UK ROADS LIAISON GROUP

# LIFECYCLE PLANNING TOOLKIT INCORPORATING DEFAULT CARRIAGEWAY DETERIORATION MODELS

## DETAILED USER GUIDANCE

OCTOBER 2019

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## COMMENTS & FEEDBACK

The HMEP Programme Board would welcome any comments and feedback on this Toolkit, so that it may be reviewed, improved and refined to give the sector the best support possible. If you wish to make a comment, please send an email to ukrlg@ciht.org.uk with the header, 'Feedback on the User Guidance for the Lifecycle Planning Toolkit'.

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# 1 INTRODUCTION

## ABOUT THIS DOCUMENT

1.1 This document is a User Guide for the Lifecycle Planning Toolkit which was originally developed under the Highways Maintenance Efficiency Programme (HMEP) and updated in 2019 under the sponsorship of the UKRLG Asset Management Board. The User Guide is applicable to the following three versions of the Lifecycle Planning Toolkit:

- The **Carriageway Toolkit** which is aimed at providing users with planning level decision support in the maintenance management of carriageways.
- The **Other Assets Toolkit** which is aimed at providing users with planning level decision support in the maintenance management of highway assets including: bridges, drainage, road signs, bollards, vehicle restraint systems, street lighting, traffic signals and linear assets such as road markings and kerbs. The user is encouraged to use their own deterioration profiles.
- The **Footway Toolkit** which is aimed at providing users with planning level decision support in the maintenance management for shared use footways and dedicated cycle ways.

1.2 The three Toolkits listed above are based on the same principles and operate in the same manner. Therefore, one User Guide covers all three Toolkits. Where there are differences in the operation between the three Toolkits, examples have been provided to demonstrate these. In addition, worked examples for each Toolkit are included in Sections 7, 8 and 9.

1.3 Default Carriageway Deterioration Models which are already entered in the Carriageway Toolkit are given in Appendix A – Default Carriageway Deterioration Models.

1.4 The lifecycle plans should be based on the authorities own local rates. Internal focus is the priority, with external groups providing checks/validation.

## ABOUT THE TOOLKIT

1.5 The Toolkits (Carriageways, Footways and Other Assets) are intended for use by local highway asset management engineers to support strategic level planning decisions including the following:

- Assessing impact of different levels of funding on asset performance and asset maintenance needs;
- Investigating current and future levels of funding required to achieve a given condition or performance target for the asset;
- Identifying the levels of funding required to minimise whole life costs; and
- Allocating resources to assets and Treatment Types to manage whole life costs.

1.6 The Toolkit produces long-term estimates of expenditure and associated asset performance. These estimates can be used to determine the likely performance of the asset under budget constraints or, alternatively, to determine the budget required to support a target asset performance.

## DOWNLOADING THE TOOLKIT

1.7 The latest version of the Toolkit can be downloaded from the UKRLG website. The Toolkit was developed to work in Microsoft Excel version 2007 in order to be compatible with most Local Highway Authorities Microsoft Office versions.

## OPENING THE TOOLKIT

1.8 The following steps should be followed when opening the Toolkit to ensure that it works correctly:

i. Open the programme Microsoft Excel.

ii. Locate and open the Toolkit.

iii. A splash screen encouraging the user to enable macros (Figure 1.1) will normally be displayed.

iv. Once macros are enabled, click anywhere on the splash screen to continue to the **'Home sheet'** worksheet. If the user needs to view the splash screen again, then click on the **'Show Splash Screen'** button at the bottom of the worksheet.


**Figure 1.1: Splash Screen**

v. If using a projector, ensure that the spreadsheet is closed when connecting to the projector. Switch on the projector and then open the Toolkit again once the projector is switched on. This is to ensure that all the buttons in the spreadsheet resize properly.

## SAVING THE TOOLKIT

i. To save a version of the Toolkit, select **'Excel Macro-Enabled Workbook'** from the **'Save as type:'** dialogue box as illustrated in Figure 1.2 below:

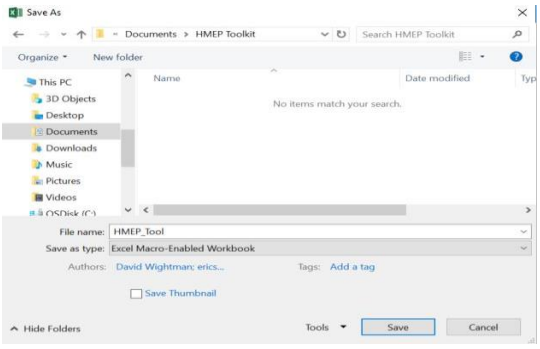



**Figure 1.2: Saving the Toolkit**

# 2 PROCESSING OF DATA

2.1 Table 2.1 sets out the input data required and how data should be processed prior to loading into the Toolkit.

- Ideally, inventory and condition data should be extracted from the user's asset management systems. If data is limited or unavailable, then engineering judgement and local experience may be used to make the necessary assumptions required to populate the Toolkit. However, these assumptions should be clearly documented, and considered as limitations to the robustness of the Toolkit's outputs.
- Homogeneous asset groups, condition measures and condition band thresholds are user-defined.

**Table 2.1: Input Data Requirements**

| Data Type/Category | Description | Units |
|---|---|---|
| **Homogenous Asset Groups** | A Homogeneous Asset Group is a grouping of assets which are assumed to deteriorate in a similar manner. The same deterioration models and treatment strategy are assumed to apply to all assets in the Homogeneous Asset Group.<br>For example, a carriageway road network may be aggregated into the following 10 Homogeneous Asset Groups based on hierarchy and environment:<br>1. Rural Strategic Roads<br>2. Rural Main Distributor Roads<br>3. Rural Secondary Distributor Roads<br>4. Rural Link Roads<br>5. Rural Local Access Roads<br>6. Urban Strategic Roads<br>7. Urban Main Distributor Roads<br>8. Urban Secondary Distributor Roads<br>9. Urban Link Roads<br>10. Urban Local Access Roads<br>More details are available in Section 4. | Not Applicable |
| **Inventory** | The following inventory data is required for each Homogeneous Asset Group: | - |
| | **Carriageway and Footway Toolkits**: Average length of each Homogeneous Asset Group. | Metres (m) |
| | **Other Asset Toolkit**: Quantity (number, length, or area) of assets within each Homogeneous Asset Group. | Number (No.), Metres (m) or Square Metres ($m^2$) |
| **Condition Measure** | Definition or selection of criteria or index for describing the Condition Band of the assets (e.g. Carriageway Condition Index (CCI) or SCANNER Road Condition Indicator (RCI)). | Not Applicable |
| **Condition Band Threshold** | Rationale for aggregating the condition of the assets into a defined number of Condition Bands ranging from an excellent state (e.g. Very Good) to a critical or failed state (e.g. Very Poor). An example of condition band thresholds is given in Appendix A – Default Carriageway Deterioration Models. | Not Applicable |

| | | |
|---|---|---|
| **Current Condition Distribution** | The percentage of the quantity of assets in each **Condition Band** for each Homogeneous Asset Group. This is normally determined from the most recently observed data or informed by expert knowledge. | Percentage (%) |

# 3 INTRODUCTION TO THE TOOLKIT

3.1 This section describes the following introductory worksheets in the Toolkit:

- **'0a - Homesheet'**: this worksheet provides basic guidance for the Toolkit and introduces task-bar buttons.
- **'0b - Model Structure'**: illustrates the structure of the Lifecycle Planning Toolkit.

## HOMESHEET

3.2 The **'0a - Homesheet'** worksheet provides the following information:

- Basic guidance.
- Software version history.
- Contacts for fault reporting.

3.3 The worksheet is protected, and the user is therefore unable to make changes to it.

### Basic user guidance

3.4 Basic guidance (Figure 3.1) provided on the **'Homesheet'** worksheet includes:

- Definition of sheet tab colours used throughout the software.
- Definition of input cell colours.
- Description of various task-bar buttons in the software.

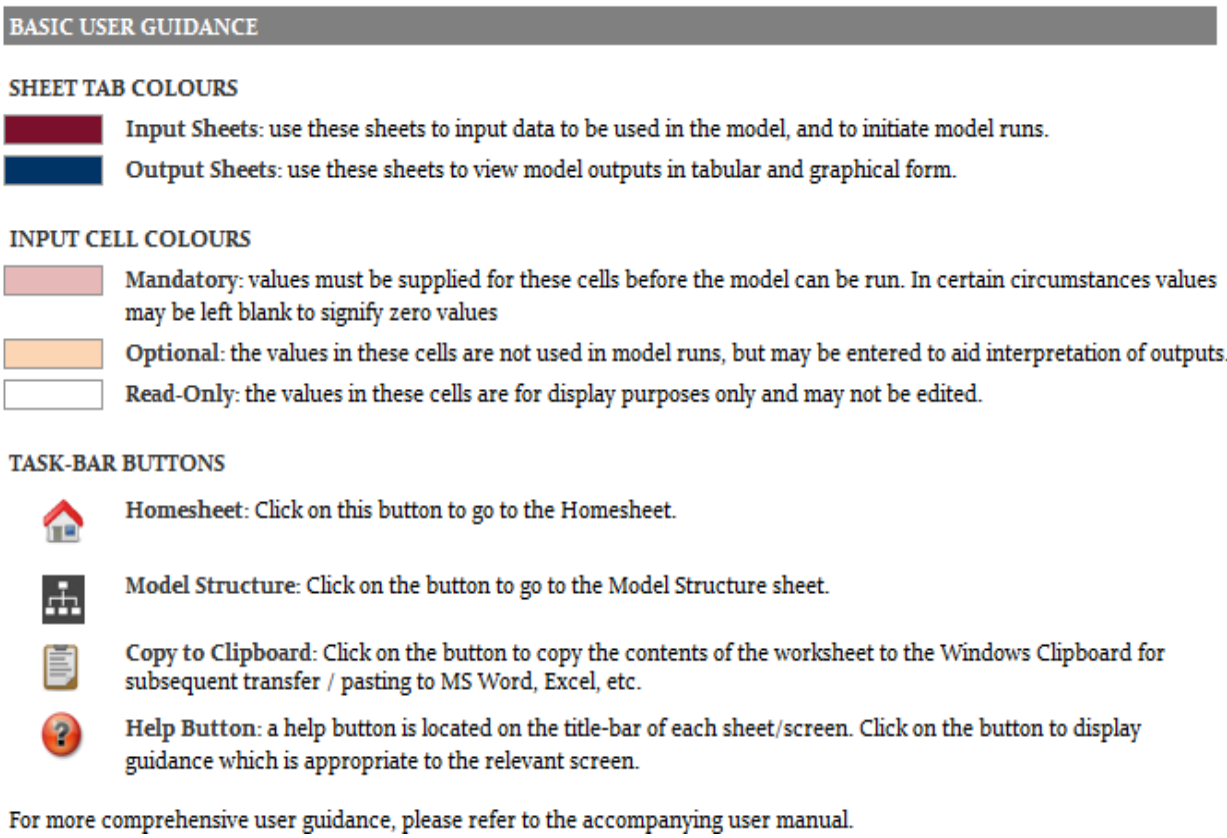



**Figure 3.1: Basic User Guidance**

### Version History

3.5 The version history table in the **'Homesheet'** worksheet (Figure 3.2) identifies the current version number of the software, the date it was last modified, and information on previous versions of the software.

VERSION HISTORY

| Version | Date | Description |
|---|---|---|
| 1.00 | 29/11/2012 | First release of the HMEP Toolkit |
| 1.01 | 18/06/2013 | Four transition probabilities corrected |
| 2.00 | 17/07/2019 | Updated version of the HMEP Toolkit |
| | | |
| | | |

**Figure 3.2: Version history**

### Fault Reporting

3.6 Faults encountered whilst using the Toolkit should be reported preferably by email using contact details provided in the **'Homesheet'**.

## MODEL STRUCTURE

3.7 The **'0b - Model Structure'** worksheet depicts the structure of the Toolkit (Figure 3.3). Each box represents a worksheet in the Toolkit. The number in the top-left corner of each box denotes the number of the worksheet, and the order in which the worksheets are typically used when conducting an analysis.

### Navigating to Other Worksheets

i. Click on a box on the Toolkit structure to navigate to the worksheet named in that box.

ii. To return to the **'Model Structure'** worksheet, click on the **'Model Structure'** button located on the top right of any worksheet.

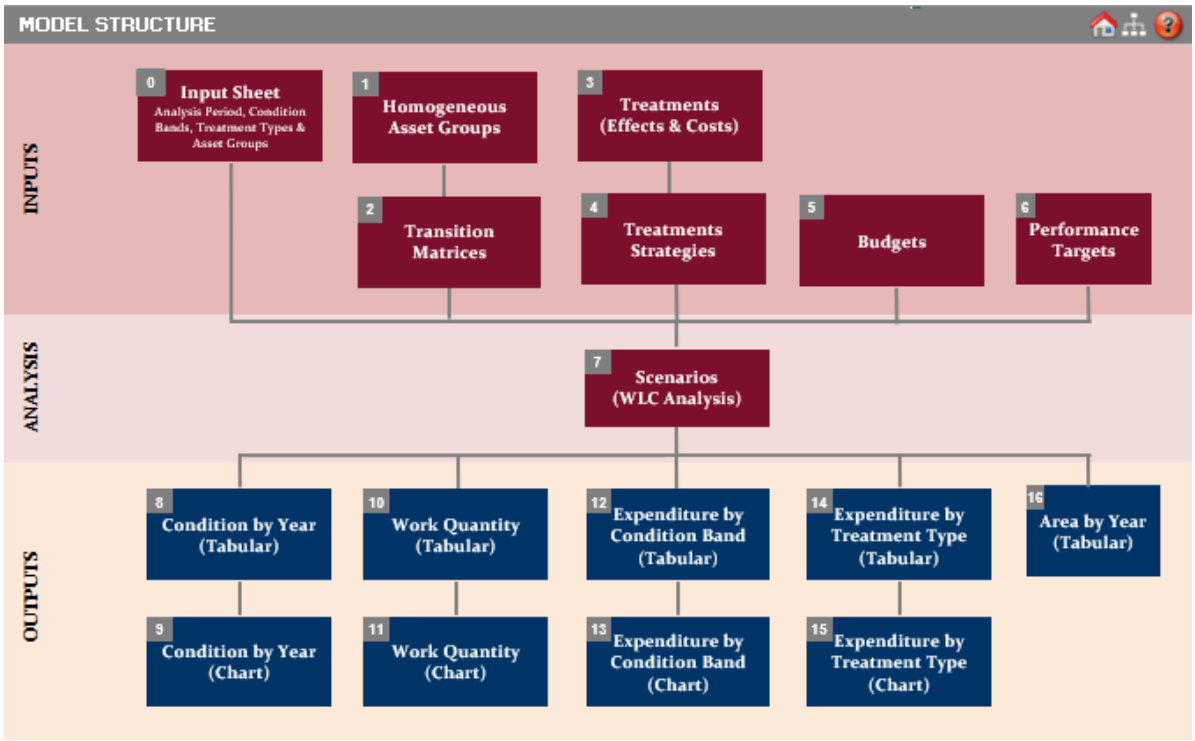



**Figure 3.3: Model Structure**

# 4 POPULATING THE TOOLKIT

4.1 The following worksheets should be populated prior to running the Toolkit:

- **0 - Input Sheet**:
  - Used for setting up the Toolkit including any definitions of parameters for Analysis Period, preferred output chart type, number and names of Condition Bands, number and names of Homogenous Asset Groups, number, name and description of Treatments.
- **1 - Homogenous Asset Groups**:
  - Inventory data and condition distribution for each asset group at the start of the year of analysis need to be loaded into this worksheet.
- **2 - Transition Matrices**:
  - This worksheet is used to define, edit and view Transition Probability Matrices (TPMs), which are used in the Toolkit to model the deterioration of assets.
  - A Transition Probability Matrix embodies all information necessary to model the annual deterioration of a particular homogeneous asset group.
- **3 - Treatment Effects & Costs**:
  - Treatment Effects and Treatment Unit Costs are specified in this worksheet.
- **4 - Treatment Strategies**:
  - The proportion of assets to be treated in each year by a particular Treatment is specified in this worksheet.
- **5 - Budgets**:
  - Budget options can be defined for each Treatment in this worksheet.
- **6 - Performance Targets**:
  - Performance Targets can be defined for each Treatment in this worksheet.

## INPUT SHEET

4.2 The **'0 - Input Sheet'** worksheet contains information for setting up the Toolkit and requires the user to enter the following information:

- Start year of the analysis and Analysis Period.
- Preferred chart type for the output graphs.
- Number and description of Condition Bands.
- Number and names of Homogeneous Asset Groups.
- Number, name and description of Treatment Types.

### Defining Start Year and Analysis Period

i. Enter the start year of the analysis (e.g. 2018) in the **'Start Year'** input cell as illustrated in Figure 4.1.

ii. Enter the Analysis Period in years in the **'Analysis Period'** input cell. The Analysis Period must be within the range from 10 to 60 years.

iii. The End Year is automatically calculated from the Start Year and the Analysis Period.

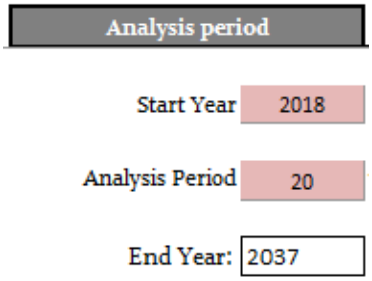



**Figure 4.1: Analysis Start Year and Analysis Period**

## Condition Bands

4.3 Condition Bands are used to categorise the condition of the assets being modelled. Condition Bands can be modified from the **'Input Sheet'** by:

- Specifying new Condition Bands.
- Deleting existing bands.

## Specifying new Condition Bands

i. Select the input cell labelled **'Number of Condition Bands'** (Figure 4.2).

ii. Increase or reduce the existing number of Condition Bands as desired. The number of Condition Bands must range from 3 to 10.

iii. Press **'Enter'** or click on any other input cell. Additional Condition Band cells will be generated below the existing Condition Bands.

iv. The numbers in the **'Rank'** column (Figure 4.2) are automatically generated when the number of Condition Bands is increased. The Rank denotes the order in which Condition Bands are ranked. A Ranking of 1 denotes the best (as new) Condition Band while the lowest Rank (e.g. 5 in Figure 4.2) denotes the worst or failed Condition Band.

v. Click on the **'Description'** cell for each new Condition Band and type an appropriate description in line with the ranking of the condition band (note this is an optional input).

vi. Click on the **'Short Code'** cell for each new Condition Band and then type an appropriate code corresponding to the description of the condition band. The short code is limited to no more than three characters. It will also be used in other worksheets in the Toolkit. For example, the short code 'VG' could be used to denote a 'Very Good' condition band as illustrated in Figure 4.2.

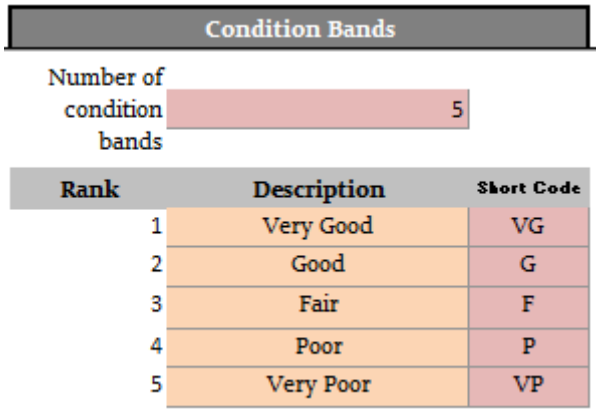



**Figure 4.2: Condition Bands**

### Reducing the number of existing Condition Bands

i. To reduce the number of existing Condition Bands, specify the number of Condition Bands that should remain in the **'Number of Condition Bands'** input cell (Figure 4.2).

ii. A pop-up will be displayed asking the user to confirm if they wish to continue.

iii. Click **'Yes'**. The number of Condition Bands will be reduced to the number specified by removing the lowest ranked Condition Bands first. For example, if the number of existing conditions illustrated in Figure 4.2 is reduced from 5 to 3, then the Very Poor (VP) and Poor (P) Condition Bands would be deleted.

### Selecting the number of Condition Bands

i. In choosing the number of condition bands, asset managers should consider the purpose of the analysis, granularity required, and how the results will be presented to decision makers. Having too few bands doesn't provide enough distinction between condition levels, whereas having too many bands makes it challenging to understand the difference between levels.

ii. Generally, having five bands provides a balance between these two factors, and it is a scale easily understood by practitioners. A 5-band system is a little less crude than a 3 band one, giving asset managers a better insight into condition and providing a more detailed level of data when understanding future maintenance requirements. While a 3-band RAG (Red Amber Green) may be more understandable for stakeholders, this leads to scenarios that might cause future maintenance issues i.e. potentially a lot of assets at the top of Amber that can suddenly become Red. The results of a 5-band analysis can be easily re-formatted to display 3 bands, whereas the opposite is not as straightforward.

### Homogeneous Asset Groups

4.4 Assets in a Homogenous Asset Group are assumed to deteriorate in a similar manner. The same maintenance strategy is assumed to apply to all assets in a Homogenous Asset Group. Outputs are generated by the Toolkit for each Homogeneous Asset Group.

4.5 Homogeneous Asset Groups can be formulated by grouping together assets using key attributes such as asset type (e.g. lighting columns, traffic signals, street furniture, etc.), geographical location (e.g. districts), environment (e.g. urban or rural) and road hierarchy (e.g. strategic routes, main distributors, etc.). For example, two (2) environment and five (5) road hierarchy attributes were used to define 10 (2 x 5) Homogeneous Asset Groups for carriageways.

### Adding new Homogeneous Asset Groups

i. Select the **'Number of Homogeneous Asset Groups'** input cell (Figure 4.3).

ii. Increase the existing number of Homogeneous Asset Groups as desired. The number of Homogeneous Asset Groups must be in the range from 1 to 100. Note that if high numbers of condition bands are chosen then the Toolkit may take several minutes to update.

iii. Press **'Enter'** or click on any other input cell. Additional Homogeneous Asset Group input cells will be generated below the existing asset groups.

iv. Click on the **'Name'** cell for each new Homogeneous Asset Group and specify the name of the asset group. The name of each Homogeneous Asset Group should normally be specified to reflect the rationale for homogeneity.

| Homogeneous asset groups | |
|---|---|
| Number of homogeneous asset groups | 10 |

| No. | Name |
|---|---|
| 1 | Urban: Strategic |
| 2 | Urban: Main |
| 3 | Urban: Secondary |
| 4 | Urban: Link |
| 5 | Rural: Local |
| 6 | Rural: Strategic |
| 7 | Rural: Main |
| 8 | Rural: Secondary |
| 9 | Rural: Link |
| 10 | Rural: Local |

**Figure 4.3: Homogeneous Asset Groups**

### Reducing the number of existing Homogeneous Asset Groups

v. To reduce the number of existing asset groups, specify the number of Homogeneous Asset Groups that should remain in the **'Number of Homogeneous Asset Groups'** input cell.

vi. A pop-up window will be displayed asking the user to confirm if they wish to continue.

vii. Click **'Yes'**, and the number of asset groups will be reduced to the number specified by removing the asset groups at the bottom of the list first.

## Treatment Types

### Adding new Treatment Types

i. Select the **'Number of Treatment Types'** input cell (Figure 4.4).

ii. Increase the existing number of Treatment Types as desired. The number of Treatment Types must range from 2 to 10.

iii. Press **'Enter'** or click on any other input cell. Additional Treatment Types inputs will be generated below existing Treatment Types.

iv. Type a short Treatment name in the input cells under the **Name** column. The specified Treatment name will be used in other worksheets.

### Reducing the number of Treatment Types

i. Specify the number of Treatment Types that should remain in the **'Number of Treatment Types'** input cell.

ii. A pop-up will be displayed asking the user to confirm if they wish to continue.

iii. Click **'Yes'**, and the number of Treatment Types will be reduced to match the number specified (in step 1 above) by removing Treatment Types starting with Treatments at the bottom of the list.

| Treatment Types | | |
|---|---|---|
| Number of treatment types | | 6 |
| No. | Description | Name |
| 1 | Includes 15% patching to binder course | Surface Dresssing |
| 2 | Includes 15% patching to binder course | Micro Asphalt |
| 3 | 40% patching to binder course & 15% patching to base course | Moderate Inlay |
| 4 | 40% patching to binder course & 15% patching to base course | Moderate Overlay |
| 5 | Full binder course replacement & 30% patching to base course | Deep Inlay |
| 6 | Full reconstruction | Reconstruction |

**Figure 4.4: Definition of Treatments**

### Output graphs

4.6 Two types of output graphs (Bar or Area) can be produced by the Toolkit. The preferred output graph type can be specified by selecting either **'Bar'** or **'Area'** option from the drop-down list located under the **'Output Graphs'** section in the **'Input Sheet'** (Figure 4.5)

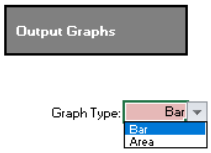



**Figure 4.5: Output Graph Types**

### Model parameters which are not user-definable

4.7 The following Toolkit parameters located in the **'Input Sheet'** are protected and the user cannot modify them:

- Minimum and maximum Analysis Period.
- Minimum and maximum Analysis Time Step.
- Minimum and maximum Number of Bands.
- Minimum and maximum Number of Homogenous Groups.
- Minimum and maximum Number of Treatments.

## HOMOGENOUS ASSET GROUPS

4.8 The **'1 - Homogenous Asset Groups'** worksheet is used for specifying the following:

- Inventory data for each Homogeneous Asset Group.
- Initial or base condition data distribution for each Homogeneous Asset Group.

