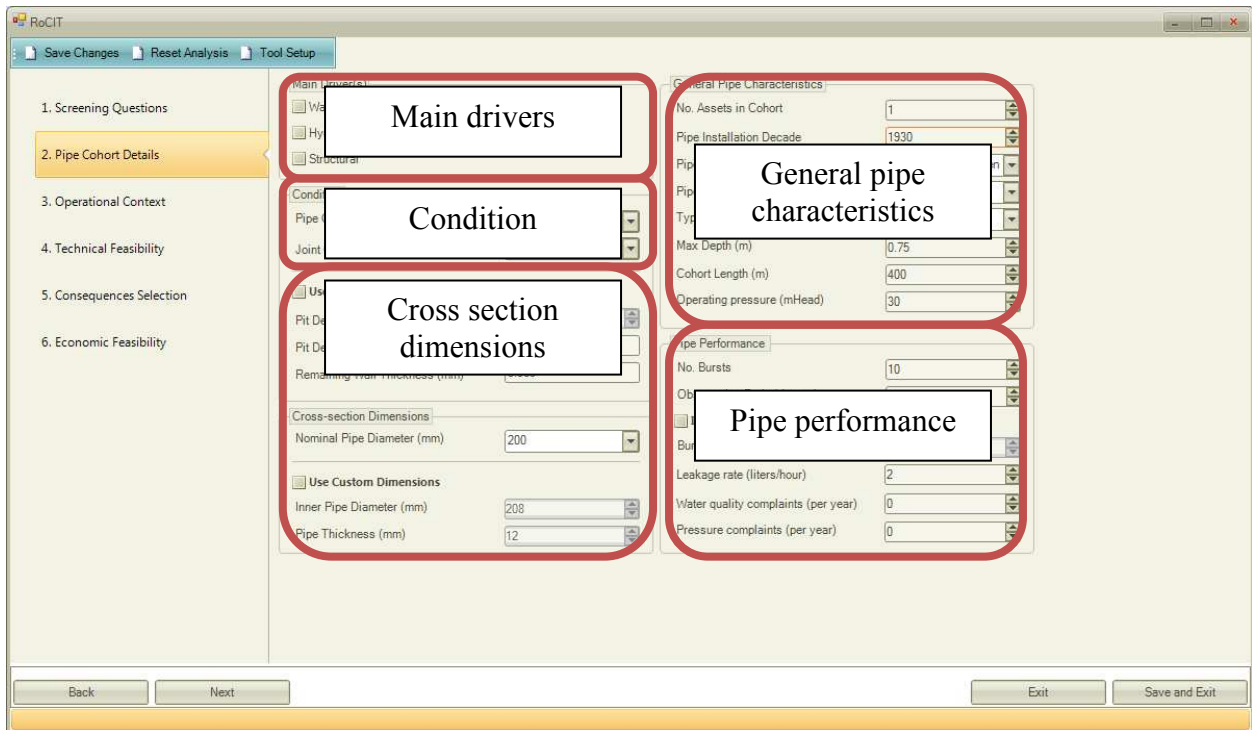 - o Number of pressure complaints per year

Figure 15 Material class screen

Table 3
Pipe condition linguistic definitions

Name	Description	Pit Depth (% original pipe thickness)
Good	None	0 (0%)
Reasonable	Small	0.50 50%)
Poor	Medium	0.90 (90%)

Note: factors like driver, depth, pipe condition, joint condition and valve type are used in conjunction with the technique exclusion criteria to determine if a rehabilitation technique is feasible or should be discounted based on the details of the pipe cohort being analyzed.