It should be noted that homogeneous asset groups should be inserted in the same order as they appear in their Authority's hierarchy wise (i.e. based on the importance of the asset). This ensures that when the "overall" budget option is used (see section 4.32 of this guide), the treatments are applied following this hierarchy.

### Loading Inventory Data

4.9 The required inventory data for the Toolkit is as follows:

**Carriageway and Footway Toolkits** (): specify the total length (in metres) and the average width (in metres) of the assets in each Homogeneous Asset Group. Commas depicting thousands should not be used as it may prevent the Toolkit from working correctly. If the

total length and average width of the assets are unknown but the area is known, the user can specify notional lengths and widths to give the desired area for the asset group. This will not impact on the outputs of the Toolkit since only the value of area is used in the calculations. If the user inserts total length <1000m a pop-up message will display to confirm that the entered input length is accurate.

- **Other Assets Toolkit** (): specify the quantity of assets in each Homogeneous Asset Group. The correct unit for each Homogeneous Asset Group should be selected from the drop-down menu under the **'Units'** column. Commas depicting thousands should not be used as it may prevent the Toolkit from working correctly.

### Initial Condition

4.10 For each Homogenous Asset Group, enter the observed or estimated percentage of the quantity of asset group in each Condition Band in the base year (Figure 4.6 and Figure 4.7). The sum of the proportions entered must add up to 100%. A validation **'ERROR'** message is displayed if this condition band is not met.

| | | | | | | Initial Condition | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | % of Asset Group in condition band in base year | | | | |
| | | | | | | 1 | 2 | 3 | 4 | 5 |
| Asset Group | Description | Length (m) | Width (m) | Area | Units | VG | G | F | P | VP |
| 1 | Strategic & Main | 43,264 | 7.80 | 337,459 | m² | 30% | 44% | 20% | 4% | 2% |
| 2 | Secondary | 15,315 | 6.30 | 96,485 | m² | 26% | 39% | 25% | 6% | 4% |
| 3 | Link | 8,930 | 5.50 | 49,115 | m² | 25% | 37% | 31% | 4% | 3% |
| 4 | Local | 34,800 | 4.40 | 153,120 | m² | 17% | 26% | 30% | 16% | 11% |

**Figure 4.6: Asset inventory and initial condition distribution (Carriageway and Footway Toolkits)**

| | | | | Initial Condition | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | % of Asset Group in condition band in base year | | | | |
| | | | | 1 | 2 | 3 | 4 | 5 |
| Asset Group | Description | Quantity | Units | VG | G | F | P | VP |
| 1 | Lighting Column | 2,000 | no. | 40% | 30% | 15% | 10% | 5% |
| 2 | Road Studs | 85,000 | m | 50% | 30% | 15% | 5% | 0% |
| 3 | Safety Fences | 4,000 | m | 80% | 15% | 5% | 0% | 0% |

**Figure 4.7: Asset inventory and initial condition distribution (Other Assets Toolkit)**

## TRANSITION PROBABILITY MATRICES

### Background

4.11 The Toolkit makes use of TPMs to model the deterioration of each Homogeneous Asset Group over one year.

4.12 The general form of the TPM denoted by *P* is given by Equation 4.1:

$$P = \begin{bmatrix} p_{11} & p_{12} & \dots & p_{1n} \\ p_{21} & p_{22} & \dots & p_{2n} \\ \vdots & & & \vdots \\ p_{n1} & p_{n2} & \dots & p_{nn} \end{bmatrix} \quad (4.1)$$

4.13 This matrix contains all the information necessary to model the deterioration of the Homogeneous Asset Group. The transition probabilities, $p_{ij}$, indicate the probability of the portion of the asset group in condition *i* moving to condition *j* in one year due to the damaging effects of traffic, environment and/or other factors, as applicable.

4.14 For every TPM the following conditions apply:

- The sum of the entries in each row must be equal to one and all entries must be non-negative.
- $p_{ij} = 0$ for $i>j$, signifying that assets cannot improve in condition without first receiving some Treatment. This is illustrated in the matrix given in Equation 4.2.
- $p_{nn} = 1$, signifying a holding state whereby assets that have reached their worst condition cannot deteriorate further. Consequently, in asset deterioration, the general form of the transition matrix P is denoted by Equation 4.2:

$$P = \begin{bmatrix} p_{11} & p_{12} & p_{13} & \dots & p_{1n} \\ 0 & p_{22} & p_{23} & \dots & p_{2n} \\ 0 & 0 & p_{33} & \dots & p_{3n} \\ : & : & : & & : \\ 0 & 0 & 0 & \dots & 1 \end{bmatrix} \quad (4.2)$$

4.15 Guidance on how to develop TPMs for Homogeneous Asset Groups from historic data is provided in Appendix A – Default Carriageway Deterioration Models. Appendix A – Default Carriageway Deterioration Models also gives default Carriageway Deterioration Models which are already entered in the Carriageway Toolkit. The user may wish to use alternative TPMs, where these are available.

4.16 The **'2 - Transition Matrices'** worksheet in the Toolkit contains options for:

- Adding a new TPM.
- Copying an existing TPM.
- Deleting an existing TPM.
- Deriving a TPM from the estimated service life of the Homogeneous Asset Group (this functionality is available in the Other Assets Toolkit only).
- Viewing and editing the deterioration matrix and the deterioration profile of a selected TPM (Figure 4.8).

### Adding a new Transition Probability Matrix

i. Click on the **'Add New'** button in the **'Transition Matrices'** worksheet. A new input row will be added at the bottom of the list of existing TPMs.

ii. Enter the name of the TPM in the **'Matrix Name'** column.

iii. Select the new TPM and click on the **'View/Edit Matrix'** button to view/edit the new TPM in a matrix format (Figure 4.8).

iv. It should be noted that the default transition matrices may need to be adjusted to suit local observations. Users of the HMEP Lifecycle Planning Toolkit are encouraged to use models that better reflect local deterioration trends, if such models are available.

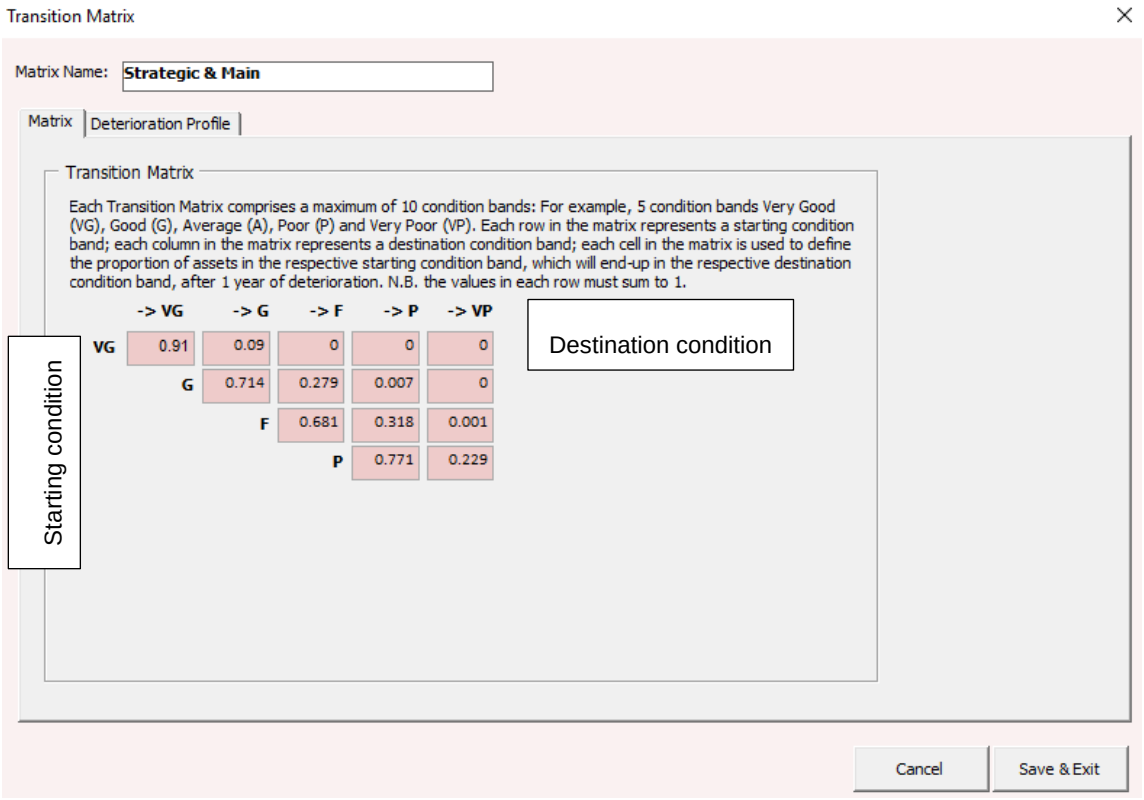
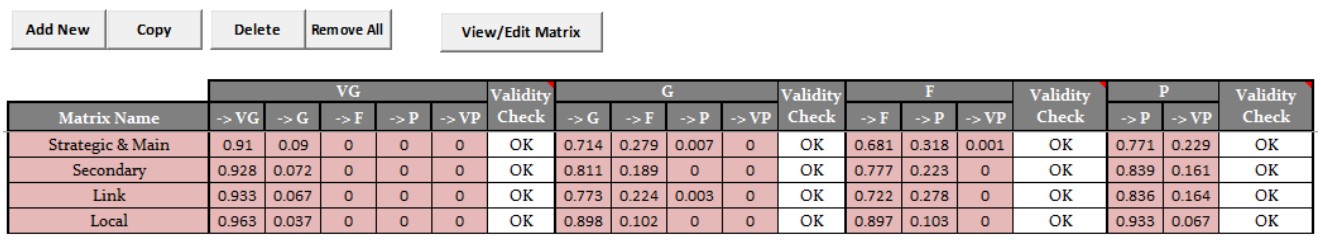



**Figure 4.8: TPM in Matrix Format**

v. The TPM in Figure 4.8 shows the proportions of assets that would remain in a starting Condition Band or move to a worst Condition Band after a single deterioration cycle (over one year). Using the TPM illustrated in Figure 4.8 as an example, after one deterioration cycle:

- 91% of assets in Very Good (VG) Condition Band will remain in Very Good (VG) condition band, while 9% will move to Good (G) Condition Band;
- 71.4% of assets in Good (G) band will remain in Good (G) condition, 27.9% of the assets in Good (G) condition band will move to Fair (F) Condition Band, and 0.7% of the assets in Good (G) condition band will move to the Poor (P) condition band;
- 68.1% of assets in Fair (F) band will remain in Fair (F) condition, while 31.8% will move to Poor (P) Condition Band and 0.1% will move to the Very Poor (VP) condition band; and
- 77.1% of assets in Poor (P) band will remain in Poor (P) condition, while 22.9% will move to Very Poor (VP) Condition Band.

vi. Click on the **'Save & Exit'** button. The sum of the proportions specified in each row must be 1 otherwise an error message will be displayed in the **'Validity Check'** column shown in Figure 4.9.




| | VG | | | | | | G | | | | | F | | | | P | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Matrix Name | -> VG | -> G | -> F | -> P | -> VP | Validity Check | -> G | -> F | -> P | -> VP | Validity Check | -> F | -> P | -> VP | Validity Check | -> P | -> VP | Validity Check |
| Strategic & Main | 0.91 | 0.09 | 0 | 0 | 0 | OK | 0.714 | 0.279 | 0.007 | 0 | OK | 0.681 | 0.318 | 0.001 | OK | 0.771 | 0.229 | OK |
| Secondary | 0.928 | 0.072 | 0 | 0 | 0 | OK | 0.811 | 0.189 | 0 | 0 | OK | 0.777 | 0.223 | 0 | OK | 0.839 | 0.161 | OK |
| Link | 0.933 | 0.067 | 0 | 0 | 0 | OK | 0.773 | 0.224 | 0.003 | 0 | OK | 0.722 | 0.278 | 0 | OK | 0.836 | 0.164 | OK |
| Local | 0.963 | 0.037 | 0 | 0 | 0 | OK | 0.898 | 0.102 | 0 | 0 | OK | 0.897 | 0.103 | 0 | OK | 0.933 | 0.067 | OK |

**Figure 4.9: TPM in Row Format**

### Copying an existing Transition Probability Matrix

4.17 To copy an existing TPM, select the TPM and click on the **'Copy'** button (Figure 4.9). The copied TPM will be placed at the bottom of the list of existing TPMs.

### Deleting an existing Transition Probability Matrix

i. To delete an existing TPM, select the TPM and click on the **'Delete'** button. The selected TPM will be deleted.

ii. The user will be asked to confirm if they wish to continue. If sure, then click on the **'Yes'** button otherwise click on the **'No'** button.

iii. To remove all the TPMs, select the "Remove All" button.

### Deriving Transition Probability Matrix from Asset Service Life (Other Asset Toolkit only)

4.18 In the absence of suitable historical data for estimating deterioration of other assets, TPMs suitable for use with the Toolkit can be estimated from the service life of the other asset**.** This functionality is available in the Other Asset Toolkit only. The steps for deriving TPMs from Asset Service Life are as follows:

i. From the **'Transition Matrices'** worksheet, add a new TPM or select an existing TPM and click on the **'View/Edit Matrix'** button.

ii. Specify an Asset Service Life (in years) in the **'Asset Life'** input box (Figure 4.10). Asset Service Life is defined as the average time (in years) it takes an asset to move from the best (as new) condition state to the worst condition state. The specified Asset Life must not be less than 4 years and should not exceed 50 years.

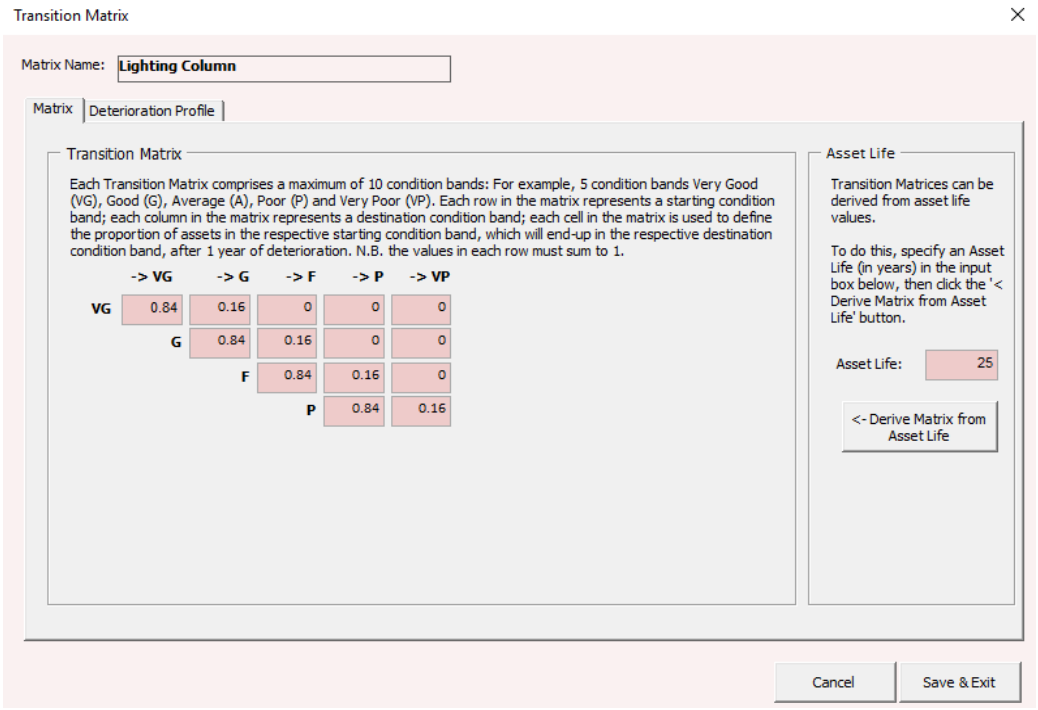



**Figure 4.10: Transition matrix in matrix format (Lighting Column Toolkit)**

iii. Click the **'<- Derive Matrix from Asset Life'** button.

iv. Click the **'Save & Exit'** button.

### Viewing Deterioration Profile

4.19 The deterioration profile of an existing TPM can be viewed graphically as follows:

i. From the **'Transition Matrices'** worksheet, select a TPM and click the **'View/Edit Matrix'** button. A transition matrix pop-up window (Figure 4.8) will appear.

ii. Select the **'Deterioration Profile'** tab at the top of the transition matrix pop-up window.

iii. Specify **'Initial Condition Values'** in the input cells adjacent to the Condition Bands and enter the duration of the scenario in the **'Analysis Period'** input cell. The sum of the Initial Condition Values must add up to 100% and the Analysis Period input must be a numeric value between 5 and 30.

iv. Click the **'Show/Update Profile'** button to generate the deterioration profile (Figure 4.11).

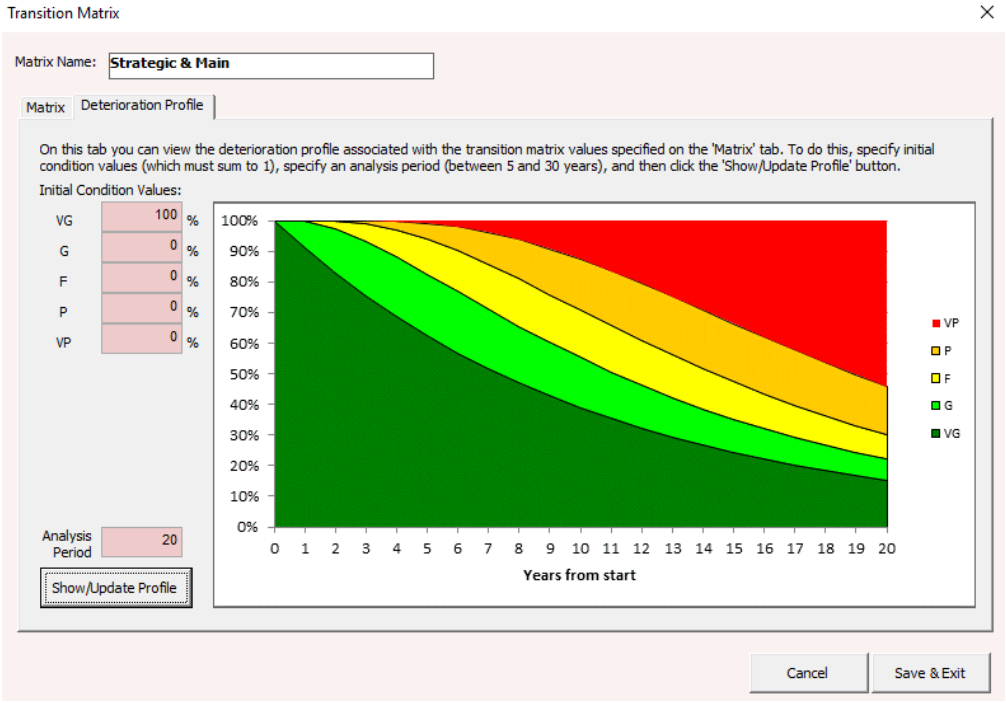



**Figure 4.11: Deterioration profile using data from Figure 4.7**

Please note that if the user intends to apply the default transition matrices, which are based on network hierarchy and not asset classification, they are encouraged to use 5 condition bands, as the models were created using this assumption. If they intend to apply a bespoke deterioration profile (as is recommended), they may use as many condition bands as the Tool allows. However, please note that the greater the number of bands, the more complex the analysis, and the longer it will take to run the toolkit. If the user has condition data in 3 condition bands (RCI for example), they can refer to the following table on how they can "translate" this into 5 bands. The values of Table 4.1 are only suggestions and indicative of a price range and should be further adapted. In any case, the user needs to adapt the transition matrix they use, if their data is in less or more than 5 condition bands.

**Table 4.1: Example condition bands and RCI equivalents**

| Asset Condition Band | RCI Equivalent |
|---|---|
| **VG (Very Good)** | RCI: 0 - 40 |
| **G (Good)** | RCI: 40 - 80 |
| **F (Fair)** | RCI: 80 - 100 |
| **P (Poor)** | RCI: 100 - 150 |
| **VP (Very Poor)** | RCI ≥265 |

## TREATMENT EFFECTS AND COSTS

4.20 The **'3 - Treatment Effects & Costs'** worksheet allows the user to define the following for each Homogeneous Asset Group:

- Effect of Treatment on Homogeneous Asset Groups
- Effect of Treatment on Condition Band
- Treatment unit costs

### Specifying the Effect of Treatments on Homogeneous Asset Groups

4.21 The **'After-Treatment Asset Group'** column (Figure 4.12) is used to model the effect of a given treatment on the performance (in terms of deterioration) of the Homogeneous Asset Group to which the treatment is associated. This facility is useful in situations such as the replacement of footways previously constructed using flags with a footway with bituminous surfacing. Before specifying the after-treatment asset group, ensure that the new Homogeneous Asset Group and associated TPMs have been defined as described earlier in this section.

4.22 When homogenous group changes occur as a result of treatment, users should bear in mind that the condition of the original (i.e. pre-treatment) group will continue to degrade, as the assets remaining in this group will only be the un-treated ones -an ever-decreasing number. The graph of this original group will show worsening condition even though funds are being spent on the asset group, which may lead users to question whether the Toolkit is working correctly or provide confused messaging if the context and reasoning behind this trend is not explained correctly.

4.23 To specify the After-Treatment Asset Group, for each Homogeneous Asset Group, select an option from the drop menu as illustrated in Figure 4.12.

| | | | | | Effect of treatment | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 | |
| No | Asset Group | Treatment | Treatment Details | After-treatment Asset Group | VG | G | F | P | VP | Validity Check |
| 1 | Flags | 1 | Lift Re-lay | No Change | VG | VG | G | G | F | OK |
| | | 2 | Replacement (Bituminous) | Bituminous | VG | VG | VG | VG | VG | OK |
| 2 | Bituminous | 1 | Lift Re-lay | No Change | None | None | None | None | None | OK |
| | | 2 | Replacement (Bituminous) | No Change | VG | VG | VG | VG | VG | OK |

No Change
Flags
Bituminous

**Figure 4.12: After Treatment Asset Group**

### Specifying the Effect of Treatments on Condition Band

4.24 The effect of each Treatment on Condition Band can be specified by selecting appropriate options from drop down menus (Figure 4.13).

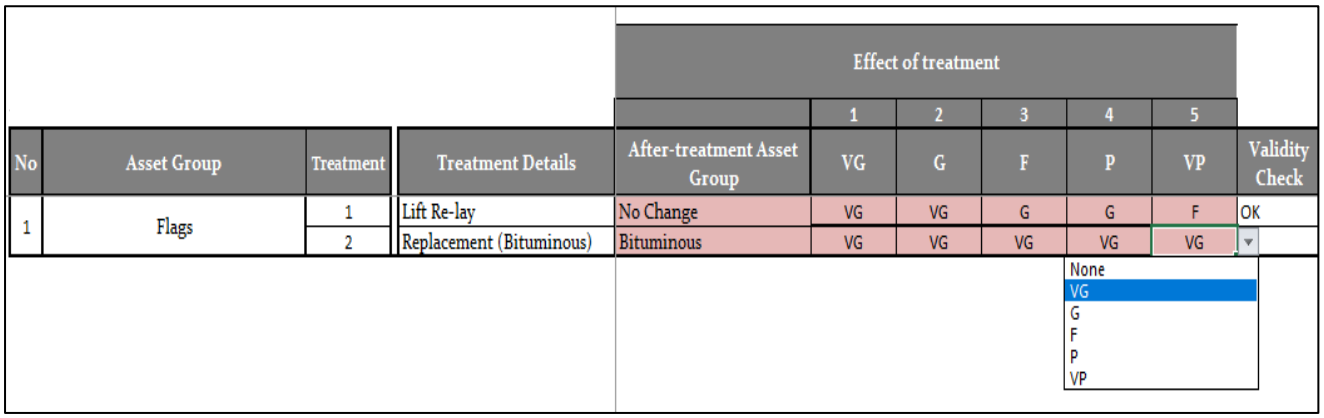



**Figure 4.13: Treatment Effects**

4.25 For example, in Figure 4.13 the effect of Replacement [Bituminous] Treatment on the Flags asset group is specified as shown in Table 4.2 as follows:

**Table 4.2: Effect of Replacement [Bituminous] Treatment on Condition**

| Asset Condition | After-treatment Asset Group | Effect of Treatment on Condition |
|---|---|---|
| **VP (Very Poor)** | Bituminous | Improves condition to Very Good (VG) |
| **P (Poor)** | Bituminous | Improves condition to Very Good (VG) |
| **F (Fair)** | Bituminous | Improves condition to Very Good (VG) |
| **G (Good)** | Bituminous | Improves condition to Very Good (VG) |
| **VG (Very Good)** | Bituminous | None (No effect) |

## Unit costs of Treatments

4.26 Unit costs of Treatments are specified by Condition Band as illustrated in Figure 4.14. It is assumed that the unit costs specified include all relevant components such as traffic management and overheads. The input cells for **'Unit Costs'** must not be left blank.

| | | | | Treatment Cost (£) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 1 | 2 | 3 | 4 | 5 | |
| No | Asset Group | Treatment | Treatment Details | VG | G | F | P | VP | Units (£ per) |
| 1 | Flags | 1 | Lift Re-lay | 18.51 | 18.51 | 18.51 | 18.51 | 18.51 | $m^2$ |
| | | 2 | Replacement (Bituminous) | 19.82 | 10 | 10 | 10 | 10 | |
| 2 | Replacement (Bituminous) | 1 | Lift Re-lay | 0 | 0 | 0 | 0 | 0 | $m^2$ |
| | | 2 | Replacement (Bituminous) | 19.82 | 19.82 | 19.82 | 19.82 | 19.82 | |

**Figure 4.14: Unit Costs of Treatments**

*(Note: unit costs values in Figure 4.14 are for the purposes of illustration only and Highway Authorities are encouraged to use their own rates)*

## TREATMENT STRATEGIES

4.27 The Toolkit assumes that Treatments are applied to Homogeneous Asset Groups at the end of each year, after deterioration as illustrated in Figure 4.15. A Treatment Strategy refers to a single Treatment or a group of Treatments that can be used to treat proportions of assets in a particular Condition Band. Treatment Strategies can be defined in the **'Treatment Strategies'** worksheet. The worksheet provides the user with the options to:

- Define a new strategy.
- Modify an existing strategy.
- Delete an existing strategy.
- Add a treatment step in the end.
- Delete a treatment step (the selected one).