Step 3: Operational context

The next step captures the operational context of the pipe or cohort. Figure 16 illustrates the operational context screen. The user provides details on the site, soil, water conveyed and water table, and traffic. Tables 4 and 5 display the linguistic definitions for the operational factors.
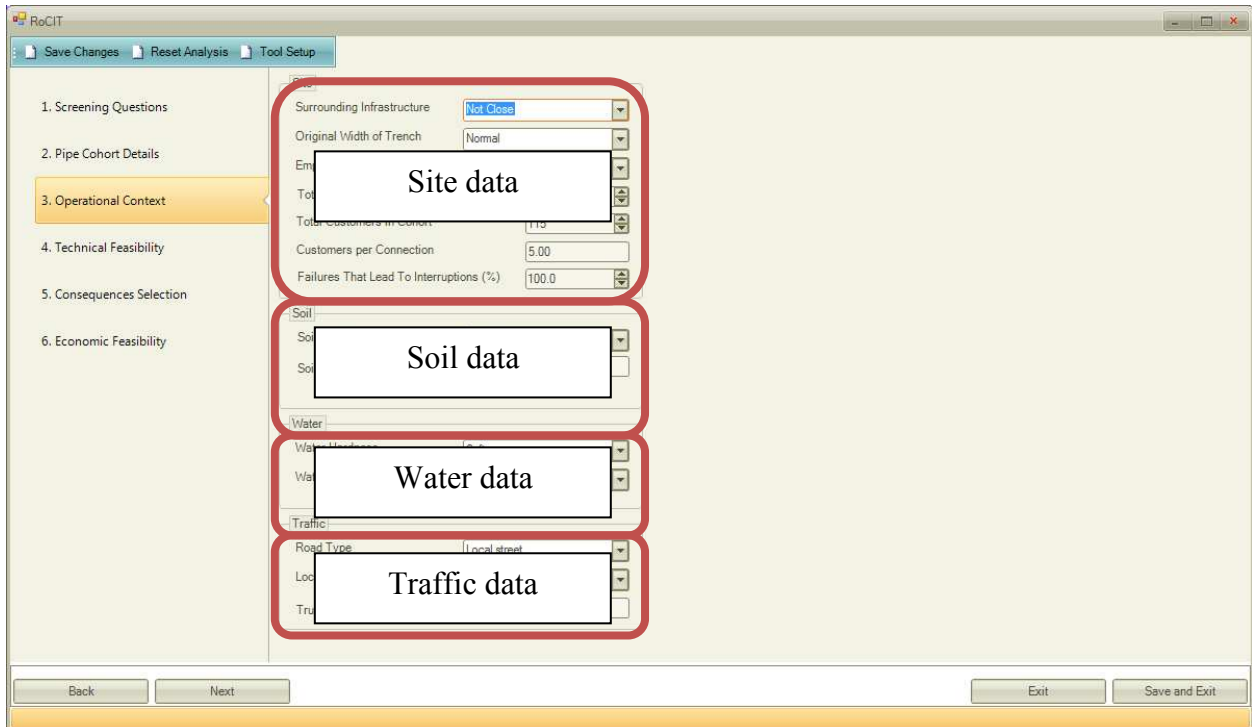

Figure 16 Material class screen

Table 4
Vehicle category linguistic definitions

Name	Definition
Light	**AASHO Truck H-10, Gross weight 10 tons**
Medium	**AASHO Truck H-15, Gross weight 15 tons**
Heavy	**AASHO Truck H-20, Gross weight 20 tons**

Table 5
Soil type linguistic definitions

Soil Type	Soil Resistivity (Ohm.cm)	Soil Corrosivity	Soil Density lb/ft^3	Reactivity
Coarse	1500	Highly corrosive	135	Stable
Moderately Coarse	1200	Highly corrosive	130	Stable
Moderately Fine	1000	Highly corrosive	120	Slightly Expansive
Fine	1000	Highly corrosive	120	Expansive
Organic	700	Extremely corrosive	100	Slightly Expansive
Rocky	2000	Highly corrosive	134	Stable
Unclassified	700	Extremely corrosive	100	Expansive

Note: factors like emplacement, location, surrounding infrastructure, water hardness, water table, and soil factors are used in conjunction with the technique exclusion criteria to determine if a rehabilitation technique is feasible or should be discounted based on the operational context of the pipe cohort being analyzed.