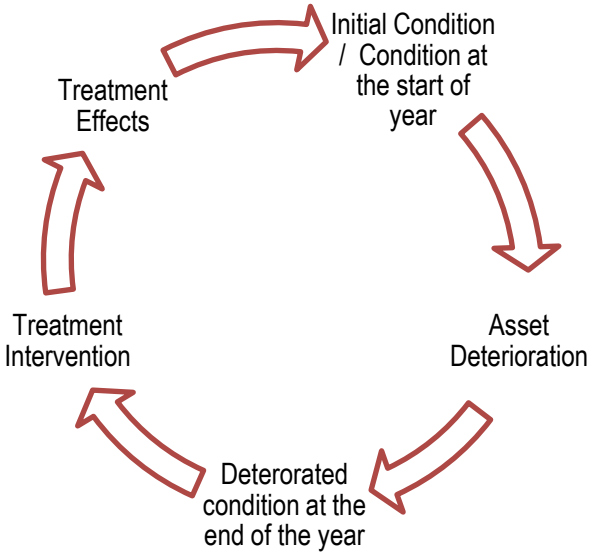



**Figure 4.15: Sequence deterioration, treatment intervention and treatment effects**

### Defining a New Treatment Strategy

i. Click the **'Add Strategy'** button in the **'Treatment Strategies'** worksheet (Figure 4.16). A new Treatment Strategy will be added below the list of existing strategies.

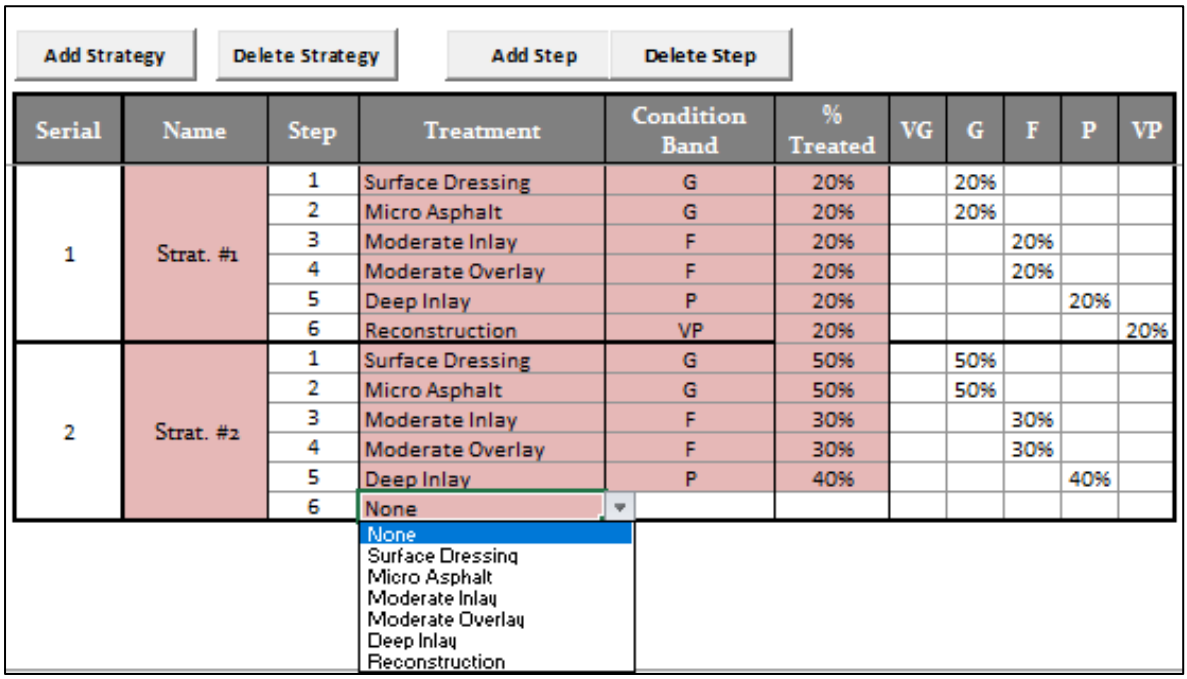
ii. Specify the name of the Treatment Strategy in the **'Name'** column.

iii. Select the **'Treatments'** (from the drop-down menu) that should be applied on a step-by-step basis, the first step being the highest priority step, and the last step being the one of lowest priority. The Toolkit will apply treatments making its way down this list (until the budget is exhausted or a performance target is reached); (each treatment strategy may have different number of steps). If the assets are defined hierarchy wise, both the assets and their treatment strategy should be inserted in priority order as treatments are prioritised based on the order inserted.

iv. Specify the asset Condition Band that should be treated in each step by selecting from the drop-down list.

v. In the **'%Treated'** column, specify the maximum percentage of the assets in the Condition Band (specified in step 4 above) that should be treated in each Treatment step (see Figure 4.16).

vi. Note that the total percentage of assets that should be treated in a particular Condition Band should not exceed 100%. If the entered values exceed 100%, an error message appears.




| Serial | Name | Step | Treatment | Condition Band | % Treated | VG | G | F | P | VP |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Strat. #1 | 1 | Surface Dressing | G | 20% | | 20% | | | |
| | | 2 | Micro Asphalt | G | 20% | | 20% | | | |
| | | 3 | Moderate Inlay | F | 20% | | | 20% | | |
| | | 4 | Moderate Overlay | F | 20% | | | 20% | | |
| | | 5 | Deep Inlay | P | 20% | | | | 20% | |
| | | 6 | Reconstruction | VP | 20% | | | | | 20% |
| 2 | Strat. #2 | 1 | Surface Dressing | G | 50% | | 50% | | | |
| | | 2 | Micro Asphalt | G | 50% | | 50% | | | |
| | | 3 | Moderate Inlay | F | 30% | | | 30% | | |
| | | 4 | Moderate Overlay | F | 30% | | | 30% | | |
| | | 5 | Deep Inlay | P | 40% | | | | 40% | |
| | | 6 | None | | | | | | | |

**Figure 4.16: Treatment Strategy**

4.28 Using the illustration in Figure 4.16, Treatment Strategy **'Strat. #1'** treats up to:

- 40% of Good (G) assets in an Asset Group (using Surface Dressing and Micro Asphalt).
- 40% of Fair (F) assets in an Asset Group (using Moderate Inlay and Moderate Overlay).
- 20% of Poor (P) assets in an Asset Group (using Deep Inlay).
- 20% of Very Poor (VP) assets in an Asset Group (using Reconstruction).

4.29 Treatment Strategies are associated with specific Homogeneous Asset Groups in the **'Scenario'** worksheet. Treatment Strategies can be combined with either Budget Constraints or Performance Targets as required, depending on the scenario being modelled. When Treatment Strategies are combined with Budget Constraints or Performance Targets, Treatments are applied in Step order (starting with Step 1) until the specified budget is exhausted, or the Performance Target achieved, or alternatively; until all the steps in the Treatment Strategy have been applied.

### Modifying an Existing Treatment Strategy

4.30 Existing Treatment Strategies can be modified by making changes to input cells in the **'Treatment Strategies'** worksheet.

4.31 The input cells that can be modified are:

- Name of Treatment Strategy.
- Treatment.
- Condition Bands being treated.
- The percentage of the assets being treated by each treatment.

### Deleting an Existing Treatment Strategy

i. Select the name of the Treatment Strategy to be deleted and click on the **'Delete Strategy'** button. A pop-up window will appear requiring the user to confirm if they would like to delete the selected Treatment Strategy.

ii. Click **'Yes'** on the pop-up window to delete the Treatment Strategy or click **'No'** to keep the selected Treatment Strategy.

### Maintenance Efficiency

i. Maintenance efficiency is a roads asset management concept which accounts for the fact that maintenance treatments are usually undertaken from joint to joint (or on given sections) and therefore they do not only target the intended areas, but also adjoining areas of the asset which may be in a better condition and may not have triggered treatment at that point in time. Maintenance efficiency should be accounted for in any lifecycle modelling, as otherwise funds allow treatment of more assets in the model than in a real-life situation.

ii. The simplest way of accounting for maintenance efficiency using the toolkit is to inflate the rates for maintenance (e.g. if for every 50m$^2$ of VP that is reconstructed an additional 10m$^2$ of pavement is also treated, then the reconstruction rate should be increased by 20%). While this method will prevent the budget from being used too efficiently, it will not account for the improved condition of the additional 10m$^2$ of treated asset, which over time can be significant.

iii. The second alternative is to build treatment strategies so that assets in other bands also get treated together with the band which is triggering the treatment. An example is shown in Figure 4.17 below, where steps 6-9 are carried out in addition to step 10 (which is triggering the treatment). This method will involve either prior calculation of budget for each treatment type (see Formula 1: % of Assets Equally Treated, page 20 in "Case studies for the HMEP LCP Toolkits") or trial and error to ensure all the steps for a given treatment are executed before the budget runs out, as each step in the treatment strategy tab gets executed in order until either the performance target is met or the budget runs out. The %ages for steps 1-3 and 6-9 in Figure 4.17 are indicative estimates of the condition of adjacent sections to the ones being targeted. Hence, if a performance target is being used, the bands which affect this target should be placed at the bottom of each 5-step list, to prevent the toolkit from stopping treatments once the condition is satisfied.


Add Strategy | Delete Strategy | Add Step | Delete Step

| Serial | Name | Step | Treatment | Condition Band | % Treated | VG | G | F | P | VP |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Worse-first | 1 | Reconstruction | VG | 1% | 1% | | | | |
| | | 2 | Reconstruction | G | 2% | | 2% | | | |
| | | 3 | Reconstruction | F | 5% | | | 5% | | |
| | | 4 | Reconstruction | P | 20% | | | | 20% | |
| | | 5 | Reconstruction | VP | 60% | | | | | 60% |
| | | 6 | Resurfacing | VG | 1% | 1% | | | | |
| | | 7 | Resurfacing | G | 5% | | 5% | | | |
| | | 8 | Resurfacing | VP | 1% | | | | | 1% |
| | | 9 | Resurfacing | P | 5% | | | | 5% | |
| | | 10 | Resurfacing | F | 60% | | | 60% | | |

**Figure 4.17: 2nd Alternative of Incorporating Maintenance Efficiency**

## BUDGETS

4.32 The **'5 - Budgets'** worksheet (illustrated in Figure 4.18) is used to define annual Budget Constraints for each Treatment Type. The user can perform the following actions in the **'Budgets'** worksheet:

- Define a new budget.

- Modify an existing budget.
- Delete an existing budget.
- Select whether or not they want to roll-over budget between treatment types of the same homogeneous asset groups.


| Serial | Name | Treatment | Budget constraints (£ 000s) | Roll Over | Total (£ 000s) |
|---|---|---|---|---|---|
| 1 | Budget Num. 1 | Surface Dressing | 100 | N | 1,100 |
| | | Micro Asphalt | 100 | Y | |
| | | Moderate Inlay | 200 | Y | |
| | | Moderate Overlay | 150 | Y | |
| | | Deep Inlay | 200 | Y | |
| | | Reconstruction | 350 | Y | |
| 2 | Budget Num. 2 | Surface Dressing | 320 | N | 2,000 |
| | | Micro Asphalt | 210 | N | |
| | | Moderate Inlay | 310 | N | |
| | | Moderate Overlay | 320 | N | |
| | | Deep Inlay | 330 | N | |
| | | Reconstruction | 510 | N | |

**Figure 4.18: Budgets**

### Defining a New Budget

i. Click on the **'Add Budget'** button on the **'Budgets'** worksheet. A new budget will be added at the bottom of the list of existing budgets.

ii. Specify the name of the budget in the **'Name'** column.

iii. Specify the annual budget available for each Treatment Type in thousands in the **'Budget Constraint'** column. For example, if the annual budget available for Surface Dressing Treatment is £100,000, then it should be specified in the Toolkit as 100.

iv. The **'Total'** column displays the total budget assigned to all Treatment Types.

4.33 Each new budget is defined by specifying the following:

- **'Name'**: name of the budget.
- **'Budget Constraint'**: the annual budget available for each Treatment Type (specified in thousands).

4.34 For example, in Figure 4.18, the specification of Budget **'Budget Num. 1'** is interpreted as follows:

- Annual Budget Constraint for Surface Dressing is £100,000.
- Annual Budget Constraint for Micro Asphalt is £100,000.
- Annual Budget Constraint for Moderate Inlay is £200,000.
- Annual Budget Constraint for Moderate Overlay is £150,000.
- Annual Budget Constraint for Deep Inlay is £200,000.
- Annual Budget Constraint for Reconstruction is £350,000.

4.35 Budgets are associated to Homogeneous Asset Groups in the **'Scenario'** worksheet.

### Modifying an Existing Budget

4.36 Existing Budgets can be modified by making changes to input cells in the **'Budgets'** worksheet.

### Deleting an Existing Budget

i. Select the name of the budget to be deleted and click on the **'Delete Budget'** button. A pop-up window requiring the user to confirm if the selected budget should be deleted is displayed.

ii. Click on **'Yes'** to delete the Treatment Strategy or click **'No'** to keep the selected budget.

### Budget Roll Over

4.37 Selecting "**Y**" in the **Roll Over** column will cause the budget to roll over between treatment types within the same homogeneous asset group, until the budget is exhausted.

4.38 To roll over budget between different homogenous groups, an Overall budget should be selected in the scenario tab (see chapter 5.5 for further detail).

## PERFORMANCE TARGETS

4.39 The **'6 - Performance Target'** worksheet (illustrated in **Error! Reference source not found.**) provides options for:

- Defining a new performance target.
- Modifying an existing performance target.
- Deleting an existing performance target.

### Defining a New Performance Target

i. Click **'Add Performance Target'** button on the **'Performance Targets'** worksheet. New input cells for the definition of Performance Targets are added at the bottom of the existing Performance Target(s). An error message prompting the user to update/enter a performance indicator is displayed (see Figure 4.19)

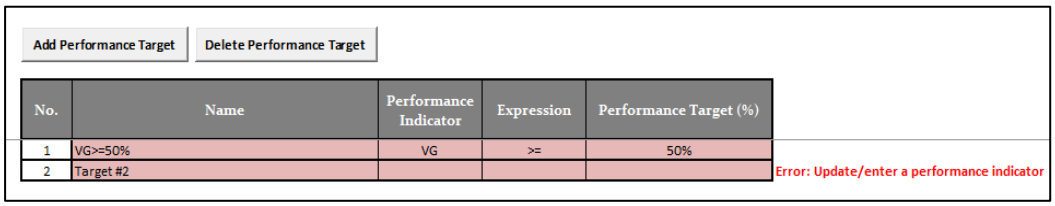



**Figure 4.19: Performance Targets**

ii. Enter the name of the new Performance Target in the **'Name'** column.

iii. Click on the input cell in the **'Performance Indicator'** column and select an indicator from the drop-down list. Performance targets can be specified for the following Condition Bands:

- The highest ranked (best) Condition Band.
- Total of the highest ranked and the next highest ranked Condition Band.
- The lowest ranked (worst) Condition Band.
- Total of the lowest ranked and the next lowest ranked Condition Band.

4.40 For example, if the following Condition Bands are defined in the **'Input Sheet'** worksheet: Very Good (VG), Good (G), Fair (F), Poor (P) and Very Poor (VP), then the following Performance Indicators can be selected from the **'Performance Targets'** worksheet:

- VG (Very Good)
- VG & G (Total in Very Good and Good Condition Bands)
- VP (Very Poor)
- VP & P (Total in Very Poor and Poor Condition Bands)

4.41 Select an appropriate expression (=, >= or <=) for the performance indicator selected in step 3 from the drop-down list in the **'Expression'** column. Expressions should be assigned to performance indicators in accordance with guidance in Table 4.3, as it makes logical sense that the aim would be to maximise (>=) condition in the higher bands or minimise (<=) condition in the lower bands. An error message will be displayed if an invalid Expression is selected. Despite the error message, the user will be able to run the analysis; the Tool will automatically change the expression to the right way around and proceed as usual. In spite of the above, the user is encouraged to insert a valid expression prior to running the analysis. For e.g., Figure 4.19 depicts a Performance Target where the user requests that assets which are in VG condition to be >=50%.

**Table 4.3: Associating Expressions to Performance Indicators**

| Expression | | Performance Indicators |
|---|---|---|
| **=** | **(equal to)** | Applicable to all Performance Indicators |
| **>=** | **(greater or equal to)** | Highest ranked Condition Band (e.g. VG) |
| | | Total of the highest ranked and the next highest ranked Condition Band (e.g. VG + G) |
| **<=** | **(less or equal to)** | The lowest ranked (worst) Condition Band (e.g. VP) |
| | | Total of the lowest ranked and the next lowest ranked Condition Band |

4.42 Specify the Performance Target as a numeric value in % in the **'Performance Target'** column. Performance targets are assigned to Homogeneous Asset Groups in the **'Scenario'** worksheet.

The user should note that the performance target and the treatment strategy should be aligned. For e.g. if the treatment strategy requests 20% of the VP assets to be treated and the performance target says that VP assets should be <= 0%, the performance target cannot be met due to the limitation in the treatment strategy tab.

### Modifying Existing Performance Targets

4.43 Existing performance targets can be modified by making changes to input cells in the **'Performance Targets'** worksheet.

### Deleting a Performance Target

4.44 Select the name of the Performance Target to be deleted and click on the **'Delete Performance Target'** button **Error! Reference source not found.**. A pop-up window requiring the user to confirm if the selected Performance Target should be deleted is displayed.

4.45 Click on **'Yes'** to delete the Performance Target or click **'No'** to keep the selected Performance Target.

# 5 SETTING UP SCENARIOS AND RUNNING THE TOOLKIT

## SETTING UP ANALYSIS SCENARIOS

5.1 The **'7 - Scenario'** worksheet (Figure 5.1) provides options for setting up Analysis Scenarios including:

- Naming Analysis Scenarios.
- Assigning TPMs to Homogeneous Asset Groups and Analysis Scenarios.
- Assigning Treatment Strategies to Homogeneous Asset Groups and Analysis Scenarios.
- Assigning Budget Constraints to Homogeneous Asset Groups and Analysis Scenarios.
- Assigning Performance Targets to Homogeneous Asset Groups and Analysis Scenarios.

| Run Analysis ... | Clear selected row(s) | Copy selected cell(s) | Paste copied cell(s) | | | |
|---|---|---|---|---|---|---|
| | | | | 1 | 2 | 3 |
| No. | Homogeneous Group | Scenario Name | Criteria | 2018 | 2019 | 2020 |
| 1 | Strategic & Main | Do Nothing | Transition matrix | Strategic & main | Strategic & main | Strategic & main |
| | | | Treatment strategy | | | |
| | | | Budget constraint | | | |
| | | | Performance target | | | |
| 2 | Secondary | Do Nothing | Transition matrix | Secondary | Secondary | Secondary |
| | | | Treatment strategy | | | |
| | | | Budget constraint | | | |
| | | | Performance target | | | |

**Figure 5.1: Scenario Worksheet**

### Naming Analysis Scenarios

5.2 An Analysis Scenario can be defined for each Homogeneous Asset Group. The name of each Analysis Scenario is specified in the **'Scenario Name'** column (Figure 5.1). The name specified should be short and concise as it will be automatically populated into the title of the output sheet graphs, should they be used.

5.3 The Toolkit does not allow the definition of multiple Analysis Scenarios for a given Homogeneous Asset Group. If the user wants to create more than one Analysis Scenario for a Homogeneous Asset Group, then several versions of the Toolkit (as many as there are Analysis Scenarios) will need to be created. Comparisons of the results of different Analysis Scenarios need to be carried out outside of the Toolkit. It is good practice to record such results in a spreadsheet that clearly shows: the Toolkit version number, a description of the analysis scenario, the date of the analysis, and the name or initials of the person who carried out the analysis.

### Assigning Transition Probability Matrix to Asset Groups and Analysis Scenarios

i. Transition Probability Matrices (TPMs) must be assigned to all Asset Groups, Analysis Scenarios and years before running the Toolkit.

ii. In the **'Scenario'** worksheet, click on the input cell corresponding to the **'Transition Matrix'** row and the first year of analysis.

iii. Select the appropriate pre-defined TPM from the drop-down list on the **'Transition Matrix'** row. The TPM should have already been defined in the **'Transition Matrices'**

worksheet as explained in Section 4.

iv. Repeat the above steps for all Homogeneous Asset Groups, Analysis Scenarios and years. This can be facilitated by the 'Clear selected row(s)', 'Copy selected row(s)' and 'Paste selected cells' buttons, as explained below.

### Assigning Treatment Strategy to Asset Groups and Analysis Scenarios

5.4 Steps for assigning Treatment Strategies to Homogeneous Asset Groups and Analysis Scenarios are as follows:

i. In the **'Scenario'** worksheet, click on the input cell corresponding to the Treatment Strategy row and the year in which the Treatment Strategy is applicable.

ii. Select the appropriate pre-defined Treatment Strategy from the drop-down list. The desired Treatment Strategy should have been defined in the **'Treatment Strategies'** worksheet in Section 4.

iii. Repeat the above steps for all Homogeneous Asset Groups, Analysis Scenarios and years for which the Treatment Strategies are intended. This can be facilitated by the **'Clear selected row(s)'**, **'Copy selected cell(s)'** and **'Paste selected cell(s)'** buttons, as explained below.

### Assigning Budget Constraints to Asset Groups and Analysis Scenarios

5.5 The Budget Constraint input in the **'Scenario'** worksheet should be left blank if the analysis is not constrained by budget. Budget Constraints can be assigned as follows:

iv. In the **'Scenario'** worksheet, click on the input cell corresponding to the **'Budget Constraint'** row and the year to which Budget Constraint should be applied.

v. Select the appropriate pre-defined **Budget** from the drop-down list. Budget Constraints are defined in the **'Budgets'** worksheet as described in Section 4. An additional option to select "Overall" is provided to the user. Overall is the sum of all the budget constraints defined in the "**Budgets**" worksheet. If the budget constraint for each treatment cannot be defined, as required by the "**Budget**" worksheet, the total budget constraint is known, then the user can insert this number in the first input row of the "**Budget**" worksheet and select "Overall" in the "**Scenario**" worksheet, in the budget constraint row. The Overall budget will be allocated across the homogeneous asset groups hierarchy wise; based on the order they are defined.

vi. Repeat the above steps for all Homogeneous Asset Groups, Analysis Scenarios and years for which Budget Constraints are intended. This can be facilitated by the **'Clear selected row(s)'**, **'Copy selected cell(s)'** and **'Paste selected cell(s)'** buttons, as explained below.

### Assigning Performance Targets to Asset Groups and Analysis Scenarios

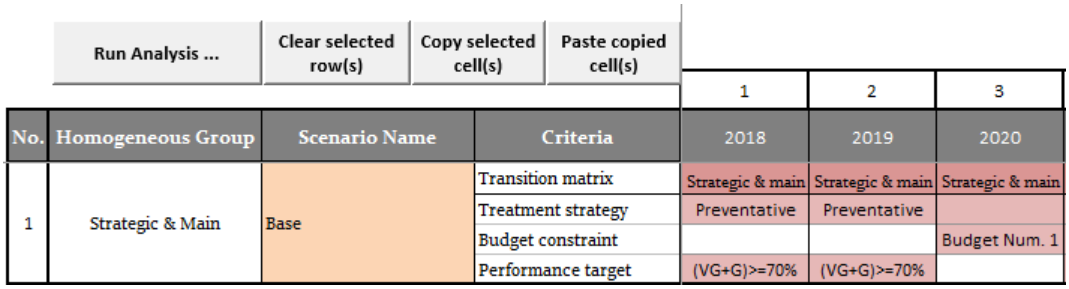
5.6 The Performance Target input cells in the **'Scenario'** worksheet should be left blank if the analysis is not constrained by pre-defined Performance Targets. Performance Targets can be assigned to Homogenous Asset Groups as follows:

vii. In the **'Scenario'** worksheet, click on the input cell corresponding to the **'Performance Target'** row and the year which the Performance Target is intended.

viii. Select the appropriate pre-defined **Performance Target** from the drop-down list. Performance targets are defined in the **'Performance Targets'** worksheet.

ix. Repeat the above steps for all Homogeneous Asset Groups, Analysis Scenarios and years for which performance targets are intended. This can be facilitated by the **'Clear selected row(s)'**, **'Copy selected cell(s)'** and **'Paste selected cell(s)'** buttons, as explained below.