Step 4: Technical feasibility

The technical feasibility step considers whether it is possible to use renovation techniques (non-structural, semi-structural and structural, if available) based on an assessment of safety factors. The module displays the outputs of calculations undertaken in the background based on the attributes specified in step 3 and 4. The safety factor calculations made are:

- Pipe crushing safety factor (resulting from vertical loading)
- Pipe splitting safety factor (resulting from internal pressures)
- Pipe bending safety factor (resulting from loss of pipe support and vertical loading)
- Pipe elongation safety factor (resulting from restrained thermal contraction and internal pressures)
- Combined bending and elongation safety factor
- Combined crushing and splitting safety factor

As shown in Figure 17, the user is presented with a traffic light summary of the safety factor calculations and an assessment on the technical feasibility of the selected pipe renovation techniques is given via a traffic light system (Figure 18).
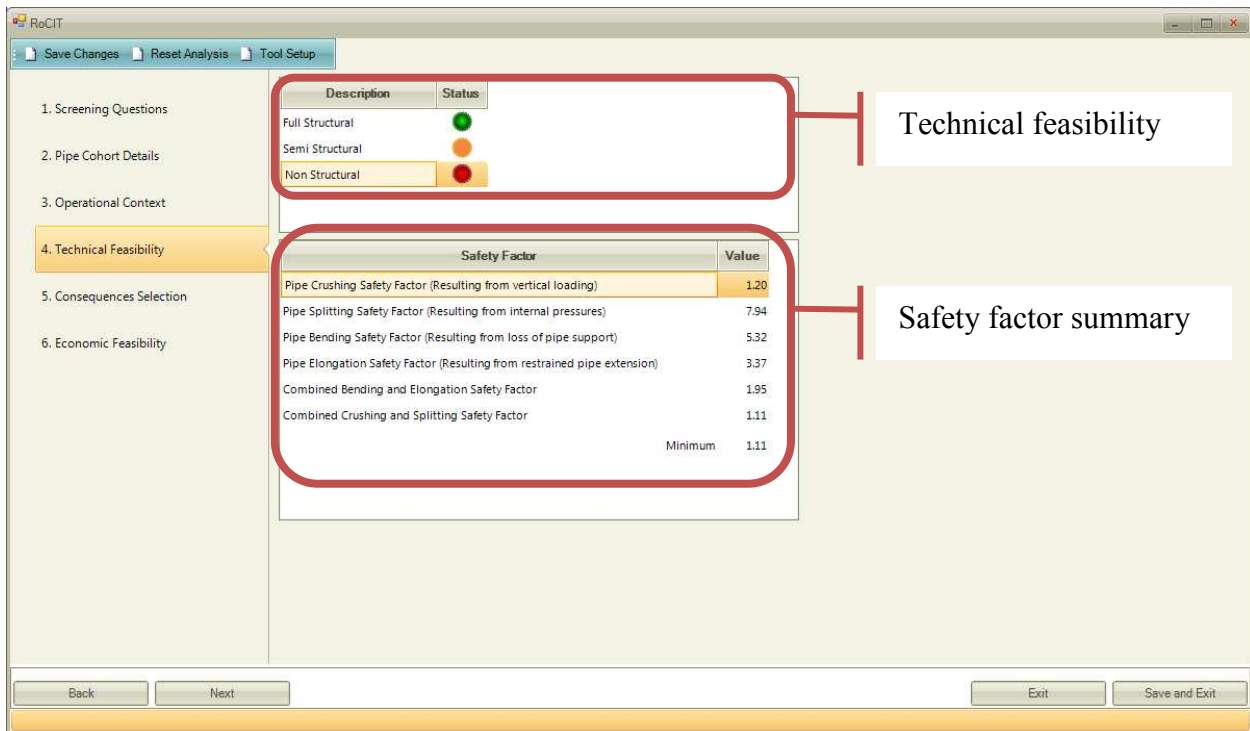

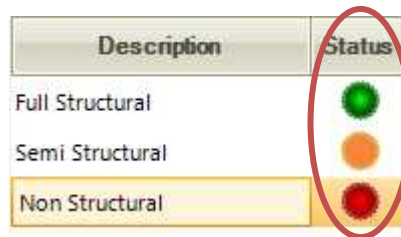**Figure 17 Technical feasibility screen**

Figure 18 Renovation feasibility traffic light

With respect to the traffic light system, green indicates that the renovation technique is suitable given the pipe attributes and operational context defined, amber indicates that the technique is risky but not excluded from consideration, and red indicates the technique is not suitable. The suitability is specified according to the renovation policy defaults input through the tool setup screen. If a renovation option is flagged as 'red', it is not considered subsequently in the economic assessment.

Step 5: Consequence selection

Step five of RoCIT allows the user to select the consequences that apply to the asset or cohort being assessed, as shown in Figure 19. The consequences listed are the consequences that were assigned monetary values within the tool setup. If a consequence factor is selected, the user then applies a consequence occurrence frequency rating. This is defined within the tool setup, and represents the proportion of bursts for which the consequence is expected to be incurred. Note: only consequences relevant to the specific pipe or cohort being considered should be checked and assigned an occurrence rating.
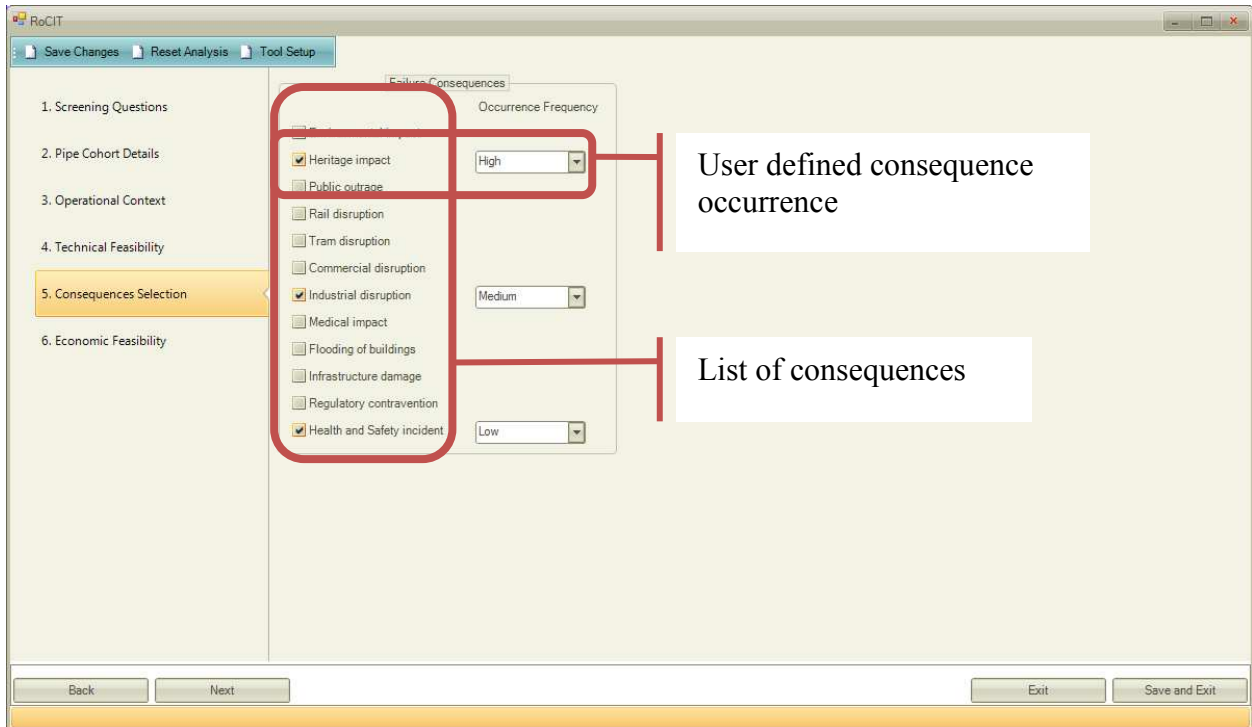