5.7 It should be noted that Performance Targets and Budget Constraints cannot be assigned together in the same year. For any Homogeneous Asset Group and Analysis Scenario, for example, when a Performance Target is assigned to a particular year then the corresponding Budget Constraint input is automatically set to blank and becomes read-only as illustrated in. Similarly, when Budget Constraint is set then Performance Target is automatically set to blank and becomes read-only as illustrated in Figure 5.2.




| | | | | 1 | 2 | 3 |
|---|---|---|---|---|---|---|
| No. | Homogeneous Group | Scenario Name | Criteria | 2018 | 2019 | 2020 |
| 1 | Strategic & Main | Base | Transition matrix | Strategic & main | Strategic & main | Strategic & main |
| | | | Treatment strategy | Preventative | Preventative | |
| | | | Budget constraint | | | Budget Num. 1 |
| | | | Performance target | (VG+G)>=70% | (VG+G)>=70% | |

**Figure 5.2: Assignment of Budget Constraints and Performance Targets to Analysis Scenarios**

### Clear a row

5.8 To clear a Transition Matrix, Treatment Strategy, Budget Constraints or Performance Target row, select any input cell on the row and click on the **'Clear selected row(s)'** button.

5.9 The user will be asked to confirm if they wish to continue. If sure, then click on the **'Yes'** button otherwise click on the **'No'** button.

### Copy and Paste a cell

5.10 To copy a Transition Matrix, Treatment Strategy, Budget Constraints or Performance Target row, select any input cell on the row and click on the **'Copy selected cell(s)'** button.

5.11 To paste the copied row into a destination row, select any input cell in the destination row and click on the **'Paste selected cell(s)'** button.

5.12 The user will be asked to confirm if they wish to continue. If sure, then click on the **'Yes'** button otherwise click on the **'No'** button. Any previous value in the destination row will be overwritten with the copied values.

## RUNNING THE TOOLKIT

5.13 Click on the **'Run Analysis...'** button on the top left of the **'Scenario'** worksheet to run the Lifecycle Planning Toolkit.

5.14 The Toolkit automatically validates all inputs. The location of any errors in the input data will be displayed in a pop-up window (e.g. Figure 5.3). Click **'OK'**, correct errors and re-run the Toolkit. Note that it is good practice to save the Toolkit before each run.

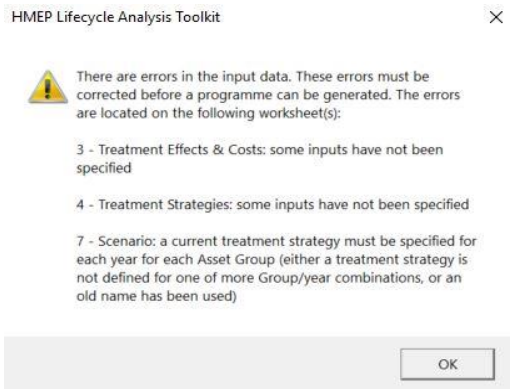



**Figure 5.3: Sources of Errors in Input Data**

5.15 The progress of the analysis is displayed on the status bar located at bottom left of the worksheet (Figure 5.4).


**Figure 5.4: Analysis Progress**

5.16 The pop-up window (Figure 5.5) indicating the duration of the analysis is displayed following the completion of a successful run.

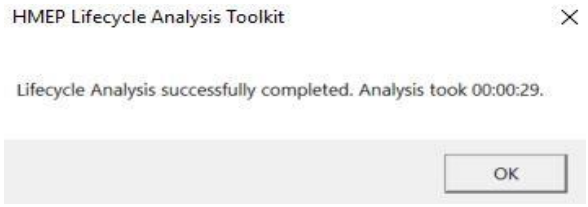



**Figure 5.5: Successful Run**

## LINK HMEP TO HMAT AND HMEA

5.17 The HMEP toolkit forms part of a suite of tools aimed at helping local highway authorities to better manage their highways assets. Other tools include:

- The Highways Maintenance Appraisal Tool (HMAT): this tool helps local highway authorities assess the economic costs and benefits of proposed maintenance
- The Highways Maintenance Economic Appraisal (HMEA) Tool: this tool helps local highway authorities assess the value of highway maintenance to the economy and society.

5.18 The HMAT and HMEA models use the outputs of the HMEP lifecycle planning model, as illustrated in Figure 5.6 below.


**Figure 5.6: Flow chart of Highway Maintenance Tools based on data import**

5.19 Therefore, if the HMEP lifecycle planning tool is being used to facilitate HMAT or HMEA analysis, this should be considered when setting up HMEP scenarios, so that output data from HMEP can be imported to HMAT. More specifically, to analyse, this will involve creating one base scenario and a number of alternative scenarios (the exact number will depend on the modelling questions being examined); these should be saved as different HMEP spreadsheets, so that they can be imported separately into HMAT (or HMEA subsequently).

5.20 Further guidance on how these outputs are used in HMAT and HMEA is available in the user guides for these models. However, the key inputs provided by HMEP include:

- A forecast of network condition for each year during the analysis period (HMEP output tabs 8 & 9);
- Value of maintenance undertaken each year during the analysis period, by treatment type (tabs 14 & 15) and by condition (tabs 12 & 13); and
- The length/area of asset treated by homogeneous asset group and treatment type each year (tabs 10 & 11).

# 6 ANALYSING OUTPUTS

## UNDERSTANDING THE OUTPUTS

6.1 The following outputs are produced by the Toolkit:

- Condition by Year.
- Condition Graph.
- Work Quantity.
- Work Quantity Graph.
- Expenditure by Condition Band.
- Expenditure by Condition Graph.
- Expenditure by Treatment
- Expenditure by Treatment Graph
- Areas or Asset Quantities by Year.

6.2 Note that the examples provided in this section are for the purposes of illustration only. Worked examples are available in Sections 7, 8 and 9.

### Condition by Year

6.3 Tabulated outputs of condition by year for each Homogeneous Asset Group are provided in the worksheet labelled **'8 – Condition by Year'**. A 5-year extract of the output is illustrated in Figure 6.1. The **'Initial Distribution'** column reports the current or base condition of the Homogeneous Asset Group. Subsequent columns report the projected condition at the end of each year.

| | | | Initial Distribution | | | | | |
|---|---|---|---|---|---|---|---|---|
| Asset Group | No. | Cond | 2018 | 2018 | 2019 | 2020 | 2021 | 2022 |
| Strategic & Main | 1 | VG | 29.56% | 37.16% | 42.13% | 39.63% | 37.57% | 35.51% |
| | 2 | G | 44.34% | 33.61% | 34.28% | 28.27% | 23.84% | 20.55% |
| | 3 | F | 20.40% | 16.97% | 13.54% | 18.34% | 19.86% | 19.72% |
| | 4 | P | 3.42% | 9.24% | 5.00% | 7.67% | 11.16% | 14.26% |
| | 5 | VP | 2.28% | 3.02% | 5.05% | 6.08% | 7.58% | 9.96% |
| Secondary | 1 | VG | 26.04% | 24.69% | 23.42% | 22.22% | 20.69% | 19.28% |
| | 2 | G | 39.06% | 34.28% | 30.23% | 26.80% | 21.62% | 17.71% |
| | 3 | F | 25.60% | 25.70% | 24.82% | 23.30% | 21.57% | 18.84% |
| | 4 | P | 5.58% | 10.62% | 14.96% | 18.50% | 22.36% | 24.83% |
| | 5 | VP | 3.72% | 4.72% | 6.57% | 9.18% | 13.75% | 19.34% |

**Figure 6.1: Condition by Year**

## Condition Graph

6.4 Graphs of predicted condition profile for each Homogeneous Asset Group are reported in the worksheet labelled **'9 – Condition Graph'**. A drop-down menu is used to select outputs for each Homogenous Asset Group as illustrated in Figure 6.2. The type of graph produced is dependent on the type of graph chosen in **'0 – Input Sheet'** as is described in Section 4.

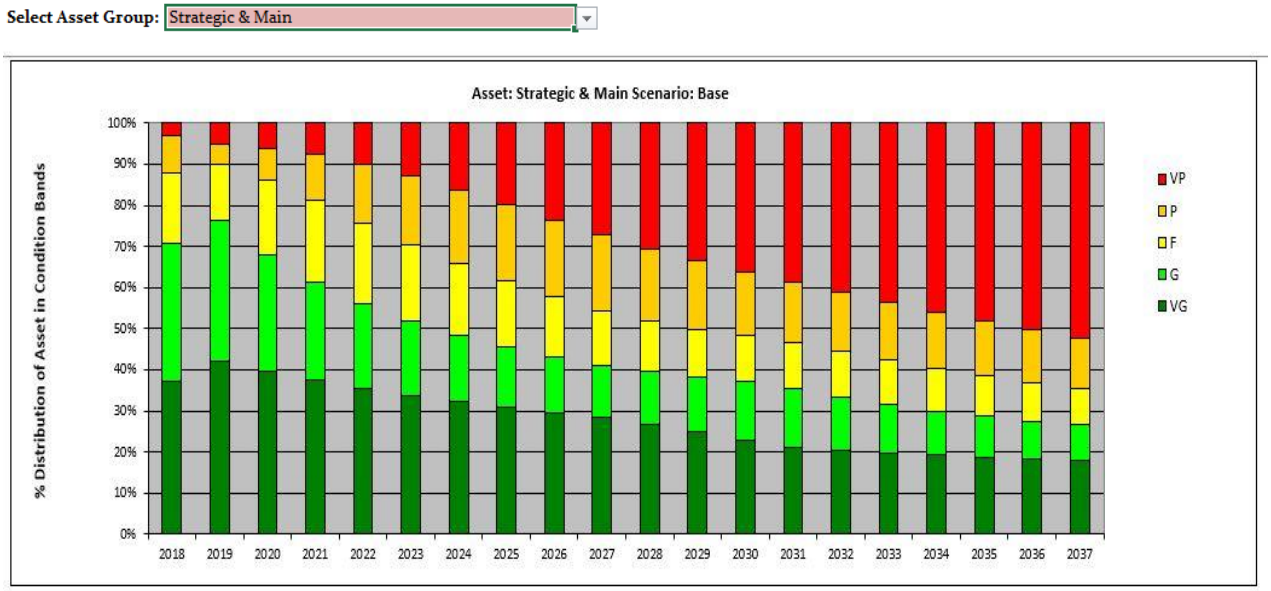



**Figure 6.2: Condition Graph**

## Work Quantity

6.5 Tabulated outputs of work quantity by Treatment and year for each Homogeneous Asset Group are provided in the worksheet labelled **'10 – Work Quantity'**. A 3-year extract of this output is illustrated in Figure 6.3.

| Asset Group | Treatment | Total (m²) | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|
| Strategic & Main | Surface Dressing | 6,000,485 | 2,613,221 | 2,127,265 | 20,000 |
| | Micro Asphalt | 0 | 0 | 0 | 0 |
| | Moderate Inlay | 0 | 0 | 0 | 0 |
| | Moderate Overlay | 0 | 0 | 0 | 0 |
| | Deep Inlay | 0 | 0 | 0 | 0 |
| | Reconstruction | 5,437,286 | 0 | 2,287,286 | 175,000 |
| | Total | 11,437,772 | 2,613,221 | 4,414,551 | 195,000 |
| Secondary | Surface Dressing | 10,992,696 | 620,000 | 620,000 | 620,000 |
| | Micro Asphalt | 0 | 0 | 0 | 0 |
| | Moderate Inlay | 0 | 0 | 0 | 0 |
| | Moderate Overlay | 0 | 0 | 0 | 0 |
| | Deep Inlay | 0 | 0 | 0 | 0 |
| | Reconstruction | 3,518,259 | 0 | 0 | 0 |
| | Total | 14,510,956 | 620,000 | 620,000 | 620,000 |

**Figure 6.3: Work Quantity ($m^2$)**

## Work Quantity Graph

6.6 Graphs of predicted work quantity by Treatment Type for each Homogeneous Asset Group are reported in the worksheet labelled **'11 – Work Qty Graph'** as illustrated in Figure 6.4. A drop-down menu is used to select the graphs for each Homogenous Asset Group.

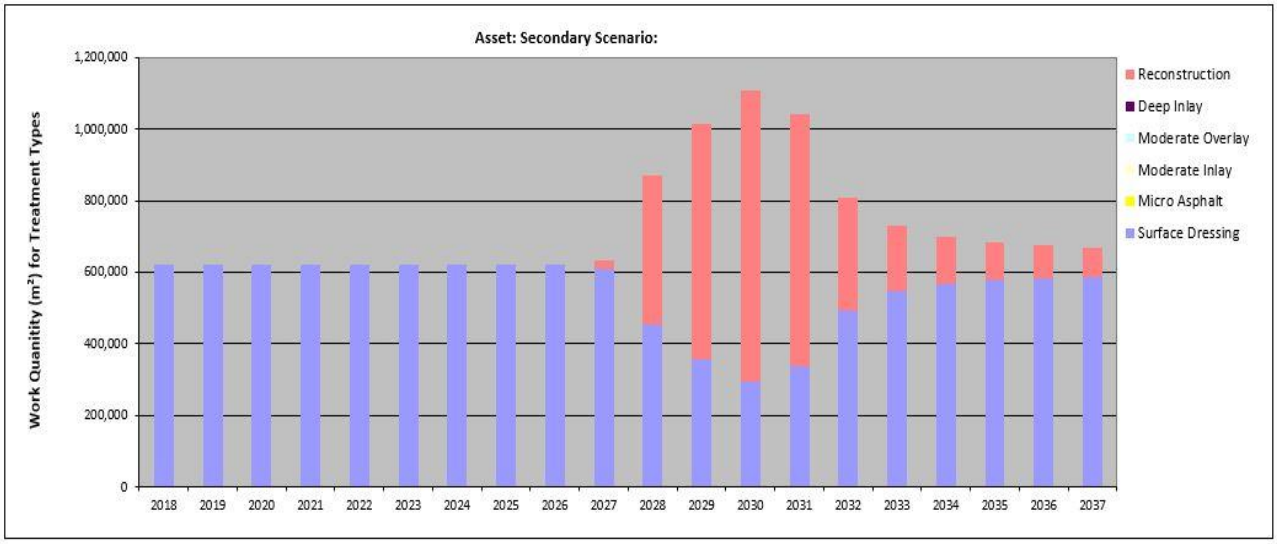



**Figure 6.4: Work Quantity Graph**

## Expenditure by Condition Band

6.7 Tabulated outputs of predicted expenditure by Condition Band and year for each Homogeneous Asset Group are provided in the worksheet labelled **'12 – Exp by Cond Band'**. A 4-year extract of this output is illustrated in Figure 6.5.

| Asset Group | Condition Band | Analysis Period Total (£) | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|
| Strategic & Main | VG | 0 | 0 | 0 | 0 | 0 |
| | G | 0 | 0 | 0 | 0 | 0 |
| | F | 27,002,427 | 13,066,103 | 10,636,324 | 100,000 | 200,000 |
| | P | 10,874,572 | 0 | 4,574,572 | 350,000 | 350,000 |
| | VP | 3,000,000 | 0 | 0 | 0 | 200,000 |
| | Total | 40,876,999 | 13,066,103 | 15,210,896 | 450,000 | 750,000 |
| | Cumulative | 40,876,999 | 13,066,103 | 28,276,999 | 28,726,999 | 29,476,999 |
| Secondary | VG | 0 | 0 | 0 | 0 | 0 |
| | G | 0 | 0 | 0 | 0 | 0 |
| | F | 42,651,274 | 3,100,000 | 3,100,000 | 3,100,000 | 3,100,000 |
| | P | 7,036,519 | 0 | 0 | 0 | 0 |
| | VP | 12,312,207 | 0 | 0 | 0 | 0 |
| | Total | 62,000,000 | 3,100,000 | 3,100,000 | 3,100,000 | 3,100,000 |
| | Cumulative | 62,000,000 | 3,100,000 | 6,200,000 | 9,300,000 | 12,400,000 |
| Total Expenditure | VG | 0 | 0 | 0 | 0 | 0 |
| | G | 0 | 0 | 0 | 0 | 0 |
| | F | 69,653,701 | 16,166,103 | 13,736,324 | 3,200,000 | 3,300,000 |
| | P | 17,911,091 | 0 | 4,574,572 | 350,000 | 350,000 |
| | VP | 15,312,207 | 0 | 0 | 0 | 200,000 |
| | Total | 102,876,999 | 16,166,103 | 18,310,896 | 3,550,000 | 3,850,000 |
| | Cumulative | 102,876,999 | 16,166,103 | 34,476,999 | 38,026,999 | 41,876,999 |

**Figure 6.5: Expenditure (£) by Condition**

## Expenditure by Condition Graph

6.8 Graphs of predicted expenditure by Condition Band for each Homogeneous Asset Group are reported in the worksheet labelled **'13 – Exp by Cond Graph'**. The worksheet contains a facility which allows the user to select and display expenditure by condition graphs for multiple assets as follows:

i. Click the **'Select/View Asset Groups...'** button on the **'13 – Expenditure by Cond Graph'** worksheet.

ii. From the pop-up window (Figure 6.6) select the asset groups to display on the graph.

iii. To select all assets, click the 'Select All' button on pop-up window. To clear all selections, click the **'Clear All'** button.

iv. Click **'OK'** to display graphs for selected asset groups (illustrated in Figure 6.7).

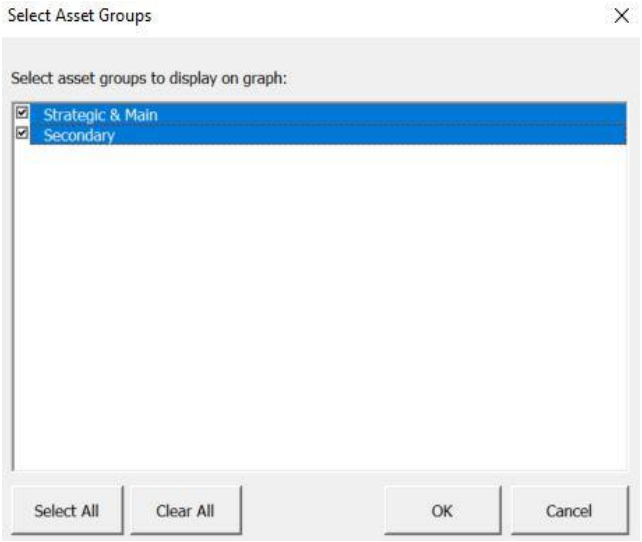



**Figure 6.6: Selecting Asset Groups**

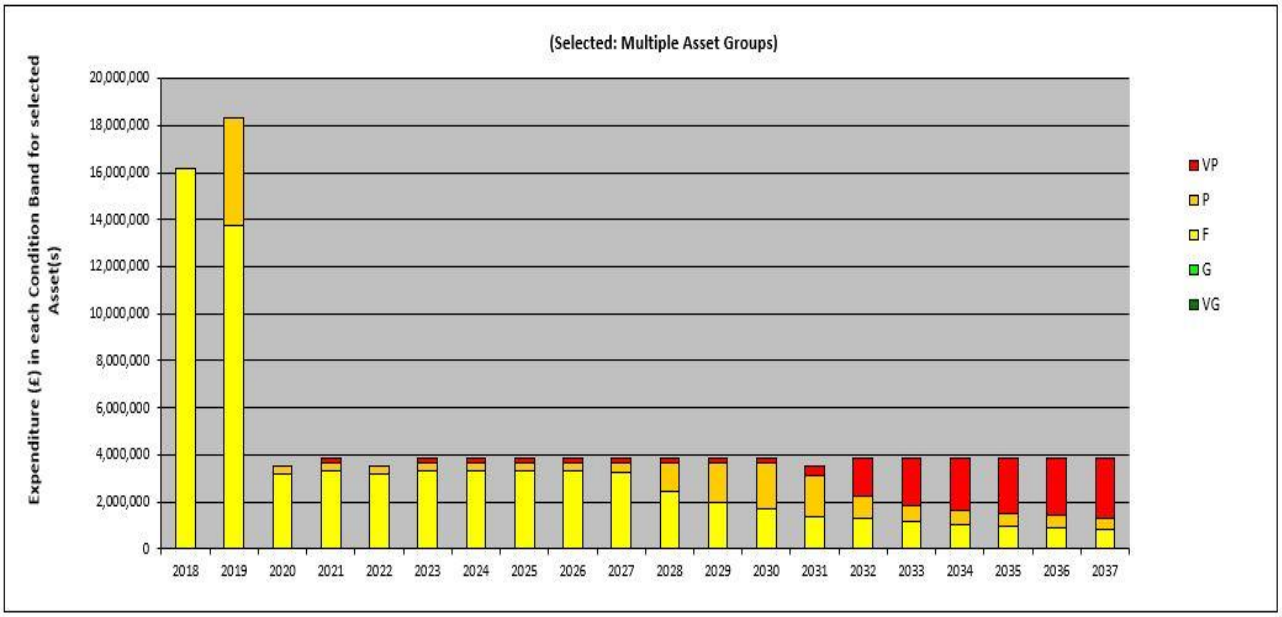



**Figure 6.7: Work Quantity Graph**

## Expenditure by Treatment

6.9 Tabulated outputs of predicted expenditure by Treatment and year for each Homogeneous Asset Group are provided in the worksheet labelled **'14 – Exp by Treatment'**. A 4-year extract of this output is illustrated in Figure 6.8.

| Asset Group | Treatment | Analysis Period Total (£) | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|
| Strategic & Main | Surface Dressing | 30,002,427 | 13,066,103 | 10,636,324 | 100,000 | 400,000 |
| | Micro Asphalt | 0 | 0 | 0 | 0 | 0 |
| | Moderate Inlay | 0 | 0 | 0 | 0 | 0 |
| | Moderate Overlay | 0 | 0 | 0 | 0 | 0 |
| | Deep Inlay | 0 | 0 | 0 | 0 | 0 |
| | Reconstruction | 10,874,572 | 0 | 4,574,572 | 350,000 | 350,000 |
| | Total | 40,876,999 | 13,066,103 | 15,210,896 | 450,000 | 750,000 |
| | Cumulative | 40,876,999 | 13,066,103 | 28,276,999 | 28,726,999 | 29,476,999 |
| Secondary | Surface Dressing | 54,963,481 | 3,100,000 | 3,100,000 | 3,100,000 | 3,100,000 |
| | Micro Asphalt | 0 | 0 | 0 | 0 | 0 |
| | Moderate Inlay | 0 | 0 | 0 | 0 | 0 |
| | Moderate Overlay | 0 | 0 | 0 | 0 | 0 |
| | Deep Inlay | 0 | 0 | 0 | 0 | 0 |
| | Reconstruction | 7,036,519 | 0 | 0 | 0 | 0 |
| | Total | 62,000,000 | 3,100,000 | 3,100,000 | 3,100,000 | 3,100,000 |
| | Cumulative | 62,000,000 | 3,100,000 | 6,200,000 | 9,300,000 | 12,400,000 |
| **Total Expenditure** | Surface Dressing | 84,965,908 | 16,166,103 | 13,736,324 | 3,200,000 | 3,500,000 |
| | Micro Asphalt | 0 | 0 | 0 | 0 | 0 |
| | Moderate Inlay | 0 | 0 | 0 | 0 | 0 |
| | Moderate Overlay | 0 | 0 | 0 | 0 | 0 |
| | Deep Inlay | 0 | 0 | 0 | 0 | 0 |
| | Reconstruction | 17,911,091 | 0 | 4,574,572 | 350,000 | 350,000 |
| | **Total** | 102,876,999 | 16,166,103 | 18,310,896 | 3,550,000 | 3,850,000 |
| | **Cumulative** | 102,876,999 | 16,166,103 | 34,476,999 | 38,026,999 | 41,876,999 |

**Figure 6.8: Expenditure (£) by Treatment**

### Expenditure by Treatment Graph

6.10 Graphs of predicted expenditure by Treatment Type for each Homogeneous Asset Group are reported in the worksheet labelled **'15 – Exp by Treat Graph'**. A dropdown menu is used to select the graphs for each Homogenous Asset Group and type of Treatment as illustrated in Figure 6.9.

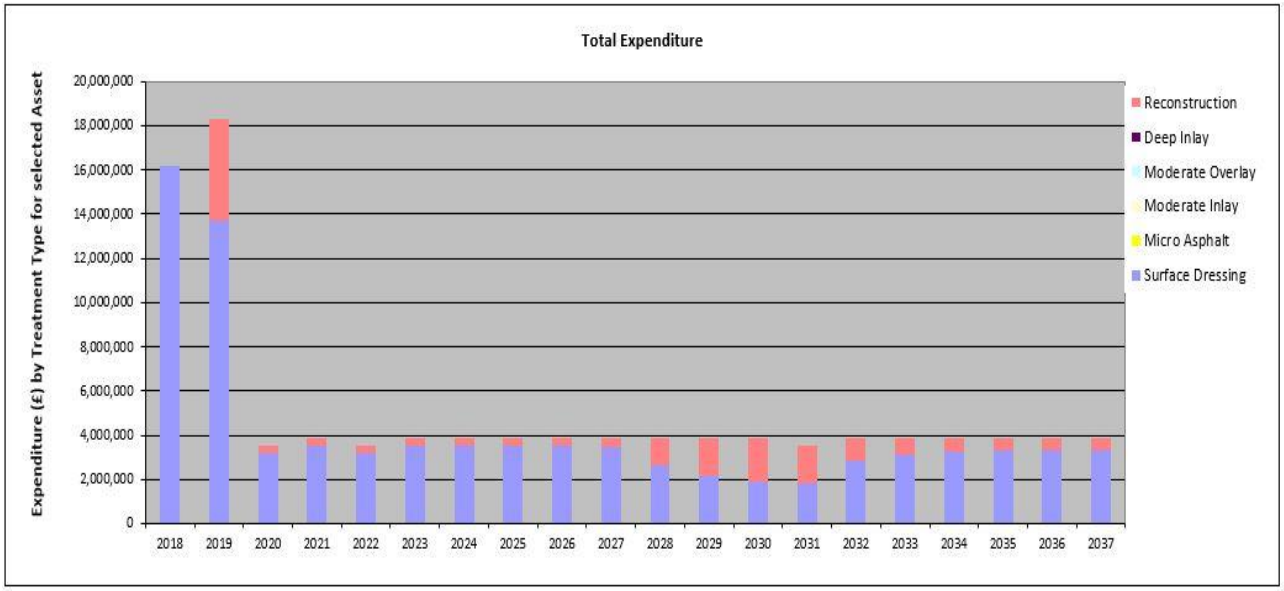



**Figure 6.9: Expenditure by Treatment Graph**

### Areas by Year

6.11 For each Homogeneous Asset Group, tabulated outputs of the quantity of assets in each condition band by year are provided in the worksheet labelled **'16 - Area by Year'** as illustrated in Figure 6.10. Note that with the exception of the initial distribution column, all other columns reflect the condition of the asset at the *end* of the year (i.e. 31st December).

6.12 Changes in the areas over the years account for assets that moved from one Homogeneous Asset Group to another as a result of a Treatment. After-Treatment Asset Groups are defined in the worksheet **'3 - Treatment Effects and Costs'**.

| | | | Initial Distribution (m²) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Asset Group | No. | Cond | 2018 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 |
| Strategic & Main | 1 | VG | 8,650,734 | 11,105,389 | 15,140,455 | 14,592,814 | 14,154,460 | 13,695,559 | 13,337,959 | 13,012,542 |
| | 2 | G | 12,976,101 | 10,043,502 | 8,170,546 | 7,196,410 | 6,451,590 | 5,880,337 | 5,431,161 | 5,078,265 |
| | 3 | F | 5,970,060 | 5,072,722 | 4,129,396 | 5,071,701 | 5,421,627 | 5,472,122 | 5,327,129 | 5,103,069 |
| | 4 | P | 1,000,863 | 2,760,977 | 1,524,857 | 2,371,007 | 3,316,222 | 4,151,046 | 4,806,753 | 5,263,052 |
| | 5 | VP | 667,242 | 902,410 | 1,539,746 | 1,893,068 | 2,401,100 | 3,165,937 | 4,081,998 | 5,148,072 |
| Secondary | 1 | VG | 7,620,606 | 7,071,922 | 6,562,744 | 6,090,226 | 5,542,106 | 5,043,316 | 4,589,418 | 4,176,370 |
| | 2 | G | 11,430,909 | 9,819,151 | 8,472,510 | 7,343,723 | 5,791,539 | 4,633,948 | 3,762,537 | 3,099,499 |
| | 3 | F | 7,491,840 | 7,361,601 | 6,955,784 | 6,385,948 | 5,777,730 | 4,930,473 | 4,030,524 | 3,174,535 |
| | 4 | P | 1,632,987 | 3,040,756 | 4,192,832 | 5,068,926 | 5,990,279 | 6,496,364 | 6,609,025 | 6,403,602 |
| | 5 | VP | 1,088,658 | 1,351,569 | 1,841,131 | 2,516,177 | 3,683,347 | 5,060,898 | 6,553,496 | 8,070,993 |

**Figure 6.10: Area by Year**

### Asset Quantity by Year

6.13 In the Other Assets Toolkit, tabulated outputs of the areas by year for each Homogeneous Asset Group are provided in the worksheet labelled **'16 – Asset Qty by Year'** as shown in Figure 6.11. The number of units within each condition band changes each year depending upon the level of deterioration during the previous 12 months and the maintenance scenario being modelled. Note that with the exception of the initial distribution column, all other columns reflect the condition of the asset at the *end* of the year (i.e. 31st December).

| | | | | Initial Distribution (units) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Asset Group | Units | No. | Cond | 2013 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
| Traffic Signs - Matrix and VMS | no. | 1 | VG | 488 | 417 | 352 | 299 | 255 | 219 | 192 |
| | | 2 | G | 88 | 152 | 194 | 220 | 232 | 236 | 233 |
| | | 3 | F | 38 | 46 | 63 | 84 | 105 | 126 | 143 |
| | | 4 | P | 6 | 11 | 17 | 24 | 34 | 45 | 58 |
| | | 5 | VP | 6 | 0 | 0 | 0 | 0 | 0 | 0 |

**Figure 6.11: Asset Quantity by Year**

## EXPORTING THE OUTPUTS

6.14 All tabulated outputs can be exported to other Microsoft Office programmes such as Excel and Word for further analysis or to create bespoke reports. Graphs are exported as images. Outputs can be exported as follows:

i. Select the desired output worksheet and click the button located on the top right of the worksheet to copy the contents of the worksheet to the Windows Clipboard.

ii. Click **'OK'** when prompted with the confirmation message in Figure 6.12 and paste the copied content in a desired programme, e.g. MS Word or MS Excel.


**Figure 6.12: Confirmation Message for Exporting Outputs**

# 7 WORKED EXAMPLE FOR THE CARRIAGEWAY TOOLKIT

## INTRODUCTION

7.1 This example illustrates the step by step application of the Lifecycle Planning Toolkit using carriageway inventory and condition data from a local highway authority in England. The example aims to demonstrate the application of the Toolkit in investigating:

- The levels of funding required to deliver user-defined carriageway network performance standards.
- The impact on the carriageway network performance trends as a result of budget constraints.

7.2 An analysis period of 30 years was used, with the start year of analysis set to 2012.

### Inventory, Condition and Deterioration Models

7.3 The inventory data used in this example is from a local highway authority's rural road network with a total length of 102 km. The lengths and widths are aggregated into four Homogeneous Asset Groups based on road hierarchy (Strategic Routes and Main Distributors, Secondary Distributors, Link Roads and Local Access roads) as illustrated in Table 7.1. Each Homogeneous Asset Group is modelled in isolation and could be subdivided further by pavement type (e.g. flexible, flexible composite, rigid, etc), districts/areas and road type (e.g. single, dual etc) as appropriate. However, it is important to note that if the number of Homogeneous Asset Groups is too large then it becomes cumbersome to set up the Toolkit and interpret the outputs.

7.4 The current condition of each Homogeneous Asset Group is represented as a distribution across five Condition Bands. This is the base year or starting point for network planning in subsequent years. Consequently, the estimate of that condition is important, as are the definitions of Condition Bands, which are used to describe it.

7.5 For this example, default rural roads TPMs given in Appendix A – Default Carriageway Deterioration Models and corresponding to the Homogenous Asset Groups in Table 7.1 were used. However, in practice it is more desirable to derive TPMs from observed data. A standard approach for deriving TPMs from observed data is described in Appendix A – Default Carriageway Deterioration Models.

**Table 7.1: Asset Inventory and Condition**

| Hierarchy | Inventory | | Current Condition (% in Condition Band) | | | | |
|---|---|---|---|---|---|---|---|
| | Length (m) | Width (m) | VG | G | F | P | VP |
| **Strategic and Main** | 43,264 | 7.8 | 29.56% | 44.34% | 20.40% | 3.42% | 2.28% |
| **Secondary Distributor** | 15,315 | 6.3 | 26.04% | 39.06% | 25.6% | 5.58% | 3.72% |
| **Link Roads** | 8,930 | 5.5 | 24.76% | 37.14% | 31.30% | 4.08% | 2.72% |
| **Local Access Roads** | 34,800 | 4.4 | 17.20% | 25.80% | 30.00% | 16.20% | 10.80% |

7.6 Notes to Table 7.1:

- VG = Very Good
- G = Good

- F = Fair
- P = Poor
- VP = Very Poor

### Treatment Types, Effects and Unit Costs

7.7 In this example, the following six generic Treatment Types are used:

- Surface Dressing.
- Micro Asphalt.
- Moderate Overlay.
- Moderate Inlay.
- Deep Inlay.
- Reconstruction.

7.8 For a particular Homogeneous Asset Group, these generic Treatments may be defined as illustrated in Table 7.2 from expert knowledge or recent maintenance history data. The percentages in the table indicate the percentage of the pavement layer that will be replaced or renewed, and the layer thicknesses shown are indicative. For example, the Surface Dressing treatment includes 15% patching of the binder course using a suitable material.

**Table 7.2: Typical Generic Treatment Types**

| Pavement Layer | Surface Dressing | Micro Asphalt | Moderate Inlay | Moderate Overlay | Deep Inlay | Reconstruction |
|---|---|---|---|---|---|---|
| **Wearing Course** | 100% Surface Dressing | 100% Micro Asphalt | 100% (40mm) | 100% (40mm) | 100% (40mm) | 100% (40mm) |
| **Binder Course** | 15% | 40% (60mm) | 100% (60mm) | 100% (60mm) | 100% (60mm) | 100% (60mm) |
| **Base Course** | - | 15% (110mm) | 15% (110mm) | 15% (110mm) | 30% (110mm) | 100% (110mm) |

7.9 The effects of the change in Condition Band (e.g. from Very Poor to Very Good) as a result of the Treatments in Table 7.2 are illustrated in Table 7.3. In practice, the change in Condition Band may be determined from maintenance records. Unit costs of Treatments used in this example are also shown in Table 7.3. These unit costs are for demonstration purposes only and should not be used in any analysis.

**Table 7.3: Treatment Type, Unit Costs and Effects**

| Treatment Details | Unit Costs (£/m$^2$) | Condition Band Treated | | | | |
|---|---|---|---|---|---|---|
| | | VG | G | F | P | VP |
| | | Effects after Treatment | | | | |
| **Surface Dressing** | 5.58 | VG | VG | G | F | P |
| **Micro Asphalt** | 8.65 | VG | VG | G | F | P |
| **Moderate Overlay** | 13.70 | None | VG | VG | G | F |
| **Moderate Inlay** | 14.87 | None | VG | VG | G | F |
| **Deep Inlay** | 20.00 | None | VG | VG | VG | G |
| **Reconstruction** | 29.39 | None | VG | VG | VG | VG |

7.10 Notes:

- VG = Very Good
- G = Good
- F = Fair
- P = Poor
- VP = Very Poor
- None = Not Applicable

## Analysis Scenarios

7.11 Maintenance scenarios investigated in this example are summarised in Table 7.4.

**Table 7.4: Analysis Scenarios**

| Scenario Name | Description |
|---|---|
| **Scenario 1: Do Nothing** | This Analysis Scenario is aimed at investigating the impact of not carrying out maintenance interventions on the road network. |
| **Scenario 2: Steady State** | This Analysis Scenario is aimed at determining the required funding level necessary to keep the road network at approximately the current condition state over the Analysis Period. |
| **Scenario 3: Budget Constraint** | This Analysis Scenario is intended to investigate the impact of a reduction in the steady state annual budget determined from Scenario 2 by 25% throughout the analysis period. |
| **Scenario 4: Performance Target** | This Analysis Scenario is aimed at investigating the impact of reducing the annual budget for each treatment from steady state (Scenario 2) by 25% for the first 10 years of analysis and investments required thereafter (Years 11 to 30) to return the predicted condition profile to steady state. |

## APPROACH

7.12 To run this example in the Toolkit, the steps set out in Table 7.5 should be followed. The **'Reference'** column refers to sections in this guidance document in which the steps were first described, whereas the table and figure numbers referred to in the **'Description'** column relate specifically to the worked example.

**Table 7.5: Steps for Implementing the Worked Example**

<table>
<tr><th>Steps</th><th>Description</th><th>Reference</th></tr>
<tr><td>STEP 1<br>Model Setup</td><td>Setup the Toolkit by specifying the following in the 'Input Sheet' worksheet:<table>
<tr><td>- Analysis Start Year:</td><td>((2012)</td></tr>
<tr><td>- Analysis Period:</td><td>(30)</td></tr>
<tr><td>- Number of Condition Bands:</td><td>(5)</td></tr>
<tr><td>- Short code for Condition Band:</td><td>(VG, G, F, P, VP)</td></tr>
<tr><td>- Number of Homogeneous Asset Groups:</td><td>(4)</td></tr>
<tr><td>- Name of Homogeneous Asset Group:</td><td>(Strategic & Main, Secondary, Link, Local)</td></tr>
<tr><td>- Number of Treatments:</td><td>(6)</td></tr>
<tr><td>- Treatment Name:</td><td>(Surface Dressing,<br>Micro Asphalt,<br>Moderate Overlay,<br>Moderate Inlay,<br>Thick Overlay,<br>Reconstruction)</td></tr>
</table></td><td>Section 4</td></tr>
<tr><td>STEP 2<br>Inventory and Condition Data</td><td>Specify inventory and condition data in the 'Homogenous Asset Groups' worksheet.</td><td>Section 4</td></tr>
<tr><td>STEP 3<br>Transition Matrices</td><td>Specify Transition Matrices in the 'Transition Matrices' worksheet.</td><td>Section 4<br>(Figures Figure A1, Figure A3, Figure A5 and Figure A7 in Appendix A – Default Carriageway Deterioration Models</td></tr>
<tr><td>STEP 4<br>Treatment Effects and Unit Costs</td><td>Specify Treatment Effects and unit costs given in Table 7.3 in the '3 - Treatment Effects & Costs' worksheet for all Asset Groups.</td><td>Section 4</td></tr>
<tr><td>STEP 5<br>Treatment Strategies</td><td>In the 'Treatment Strategies' worksheet, specify or modify the Treatment Strategy based on Analysis Scenarios (Table 7.4).<br><br>Treatment Strategies used in this example are given in Figure B1 in</td><td>Section 4</td></tr>
</table>

| Steps | Description | Reference |
|---|---|---|
| | Appendix B – illustrations for the carriageway toolkit. | |
| **STEP 6 Scenario 1: Do Nothing** | In the **'Scenario'** worksheet:<br>- Select the Transition Matrix for each Homogeneous Asset Group for each year.<br>- Select the Treatment Strategy **'Do Nothing'** for each year.<br>- The inputs for Budget Constraints and Performance Targets should be left blank to simulate a **'Do Nothing'** strategy.<br>Completed scenarios worksheets for this example are illustrated in Figure B2 in Appendix B – illustrations for the carriageway toolkit.<br>Run analysis to derive outputs for the 'Do Nothing' Analysis Scenario. Export the outputs and/or save a new version of the model. The results are discussed below. | Section 5 |
| **STEP 7 Scenario 2: Steady State** | In the **'Scenario'** worksheet, use the dropdown menu in the **'Treatment Strategy'** row to replace **'Do Nothing'** with the appropriate Treatment Strategy to each Homogeneous Asset Group, for every year of analysis.<br><br>Run the Toolkit and view the results to check if the Steady State condition is achieved. If not, then return to Step 5. This is an iterative process that should be repeated until the desired output (Steady State condition) is achieved for each homogeneous group. Export the outputs and/or save a new version of the model. | Section 5 |
| **STEP 8 Budget** | In the **'Budgets'** worksheet, specify the budget for Scenario 3 as illustrated in Figure B3 in Appendix B – illustrations for the carriageway toolkit.<br><br>The budget values are determined by taking the annual average estimated expenditure for each Treatment Type and Homogeneous Asset Group under Scenario 2 (Steady State) and then reducing those values by 25% to give the budget for Scenario 3. | Section 4 |
| **STEP 9 Scenario 3: Budget Constraint** | In the '**Scenario**' worksheet, assign the Budget specified in Step 8 to the **'Budget Constraint'** row for each Homogeneous Asset Group and year as illustrated in Figure B4 in Appendix B – illustrations for the carriageway toolkit.<br><br>Run the Toolkit and analyse outputs. Export the outputs and/or save a new version of the model. | Section 5 |
| **STEP 10 Performance Target** | In the **'Performance Targets'** worksheet specify the Performance Target to return the condition profile to steady state (Scenario 2) level as illustrated Figure B5 in Appendix B – illustrations for the carriageway toolkit. | Section 4 |
| **STEP 11 Scenario 4: Performance Target** | In the **'Scenario'** worksheet, delete annual Budget assignments from the **'Budget Constraint'** row for years 11 to 30.<br><br>Assign the Performance Target defined in Step 10 in years 11 to 30 as illustrated in Figure B6 in Appendix B – illustrations for the carriageway toolkit.<br><br>Run the Toolkit and analyse the outputs. Export the outputs and/or save a new version of the model. | Section 5 |

# OUTPUTS

7.13 The following paragraphs summarise the outputs of the analysis under the following headings:

- Predicted condition profile.
- Predicted expenditure.

## Predicted Condition Profile

7.14 Predicted condition profile following each run of the Toolkit are reported in worksheets **'8 - Condition by Year'** and **'9 - Condition Graph'**. The Tabulated predicted condition profile can be exported to Microsoft Word, Excel or similar programmes using the export button located on the top right of the output worksheet. The exported data can then be used to produce bespoke graphs and reports.

7.15 In this example, the predicted condition profile data were exported to another Excel spreadsheet and predicted condition profile for the whole network that was modelled was the produced by averaging the predicted condition profile for each Homogeneous Asset Group.

## Scenario 1 – Do Nothing

7.16 Figure 7.1 shows the predicted road network condition profile under Scenario 1 (Do Nothing). The proportions of assets in the Very Poor (VP) condition band increases with time. This illustrates the impact of not carrying out any treatment interventions on the road network that was modelled.

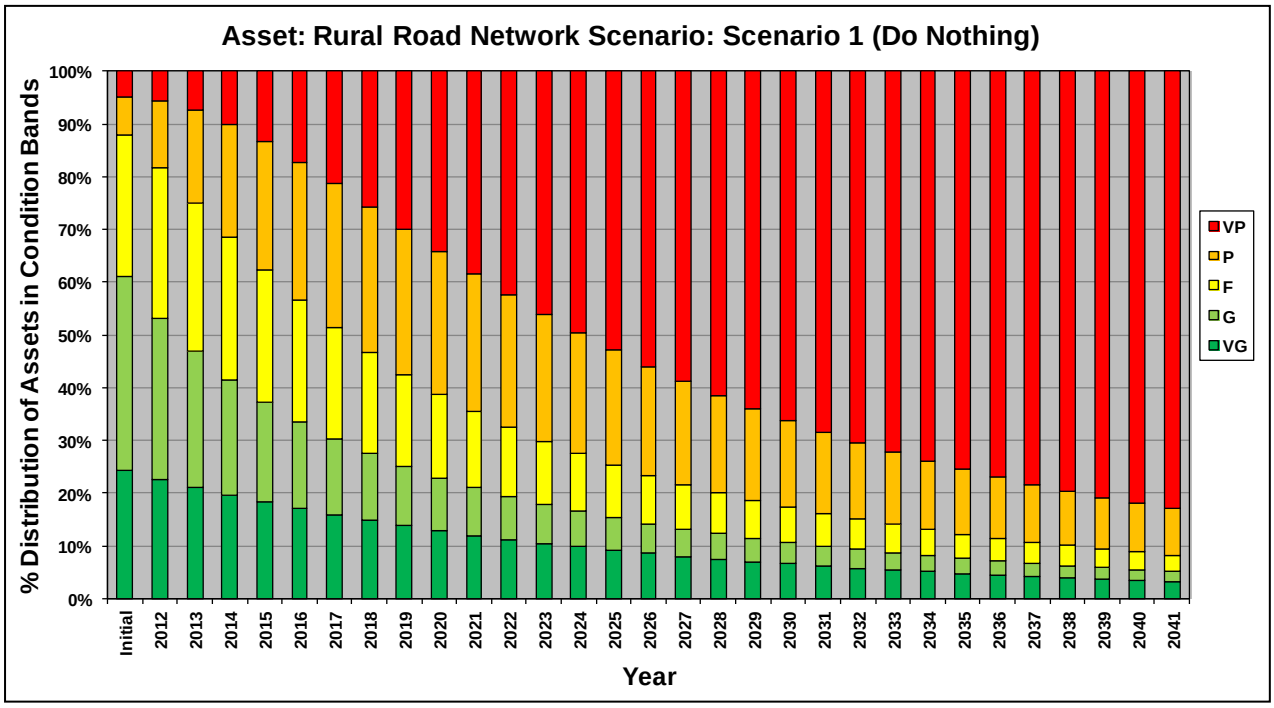



**Figure 7.1: Scenario 1 (Do Nothing) Predicted Condition Profile**

## Scenario 2 – Steady State

7.17 The average predicted condition profile for the whole carriageway network under Scenario 2 (Steady State) is illustrated in Figure 7.2.

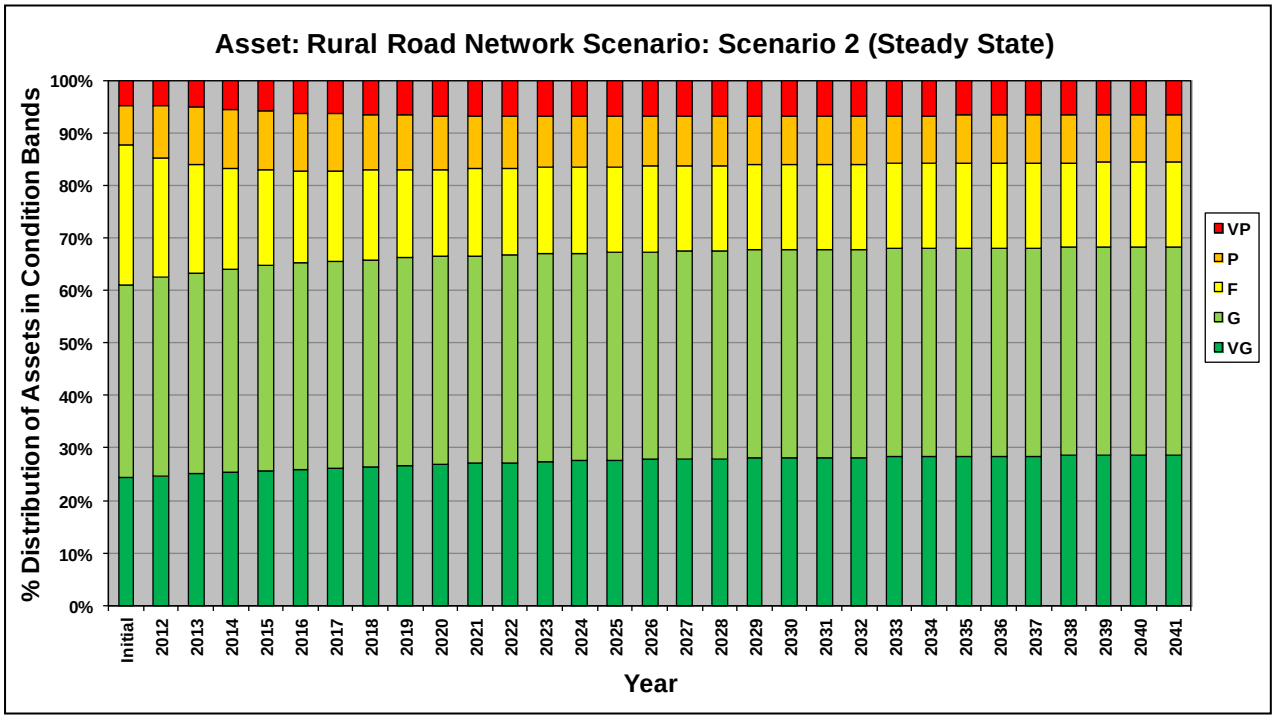



**Figure 7.2: Scenario 2 (Steady State) Predicted Condition Profile**

## Scenario 3 – Budget Constraint

7.18 The average predicted condition profile for the whole carriageway network under Scenario 3 (Budget Constraint) is illustrated in Figure 7.3.

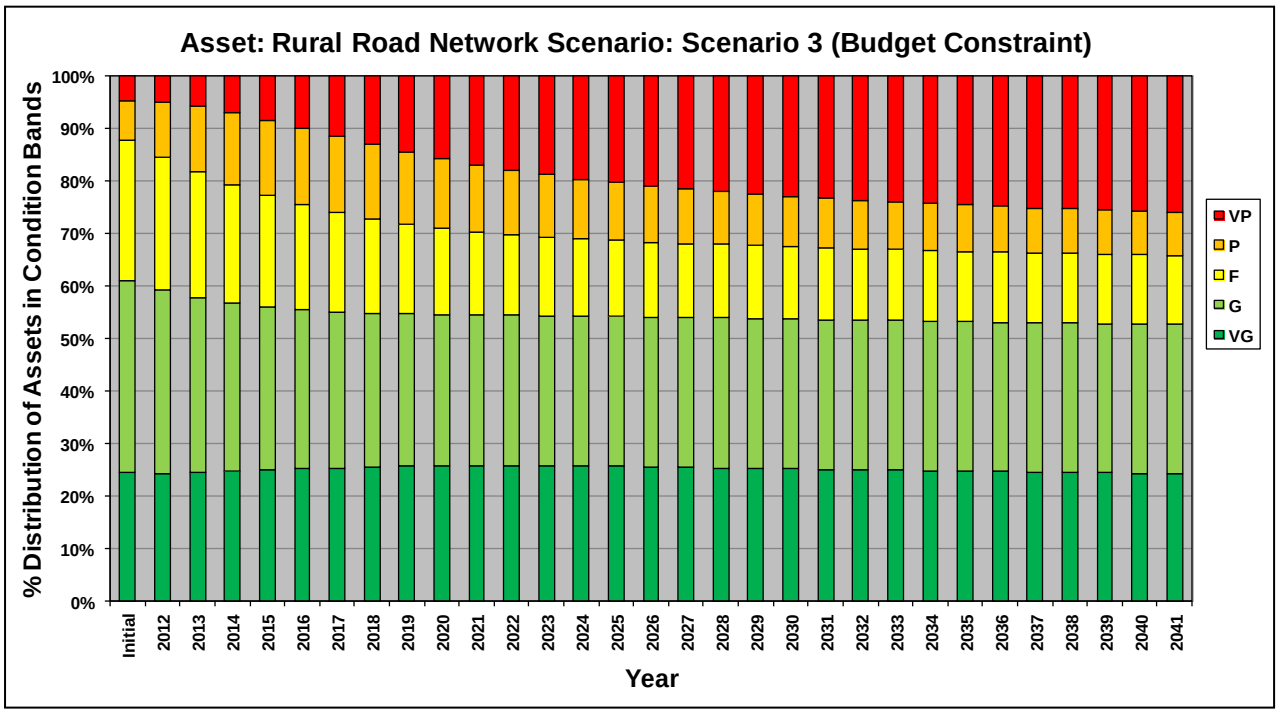



**Figure 7.3: Scenario 3 (Budget Constraint) Predicted Condition Profile**

## Scenario 4 – Performance Target

7.19 The average predicted condition profile for the whole carriageway network under Scenario 4 (Performance Target) is illustrated in Figure 7.4.