Figure 19 Consequence selection screen

Step 6: Economic feasibility

The last step of the RoCIT is the economic feasibility screen (Figure 20). Here the user is presented with a renovation summary, a replacement summary and graph of the life cycle costs of the existing pipe (without rehabilitation), the replaced pipe, the renovated pipe (without replacement) and the renovated pipe with subsequent replacement.
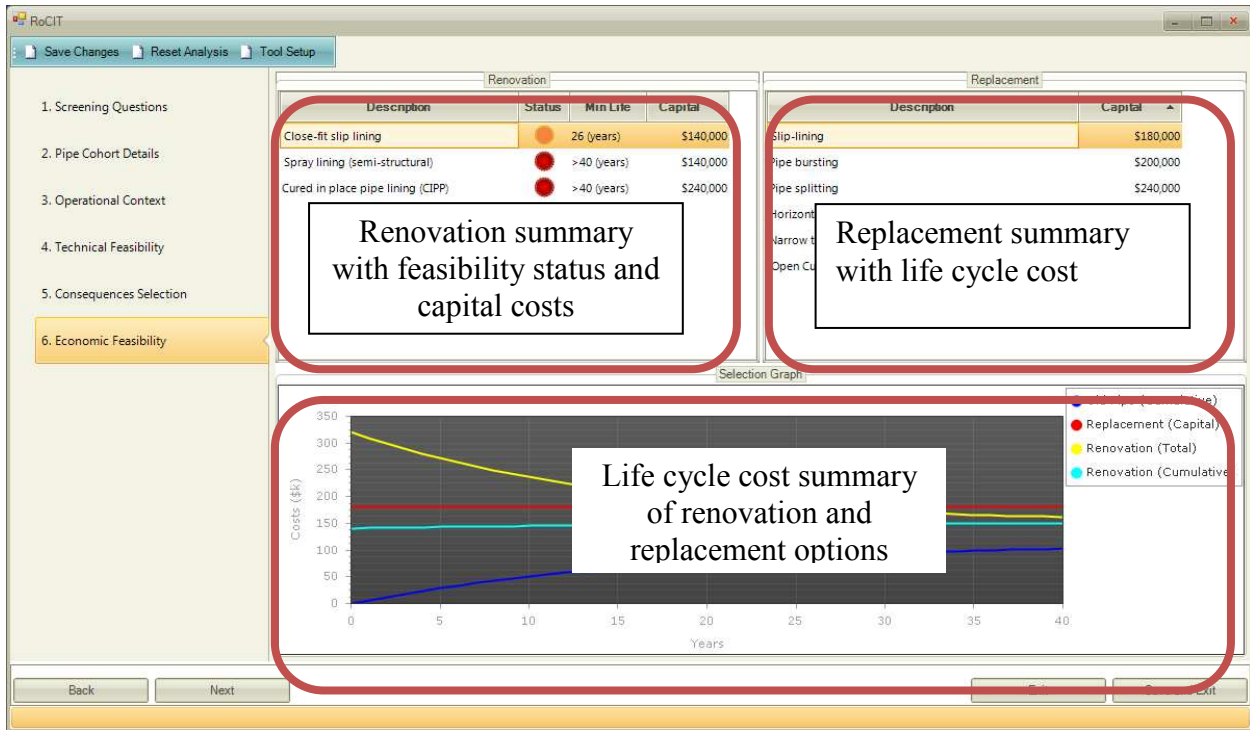
Figure 20 Economic feasibility screen

Selecting the relevant renovation and replacement technique dynamically updates the life cycle costs summary graph and the minimal service life of the renovation for the decision to be economic. Similar to technical feasibility, the traffic light next to the renovation techniques indicates if the solution is economically feasible or not based on the defaults input in the economic settings. The graph shows the MRSL as the point where the yellow line (total cost of renovation) crosses the red line. The user should consider if the MRSL is short enough to warrant renovation, as described in the main report.