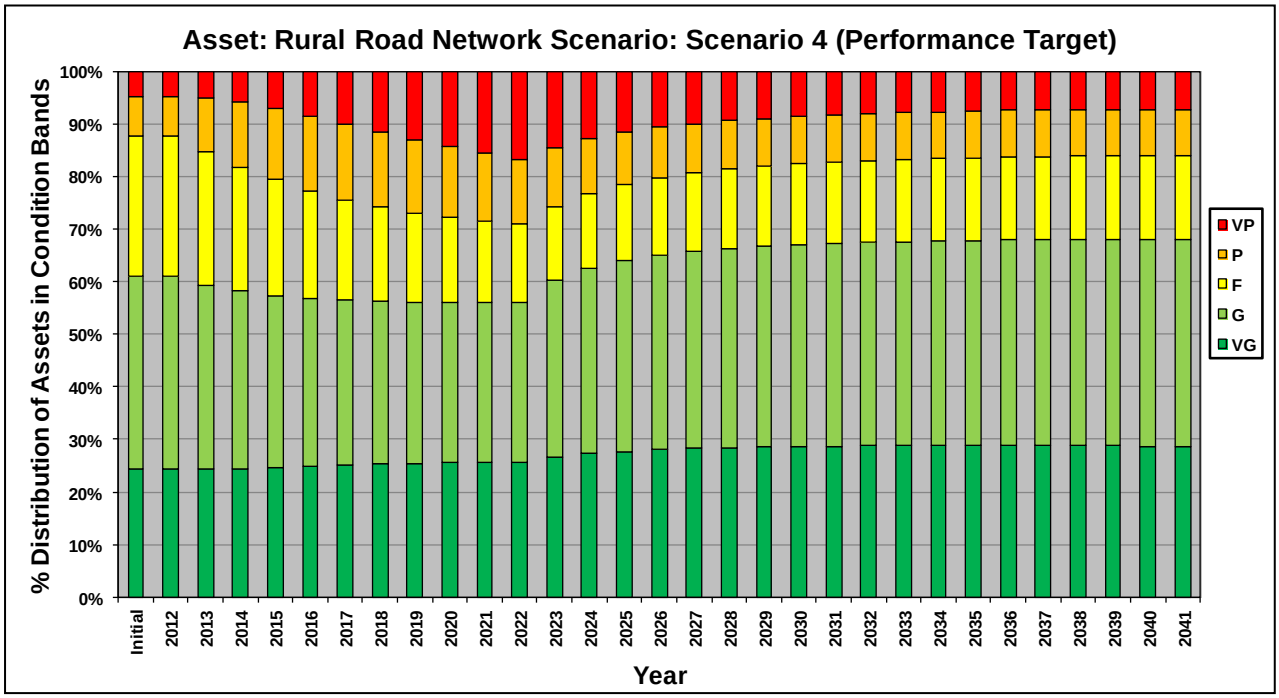



**Figure 7.4: Scenario 4 (Performance Target) Predicted Condition Profile**

## Predicted Expenditure

7.20 Predicted annual expenditure profile for the whole carriageway network by Treatment Type for each Analysis Scenario can be found in the **'15 – Exp by Treat Graph'** worksheet. For each Analysis Scenario, the graph obtained is as follows:

## Scenario 2 – Steady State

7.21 The predicted annual expenditure profile for the whole carriageway network by Treatment Type for Scenario 2 (Steady State) is illustrated in Figure 7.5 below.

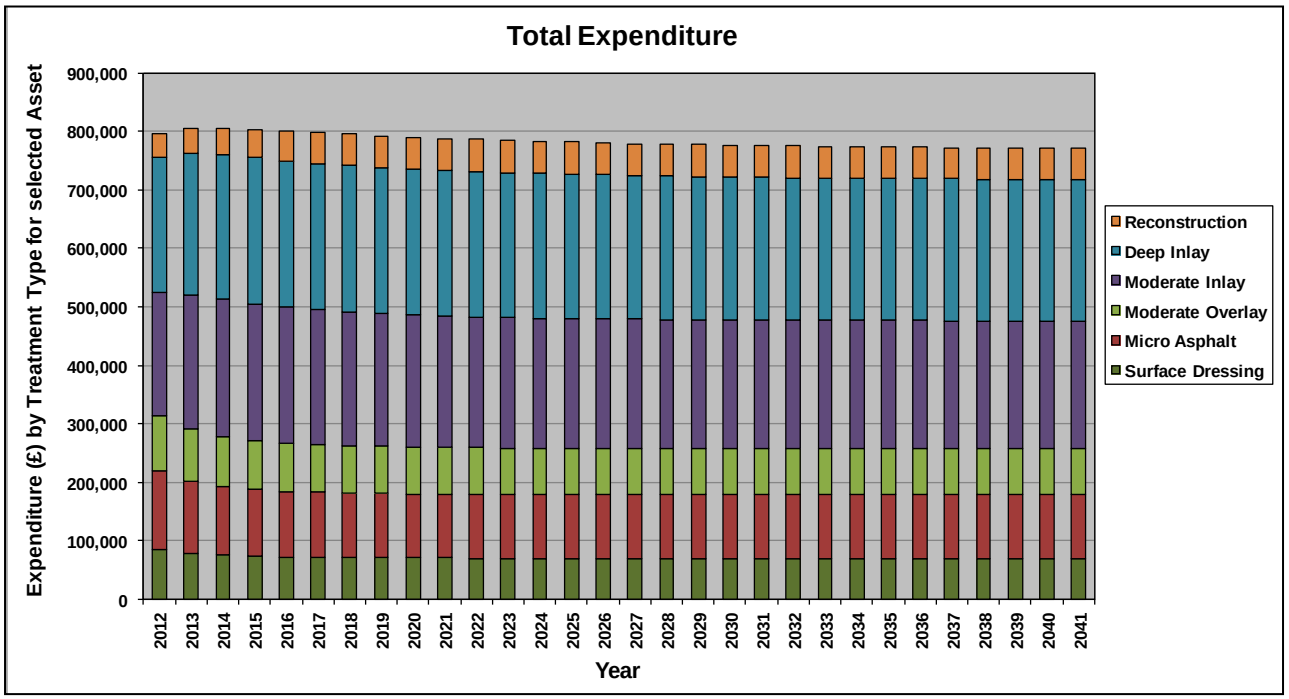



**Figure 7.5: Scenario 2 (Steady State) Predicted Expenditure Profile by Treatment Type**

7.22 Table 7.6 below summarises the estimated average annual expenditure by Treatment Type. This was produced outside of the Toolkit using the export functions.

**Table 7.6: Average Annual Budget for Scenario 2 (Steady State) in £**

| Treatment | Strategic & Main | Secondary | Link | Local | Overall |
|---|---|---|---|---|---|
| **Surface Dressing** | 46,634 | 15,112 | 3,051 | 6,544 | 71,341 |
| **Micro Asphalt** | 72,291 | 23,427 | 4,729 | 10,145 | 110,592 |
| **Moderate Overlay** | 57,247 | 12,368 | 2,996 | 8,034 | 80,645 |
| **Moderate Inlay** | 176,917 | 13,757 | 21,502 | 10,725 | 222,901 |
| **Deep Inlay** | 171,530 | 24,501 | 13,880 | 35,186 | 245,097 |
| **Reconstruction** | 14,601 | 11,204 | 14,659 | 12,204 | 52,668 |
| **All Treatments** | 539,219 | 100,369 | 60,818 | 82,837 | 783,244 |

## Scenario 3 – Budget Constraint

7.23 Predicted annual expenditure profile for the whole carriageway network by Treatment Type under Scenario 3 (Budget Constraint) is shown in Figure 7.6 below.

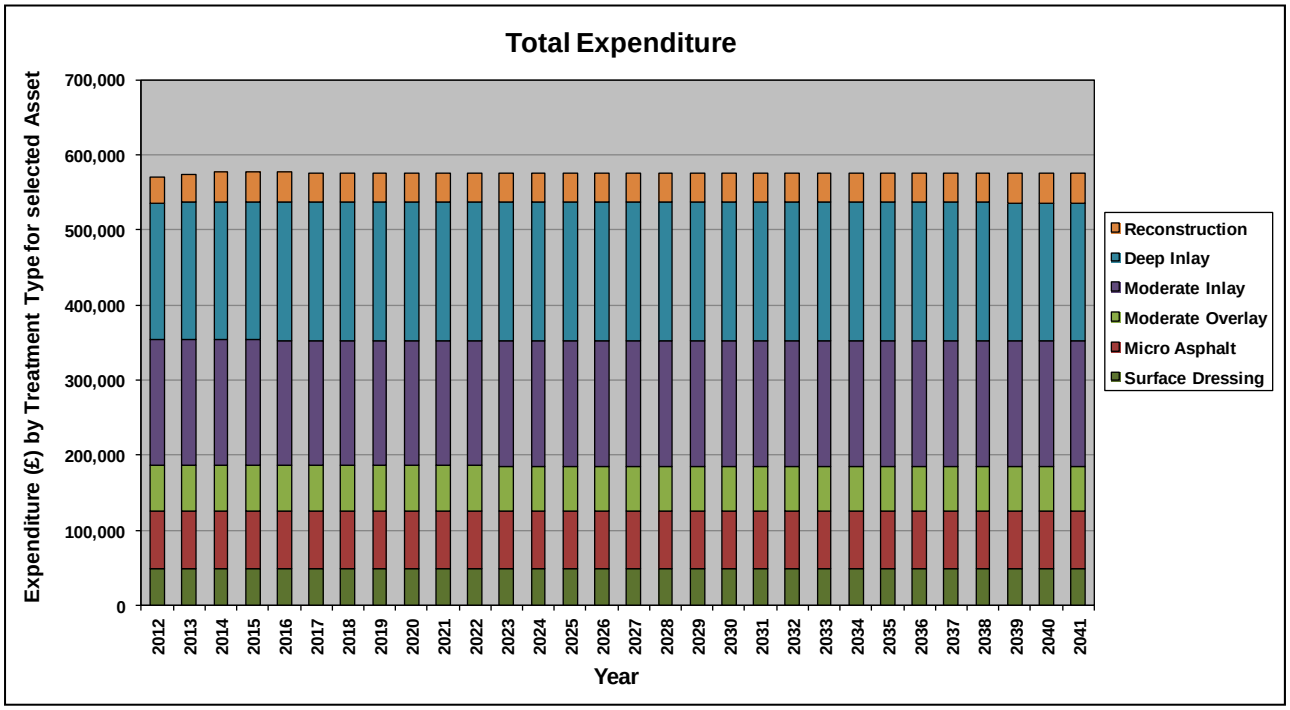



**Figure 7.6: Scenario 3 (Budget Constraint) Predicted Expenditure Profile by Treatment Type**

## Scenario 4 – Performance Target

7.24 Predicted annual expenditure profile for the whole carriageway network by Treatment Type under Scenario 4 (Performance Target) is shown in Figure 7.7.

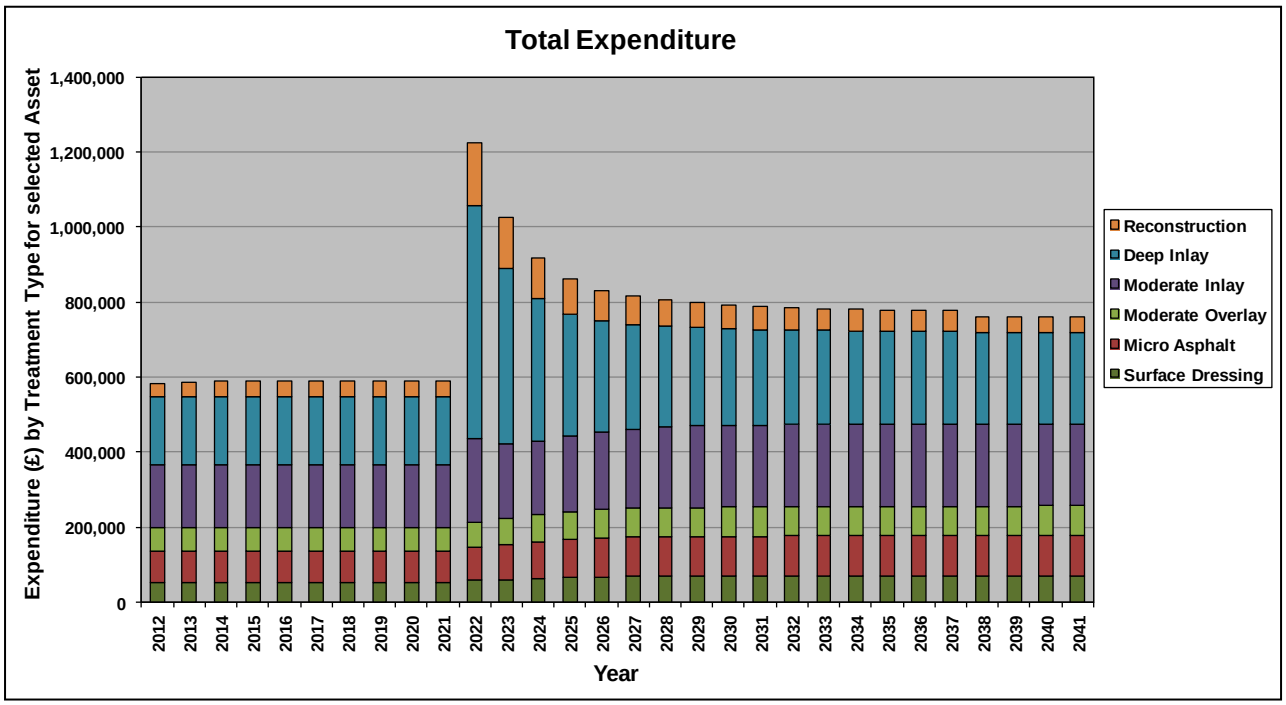



**Figure 7.7: Scenario 4 (Performance Target) Predicted Expenditure Profile by Treatment Type**

## Comparison by Scenario

7.25 A comparison of the predicted proportions of the carriageway network in Very Poor and Poor conditions for the four Analysis Scenarios is illustrated in Figure 7.8. This output was manually prepared by exporting the **'12 – Exp by Condition Band'** worksheet for each Analysis Scenario into a spreadsheet and then using the spreadsheet to generate the analysis scenario graph.

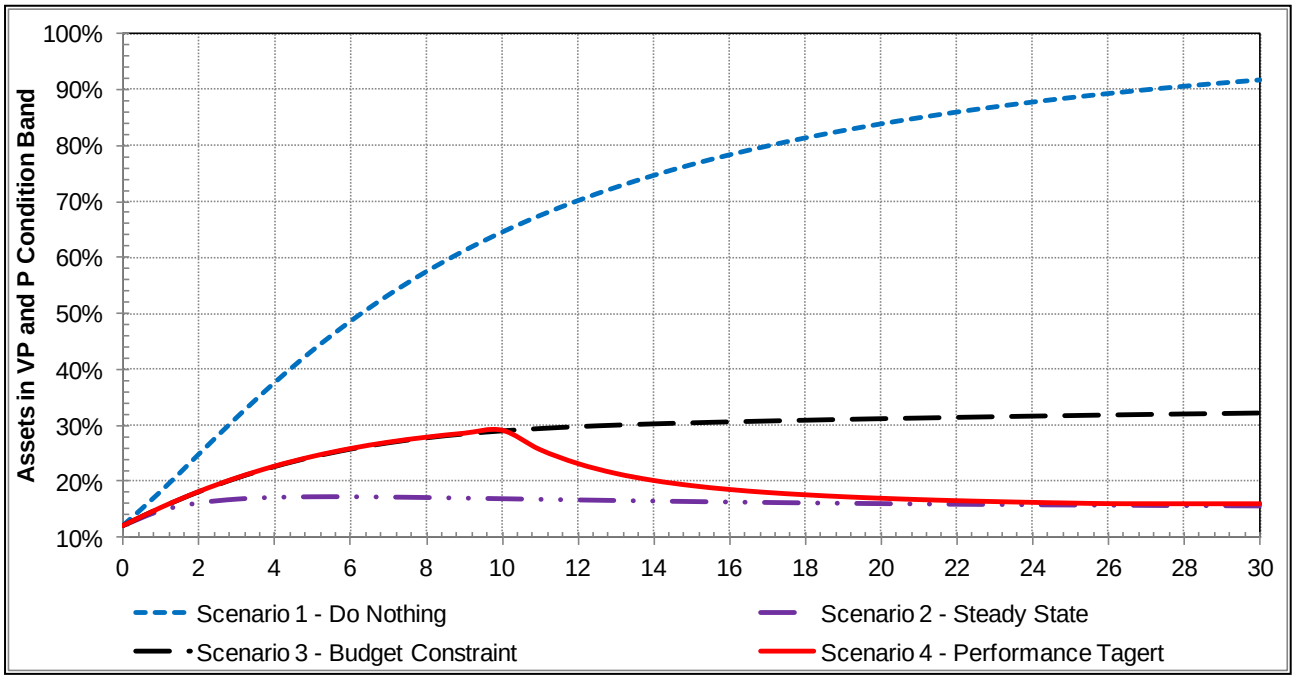



**Figure 7.8: Asset Proportions in Very Poor and Poor Condition by Analysis Scenario**

7.26 From Figure 7.8, it can be seen that:

- **In Scenario 1 – Do Nothing** the percentage of assets in poor and very poor condition increases rapidly during the ten years, then at a slower rate thereafter until the end of the 30-year period modelled, by which point approximately 92% of assets are in poor condition.
- **In Scenario 2 – Steady State** the percentage of assets in poor and very poor condition remains at approximately 13% as the overall condition of assets on the network is maintained at the same level, indicating that the budget is sufficient to maintain assets in their current condition.
- **In Scenario 3 – Budget Constraint** the percentage of assets in poor and very poor condition increases slowly during the first twenty years when approximately 32% of assets have deteriorated to either a poor or very poor condition. After this, the percentage of assets in poor or very poor condition remains consistent until the end of the thirty-year period modelled, indicating that the budget allocated is sufficient to prevent the remaining assets that have not entered a poor or very poor condition from doing so.
- **In Scenario 4 – Performance Target** the percentage of assets in poor or very poor condition increases at the same rate as in scenario 3 during the first ten years, at which point the performance target strategy is adopted which reduces the number of assets in poor or very poor condition back down to the same level as there were initially, at around 13%. This indicates that the budget allocated from Year 10 onwards is sufficient to firstly, reduce the number of assets in poor or very poor condition to initial levels and that secondly, the budget is sufficient to maintain assets in the same condition until the end of the analysis period.

7.27 Predicted expenditure profile for the whole network by Analysis Scenario is illustrated in Figure 7.9 and can be compared with Figure 7.8. This output was manually prepared by exporting the **'14 – Exp by Treatment'** worksheet for each Analysis Scenario.

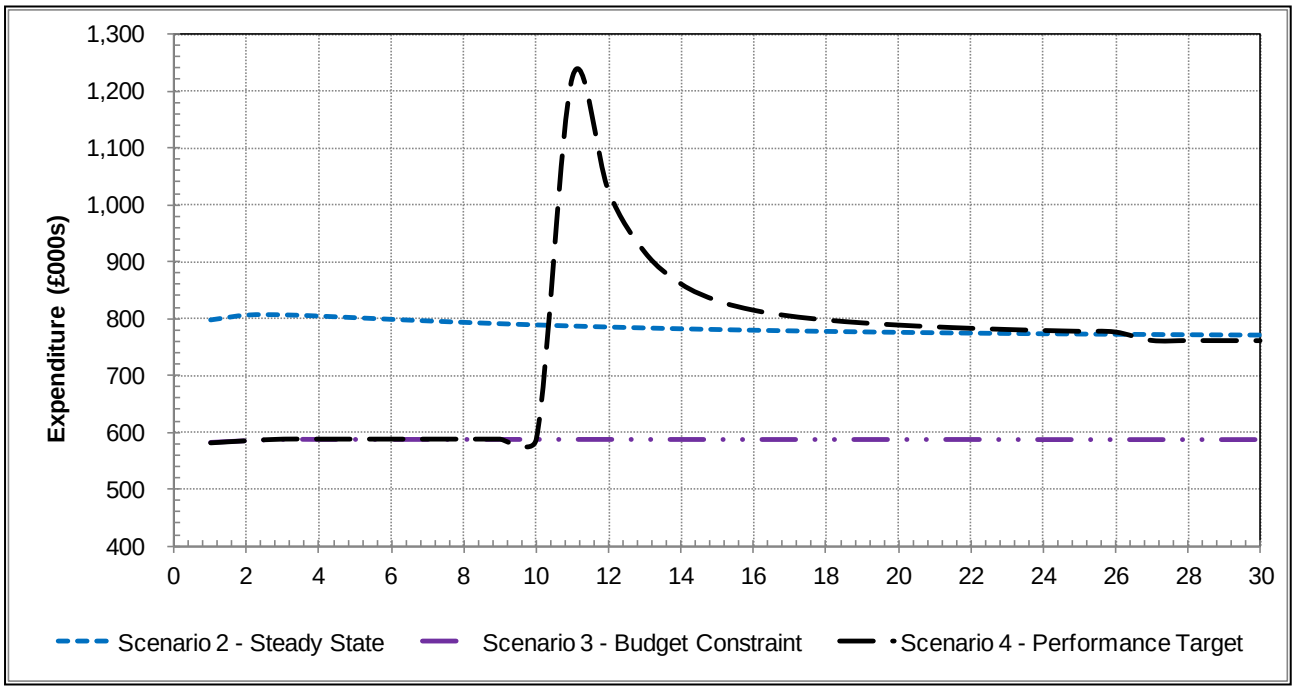



**Figure 7.9: Summary of Expenditure Profile by Analysis Scenario**

7.28 From Figure 7.9 it can be seen that:

- **In Scenario 1 – Do Nothing** there is no profile on the graph as there is no spending.
- **In Scenario 2 – Steady State** the expenditure remains consistent in order to maintain the assets in the same condition across the network.
- **In Scenario 3 – Budget Constraint** the expenditure remains at 20% less than for the Steady State Condition.
- **In Scenario 4 – Performance Target** the expenditure profile matches that of Scenario 3 during the first ten years, after which point the performance target strategy is adopted and the expenditure increases until the assets on the network have been returned to their initial condition. At this point, the expenditure profile stabilises at the level required to maintain those assets in the same condition.

7.29 Note that when the results are reviewed, the user may wish to run the Toolkit again with recorded changes in the input data (e.g. treatment or budgets) to explore the impact on performance and expenditure. These results can be used not only to support asset managers in decision making, but also build the case for funding and report to senior stakeholders in the local highway authority.

# 8 WORKED EXAMPLE FOR THE OTHER ASSETS TOOLKIT

## INTRODUCTION

8.1 This example illustrates the step by step application of the Other Asset Lifecycle Planning Toolkit. In this example, Homogeneous Asset Groups are used for the purposes of illustration only.

8.2 The examples aim to demonstrate the application of the Toolkit in investigating:

- The required levels of funding for user-defined other assets performance using the Performance Target option.
- The effect of constraints on budgets available for other assets replacement on long-term performance trends.

8.3 An Analysis Period of 20 years was used, with the start year of analysis set to 2012.

### Inventory, Condition and estimated Asset Service Life

8.4 The Inventory data used was from a region in Scotland where the performance of 626 traffic signs (Matrix and VMS) was modelled. One Homogeneous Asset Group for all 626 assets was created. No region-specific inventory data was used for the Lighting Columns Homogenous Asset Group, which is provided for the purposes of illustration only.

8.5 The current condition of assets in the Homogeneous Asset Groups was represented as a distribution across five Condition Bands as illustrated in Table 8.1. This provides the base year or starting point for network planning in subsequent years.

8.6 For this example, the Estimated Asset Service Life for the Homogenous Asset Group was used and is provided in Table 8.1. Asset Service Life is defined as the average time (in years) it takes the asset to deteriorate from an as new or very good condition stated to a critical or very poor condition state. The Asset Service Life assumption (based on expert engineering opinion) is used in this example to estimate the TPM for each Homogeneous Asset Group. In practice, it is more desirable to derive TPMs from observed data. Guidance on deriving Deterioration Models from observed data is provided in Appendix A – Default Carriageway Deterioration Models.

**Table 8.1: Asset Inventory, Condition and Service Life**

| Description | Inventory | Current Condition (% in Condition Band) | | | | | Asset Surface Life Assumptions (Years) |
|---|---|---|---|---|---|---|---|
| | Quantity | VG | G | F | P | VP | |
| **Traffic Signs – Matrix and VMS** | 626 | 78% | 14% | 6% | 1% | 1% | 12 |
| **Lighting Columns** | 569 | 69% | 19% | 8% | 3% | 1% | 30 |

8.7 Notes:

- VG = Very Good
- G = Good
- F = Fair

- P = Poor
- VP = Very Poor

## Treatment Types, Effects and Unit Costs

8.8 In this example, the only Treatment Type used is Asset Replacement. The effect of this Treatment is to upgrade all assets (regardless of their condition state) to a very good (VG) condition. This is illustrated in Table 8.2 below. The unit cost for this treatment is given in Table 8.2.

**Table 8.2: Treatment Type, Unit Costs and Effects**

| Treatment Details | Unit Costs (£/unit) | Condition Band Treated | | | | |
|---|---|---|---|---|---|---|
| | | VG | G | F | P | VP |
| | | Effects after Treatment | | | | |
| **Asset Replacement (Matrix and VMS Signs)** | 10,000 | VG | VG | VG | VG | VG |
| **Asset Replacement (Lighting Columns)** | 1,500 | VG | VG | VG | VG | VG |

## Analysis Scenarios

8.9 Maintenance scenarios investigated in this example are summarised in Table 8.3.

**Table 8.3: Analysis Scenarios**

| Scenario Name | Description |
|---|---|
| **Scenario 1: Replace on Fail** | This Analysis Scenario is aimed at investigating the required funding level necessary to replace all assets in Very Poor (VP) condition every year. |
| **Scenario 2: Budget Constraint** | This Analysis Scenario is aimed at investigating the implication of user-defined Budget Constraints on the performance of the other assets over 20 years. |

## APPROACH

8.10 To use the Toolkit for the analysis described in this example, the steps described in Table 8.4 may be followed. The **'Reference'** column refers to sections in this guidance document in which the steps are first described, whereas the table and figure numbers referred to in the **'Description'** column relate specifically to the worked example.

**Table 8.4: Steps for Implementing the Worked Example**

| Steps | Description | Reference |
|---|---|---|
| **STEP 1 Model Setup** | Setup the Toolkit by specifying the following in the **'Input Sheet'** worksheet:<br>- **Analysis Start Year:** **(2012)**<br>- **Analysis Period:** (20)<br>- **Number of Condition Bands:** (5)<br>- **Short code for Condition Band:** (VG, G, F, P, VP)<br>- **Number of Homogeneous Asset Groups:** (2)<br>- **Name of Homogeneous Asset Group:** (Traffic Signs – Matrix and VMS, Lighting Columns)<br>- **Number of Treatments:** (1)<br>- **Treatment Name:** (Asset Replacement) | Section 4 |
| **STEP 2 Inventory and Condition Data** | Specify the inventory and condition data given in Table 8.1 in the **'Homogenous Asset Groups'** worksheet. | Section 4 |
| **STEP 3 Transition Matrices** | Specify Transition Probability Matrices for both Homogenous Asset Groups by opening the **'Transition Matrices'** worksheet, then selecting the first row and naming the matrix to be assigned to the Traffic Signs – Matrix and VMS Homogenous Asset Group (e.g. TS_M&V).<br><br>Click on the **'View / Edit Matrix'** button in the worksheet and enter the appropriate asset life in years (e.g. 12) into the **'Asset Life'** cell for the Traffic Signs – Matrix and VMS Homogenous Asset Group and then click on the **'Derive Matrix from Asset Life'** to generate the appropriate deterioration profiles.<br><br>Click the **'Save & Exit'** button and then repeat this process for the Lighting Columns Homogenous Asset Group, only this time entering an estimated asset life of 30 years. | Section 4 |
| **STEP 4 Treatment Effects and Unit Costs** | Specify Treatments Effects and unit costs given in Table 8.2 in the **'Treatment Effects & Costs'** worksheet for both Asset Groups. | Section 4 |
| **STEP 5 Treatment Strategies** | In the **'Treatment Strategies'** worksheet, specify the Treatment Strategy based on Analysis Scenarios (Table 8.3).<br><br>There is only one Treatment Strategy used in this example - see Figure C1 in Appendix C – Illustrations for the Other Assets Toolkit. | Section 4 |

| Steps | Description | Reference |
|---|---|---|
| **STEP 6 Scenario 1: Replace on Fail** | In the **'Scenario'** worksheet (see Figure C2 in Appendix C – Illustrations for the Other Assets Toolkit):<br>- Select the Transition Matrix for each Homogenous Asset Group for each year from the dropdown menu.<br>- Select **'Replace on Fail'** as the Treatment Strategy for each year from the dropdown menu.<br>- Delete all data from the **'Budget Constraint'** or **'Performance Target'** rows if present.<br><br>Run the analysis to derive outputs for the Replace on Fail scenario. The results are discussed below.<br>Export the outputs and/or save a new version of the model. | Section 5 |
| **STEP 7 Scenario 2: Budget** | In the **'Budgets'** worksheet, specify the annual average expenditure for asset replacement under Scenario 2 (Budget Constraint) as shown in Figure C3 in Appendix C – Illustrations for the Other Assets Toolkit. | Section 4 |
| **STEP 8 Scenario 2: Budget** | In the **'Scenario'** worksheet, assign the Budget Constraint for each year (See Figure C4 in Appendix C – Illustrations for the Other Assets Toolkit).<br><br>Run the analysis to derive outputs for the Budget Constraint scenario. The results are discussed below. Export the outputs and/or save a new version of the model. | Section 5 |

# OUTPUTS – TRAFFIC SIGNS

8.11 The paragraphs that follow summarise the outputs of the analysis under the following headings:

- Predicted condition profile.
- Predicted expenditure.
- Predicted work quantity.

## Predicted Condition Profile

8.12 The predicted condition profile for each Analysis Scenario can be found in the **'9 - Condition Graph'** worksheet of the Toolkit.

## Scenario 1 – Replace on Fail

8.13 The average predicted condition profile for traffic signs under Scenario 1 is shown in Figure 8.1. Since the Treatment Strategy was to replace all Very Poor (VP) assets each year, the %Distribution of Very Poor assets are null every year.

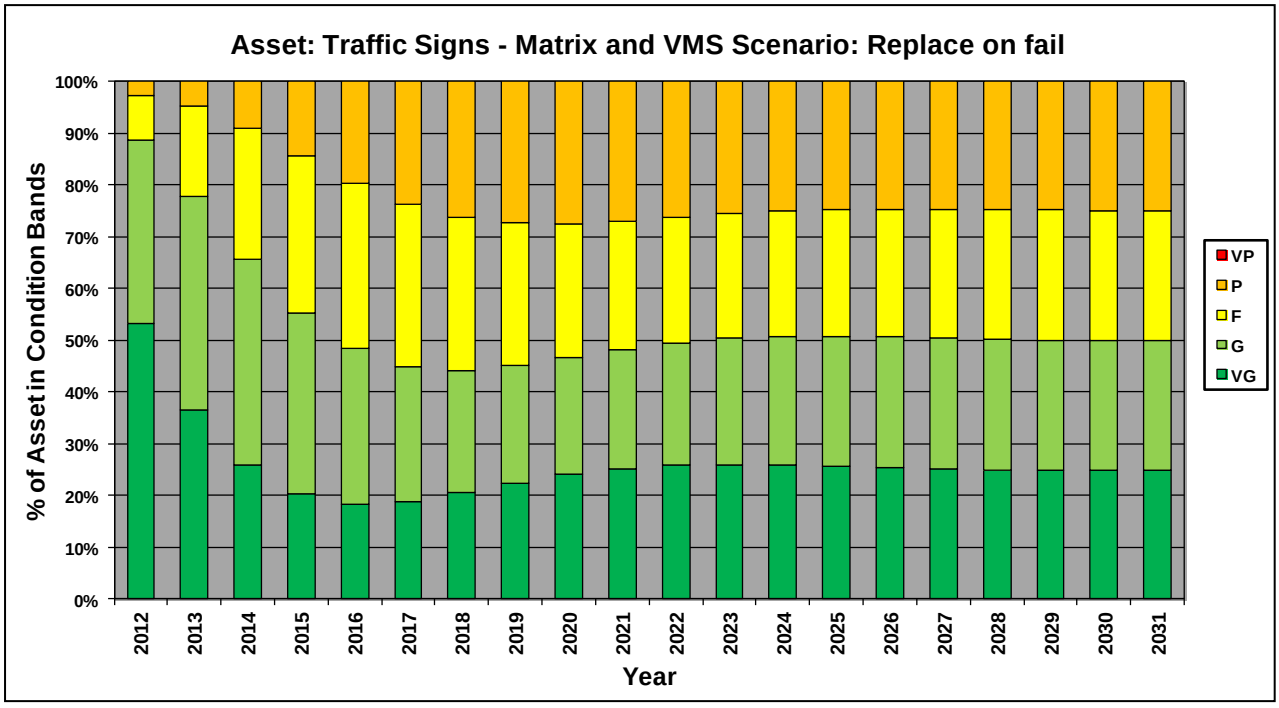



**Figure 8.1: Scenario 1 (Replace on Fail) Predicted Condition Profile**

## Scenario 2 – Budget Constraint

8.14 The average predicted condition profile for traffic signs under Scenario 2 (Budget Constraint) is shown in Figure 8.2.

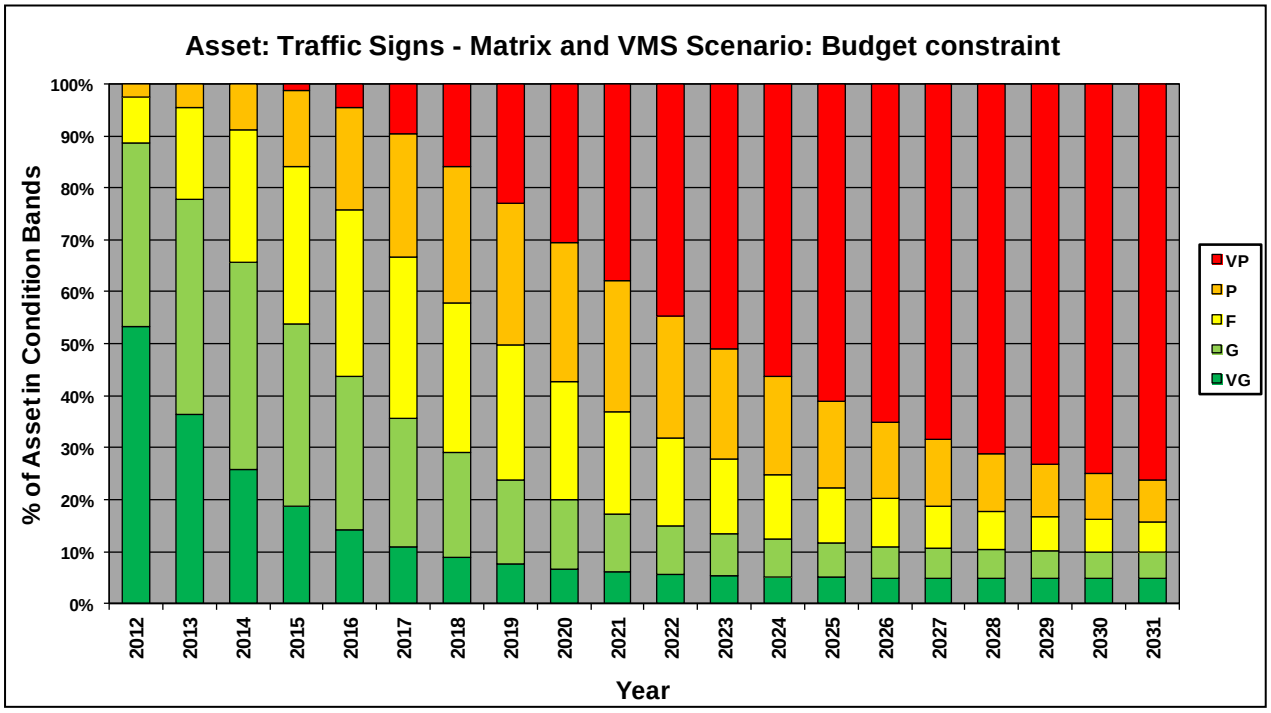



**Figure 8.2: Scenario 2 (Budget Constraint) Predicted Condition Profile**

8.15 From Figure 8.2 it may be observed that:

- The percentage of assets in Very Poor (VP) condition is null in years 2012, 2013 and 2014, which implies that it was possible to eliminate the population of Very Poor assets in these years whilst staying within the Budget Constraints.
- From 2015 onwards, the percentage of assets in Very Poor (VP) condition increases dramatically, which implies that the budget for these years was too low to eliminate the population of Very Poor assets.

## Predicted Expenditure

8.16 Predicted annual expenditure profiles for each Analysis Scenario can be found in the **'15 – Exp by Treatment Graph'** worksheet.

## Scenario 1 – 'Replace on Fail' scenario

8.17 The predicted annual expenditure profile for traffic signs under Scenario 1 (Replace on Fail) is shown in Figure 8.3 below.

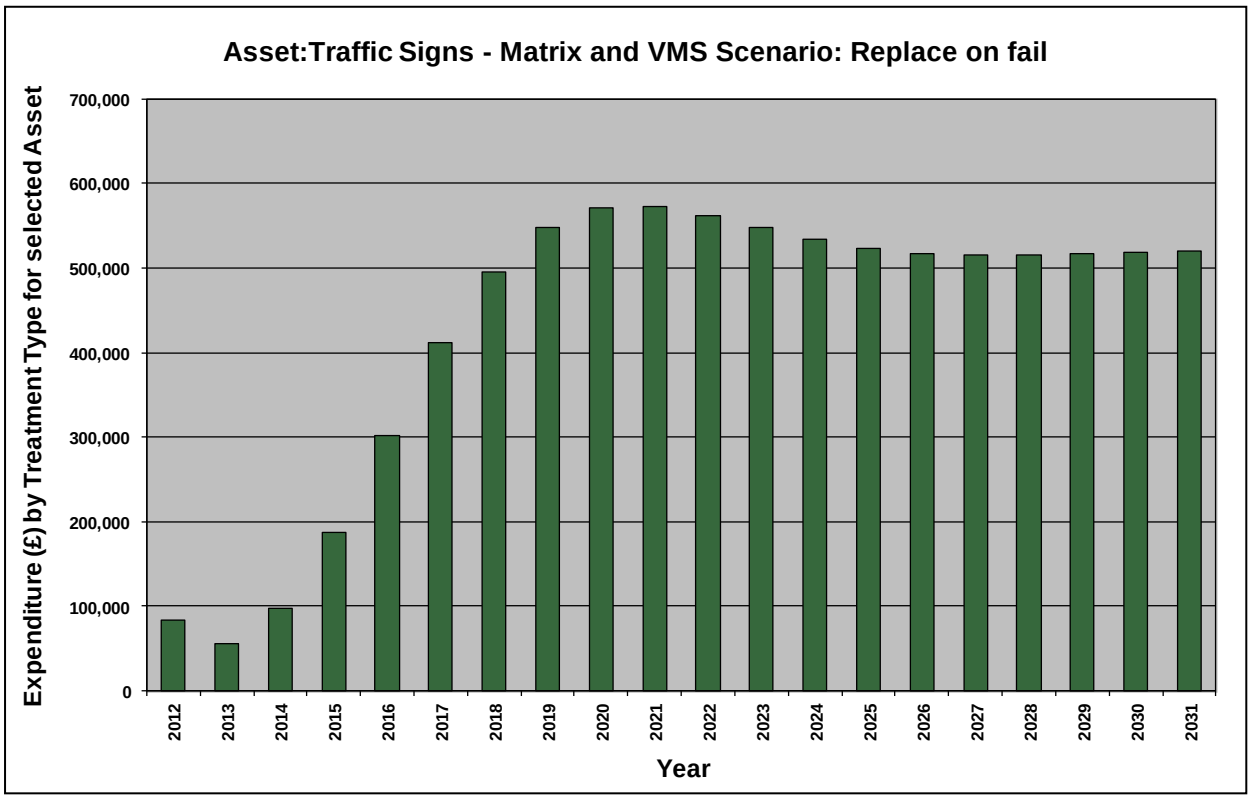



**Figure 8.3: Scenario 1 (Replace on Fail) Predicted Expenditure Profile**

## Scenario 2 – Budget Constraint

8.18 The predicted annual expenditure profile for traffic signs under Scenario 2 (Budget Constraint) is shown in Figure 8.4 below.

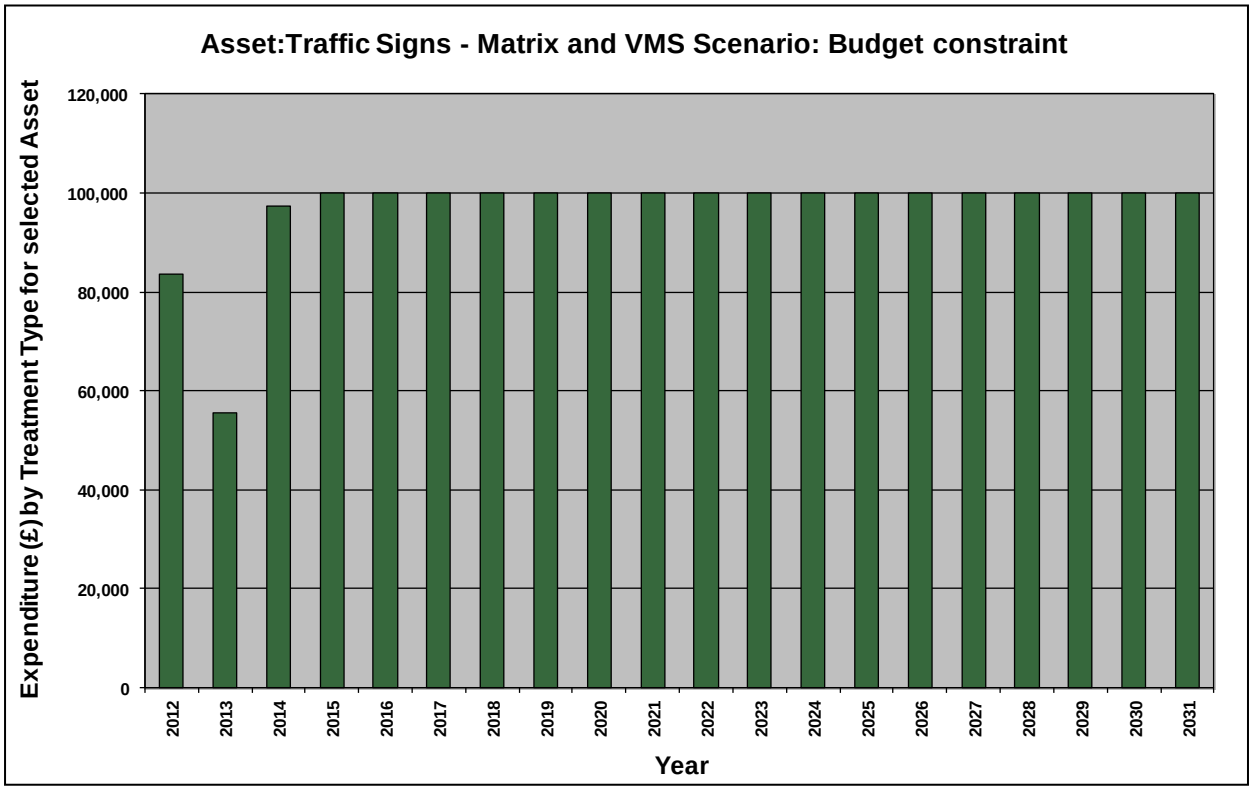



**Figure 8.4: Scenario 2 (Budget Constraint) Predicted Expenditure Profile**

8.19 From Figure 8.4 it may be observed that:

- The population of Very Poor (VP) assets in 2012, 2013 and 2014 could be reduced to zero at a cost below the annual Budget Constraint of £100,000.
- From 2015 onwards, the entire annual budget was spent.

## Work Quantity

8.20 Predicted work quantities profile for traffic signs under each Analysis Scenario can be found in the **'11 – Work Qty Graph'** worksheet.

## Scenario 1 – 'Replace on Fail' scenario

8.21 The predicted work quantities profile for traffic signs under Scenario 1 (Replace on Fail) is shown in Figure 8.5 below.

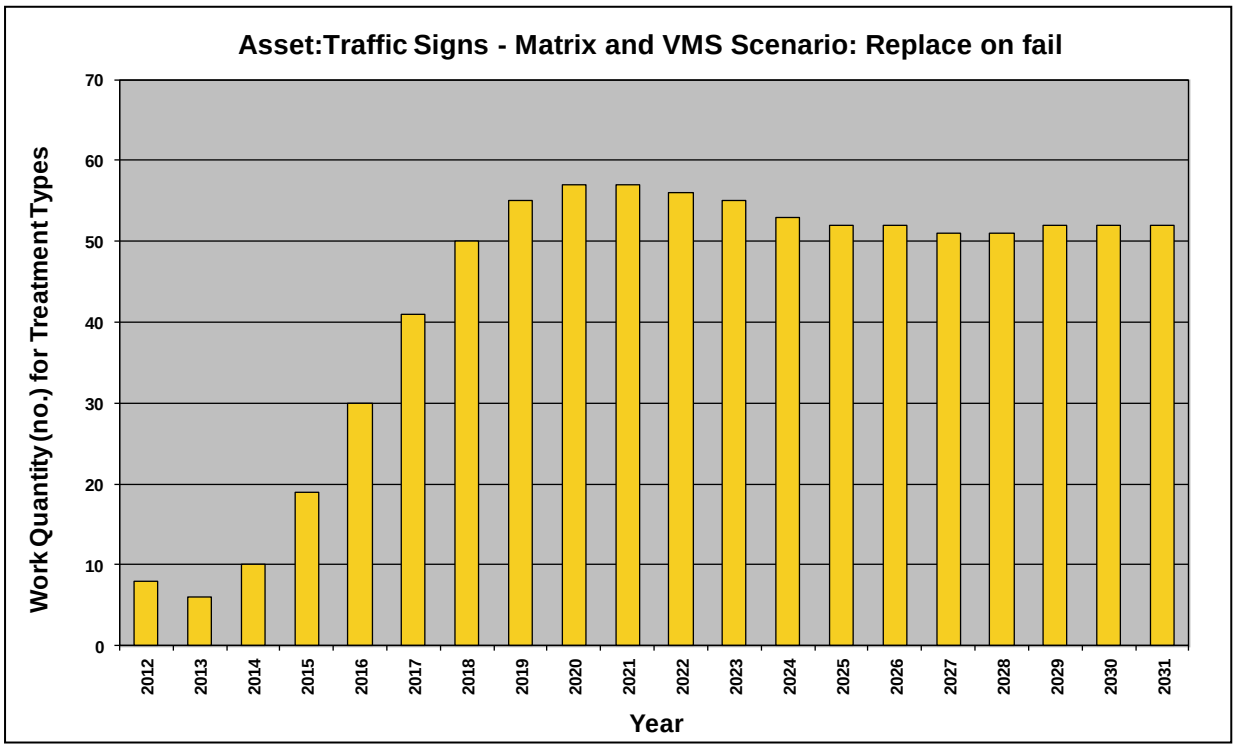



**Figure 8.5: Scenario 1 (Replace on Fail) Predicted Work Quantities**

### Scenario 2 – 'Budget Constraint' scenario

8.22 The predicted work quantities profile for traffic signs under Scenario 2 (Budget Constraint) is shown in Figure 8.6 below.

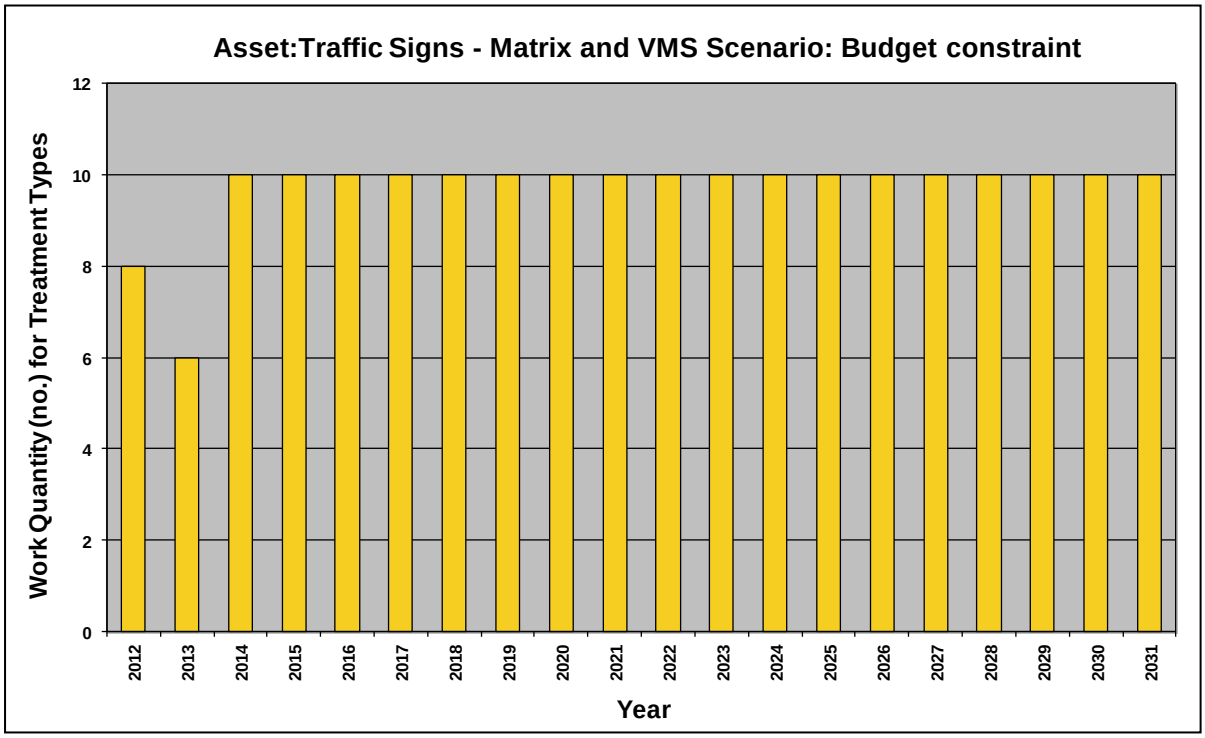



**Figure 8.6: Scenario 2 (Budget Constraint) Predicted Work Quantities**

# OUTPUTS – LIGHTING COLUMNS

## Predicted Condition Profile

### Scenario 1 – Replace on Fail

8.23 The average predicted condition profile for lighting columns under Scenario 1 is shown in Figure 8.7. Since the Treatment Strategy was to replace all Very Poor (VP) assets each year, the %Distribution of Very Poor assets are null every year.

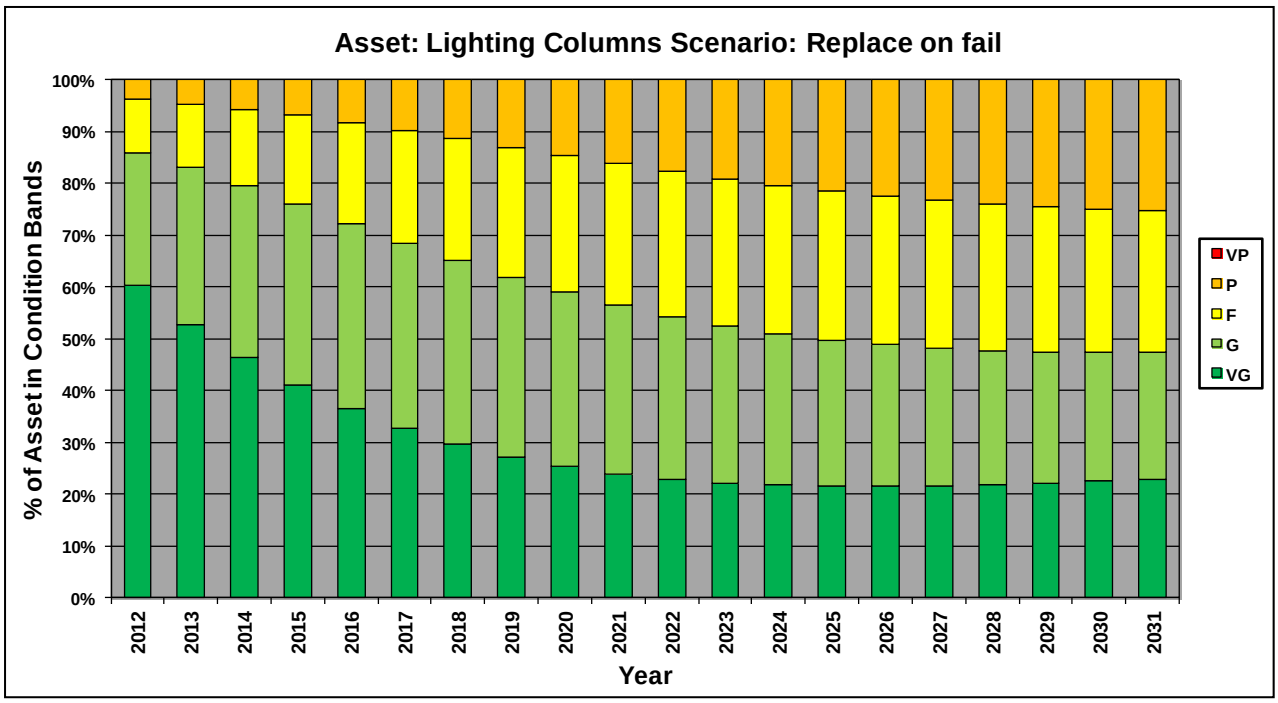



**Figure 8.7: Scenario 1 (Replace on Fail) Predicted Condition Profile**

## Scenario 2 – Budget Constraint

8.24 The average predicted condition profile for lighting columns under Scenario 2 (Budget Constraint) is shown in Figure 8.8.

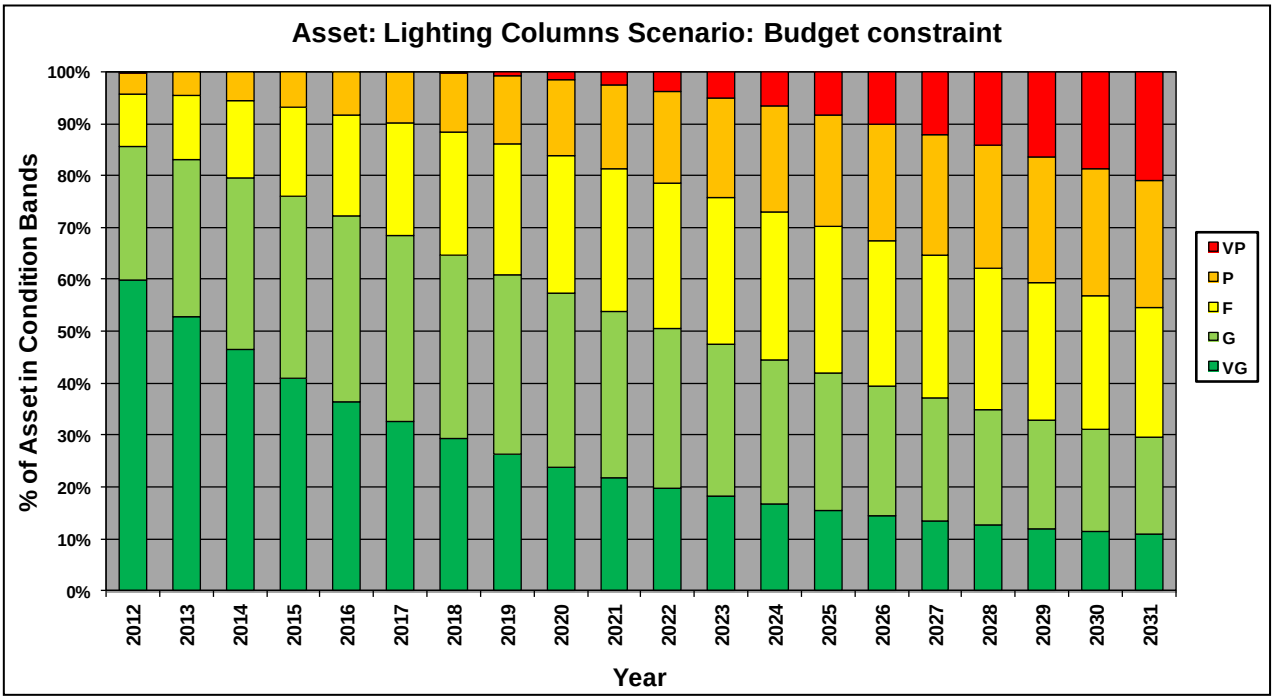



**Figure 8.8: Scenario 2 (Budget Constraint) Predicted Condition Profile**

8.25 From Figure 8.8 it may be observed that:

- The percentage of assets in Very Poor (VP) condition only begins to increase from 2018, which implies that it was possible to eliminate the population of Very Poor assets prior to this whilst staying within the Budget Constraints.
- From 2018 onwards, the percentage of assets in Very Poor (VP) condition increases, which implies that the budget for these years was too low to eliminate the population of Very Poor assets.

### Predicted Expenditure

8.26 Predicted annual expenditure profiles for each Analysis Scenario can be found in the **'15 – Exp by Treatment Graph'** worksheet.

### Scenario 1 – 'Replace on Fail' scenario

8.27 The predicted annual expenditure profile for lighting columns under Scenario 1 (Replace on Fail) is shown in Figure 8.9 below.

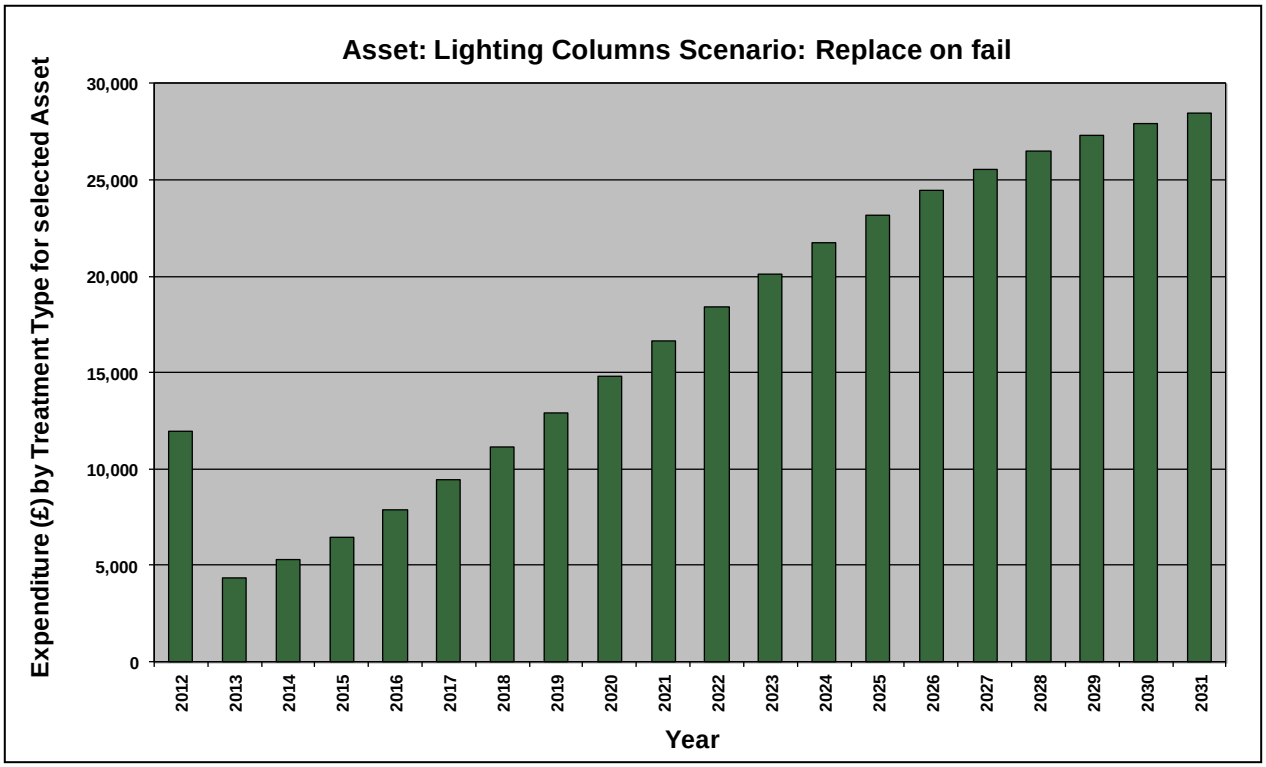



**Figure 8.9: Scenario 1 (Replace on Fail) Predicted Expenditure Profile**

### Scenario 2 – Budget Constraint

8.28 The predicted annual expenditure profile for lighting columns under Scenario 2 (Budget Constraint) is shown in Figure 8.10 below.

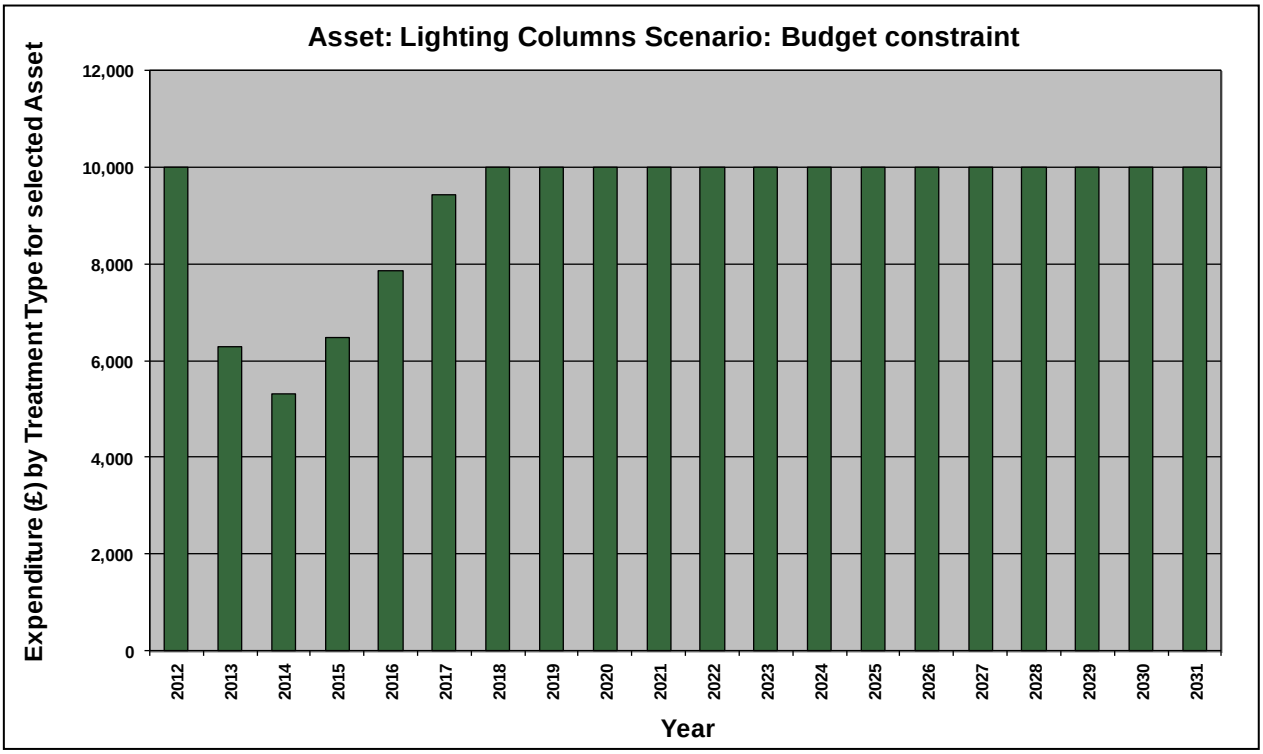



**Figure 8.10: Scenario 2 (Budget Constraint) Predicted Expenditure Profile**

8.29 From Figure 8.10 it may be observed that:

- The population of Very Poor (VP) assets from 2013 to 2017 could be reduced to zero at a cost below the annual Budget Constraint of £10,000.
- From 2018 onwards, the entire annual budget was spent.

### Work Quantity

8.30 Predicted work quantities profile for lighting columns under each Analysis Scenario can be found in the **'11 – Work Qty Graph'** worksheet.

### Scenario 1 – 'Replace on Fail' scenario

8.31 The predicted work quantities profile for lighting columns under Scenario 1 (Replace on Fail) is shown in Figure 8.11 below.

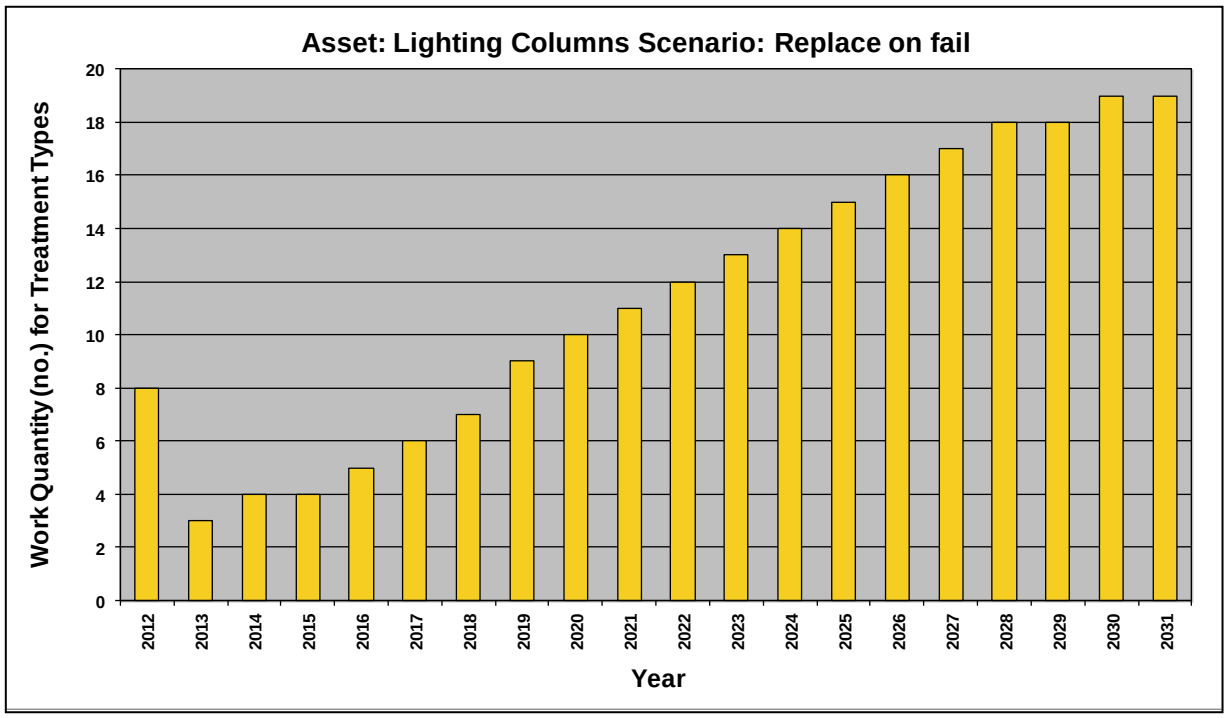



**Figure 8.11: Scenario 1 (Replace on Fail) Predicted Work Quantities**

### Scenario 2 – 'Budget Constraint' scenario

8.32 The predicted work quantities profile for lighting columns under Scenario 2 (Budget Constraint) is shown in Figure 8.12 below.

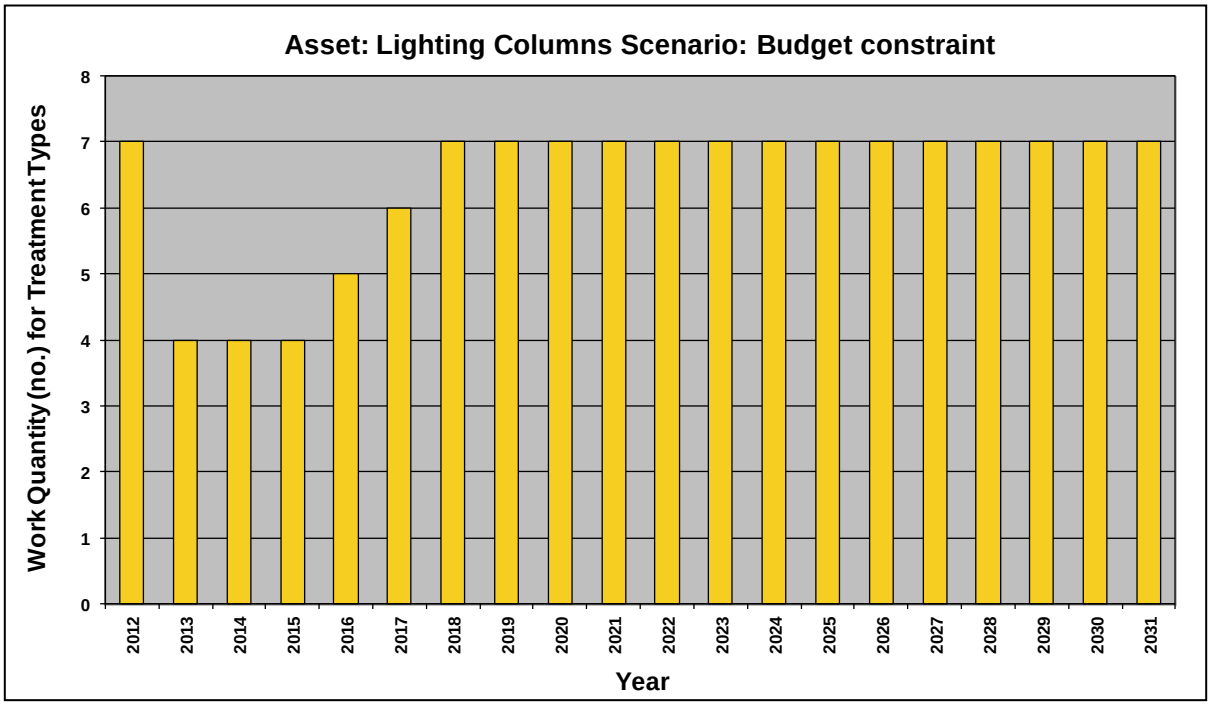



**Figure 8.12: Scenario 2 (Budget Constraint) Predicted Work Quantities**

# 9 WORKED EXAMPLE FOR THE FOOTWAY TOOLKIT

## INTRODUCTION

9.1 This example illustrates the step by step application of the Lifecycle Planning Toolkit using Footway inventory and condition data from a local highway authority in England. The example aims to demonstrate the application of the Toolkit in investigating:

- The required levels of funding for user-defined Footway network performance standards.
- The effect of Treatment on the Homogeneous Asset Groups over the period of the analysis.

9.2 An Analysis Period of 30 years was used, with the start year of analysis set to 2012.

### Inventory, Condition and Deterioration Models

9.3 The inventory data used in this example was from an urban network with a total length of 722km of footways. The lengths and widths of the Footway network were aggregated into two Homogeneous Asset Groups based on the Footway surface (Flags, Bituminous) as illustrated in Table 9.1. Each Homogeneous Asset Group is modelled in isolation.

9.4 The current condition of assets in each Homogeneous Asset Group is represented as a distribution across five Condition Bands as illustrated in Table 9.1. This is the base year or starting point for network planning in subsequent years. Consequently, the estimate of the condition is important, as are the definitions of the Condition Bands which are used to describe them.

9.5 For this example, Deterioration Models for each Homogenous Asset Group are provided in Figure 9.1 in the format given in Section 4. These models are used for the purpose of illustration only.

**Table 9.1: Asset Inventory and Condition**

| Class | Inventory | | Current Condition (% in Condition Band) | | | | |
|---|---|---|---|---|---|---|---|
| | Length (m) | Width (m) | VG | G | F | P | VP |
| **Flags** | 164,000 | 2.90 | 54% | 27% | 10% | 9% | 0% |
| **Bituminous** | 558,000 | 2.90 | 45% | 28% | 16% | 11% | 0% |

9.6 Notes:

- VG = Very Good
- G = Good
- F = Fair
- P = Poor
- VP = Very Poor

$$P_{Flags} = \begin{bmatrix} 0.95 & 0.05 & 0 & 0 & 0 \\ 0 & 0.95 & 0.05 & 0 & 0 \\ 0 & 0 & 0.95 & 0.05 & 0 \\ 0 & 0 & 0 & 0.95 & 0.05 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} \qquad P_{Bituminous} = \begin{bmatrix} 0.98 & 0.02 & 0 & 0 & 0 \\ 0 & 0.98 & 0.02 & 0 & 0 \\ 0 & 0 & 0.98 & 0.02 & 0 \\ 0 & 0 & 0 & 0.98 & 0.02 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

**Figure 9.1: Deterioration Models for each Asset Group**

## Treatment Types, Effects and Unit Costs

9.7 In this example, the Treatment Types in Table 9.2 are used:

**Table 9.2: Treatment Types**

| Treatment | Material | Description |
|---|---|---|
| **Lift and Re-Lay** | Flags | Lift and re-lay plus 5% replacement – with re-pointing where needed |
| **Replacement [Bituminous]** | Bituminous | Replace/reconstruct (recycling) – 75/25 plus foundation using HRA and/or a dense wearing course |

9.8 The effects of the above Treatments in terms of the change in condition (e.g. from Very Poor to Very Good) following maintenance intervention are illustrated in Table 9.3. In practice, the effects of Treatments can be determined from records of past treatments on the road network.

9.9 The After-treatment Asset Groups are also specified in Table 9.3. The first Treatment (**'Lift and Re-Lay'**) has no impact on Homogeneous Asset Groups because this treatment applies to 'Flags' only and assets still belong to the Flags group after Treatment. On the other hand, with the second Treatment (**'Replacement [Bituminous]'**), the Flags assets are replaced with Bituminous assets i.e. they are transferred to the Bituminous Homogeneous Asset Group after Treatment. This also means that the areas covered by each asset group will change over the period of analysis. This aspect is covered in Section 2. Unit costs of Treatments used in this example are also shown in Table 9.3.

**Table 9.3: Treatment Effects & Unit Costs**

| Treatment Details | After Treatment Asset Group | Unit Costs (£/m²) | Condition Band Treated | | | | |
|---|---|---|---|---|---|---|---|
| | | | VG | G | F | P | VP |
| | | | Effects after Treatment | | | | |
| **Lift and Re-Lay** | No change | 18.51 | VG | VG | G | G | F |
| **Replacement [Bituminous]** | Bituminous | 19.82 | VG | VG | VG | VG | VG |

## Analysis Scenarios

9.10 Maintenance scenarios investigated in this example are summarised in Table 9.4.

**Table 9.4: Analysis Scenarios**

| Scenario Name | Description |
|---|---|
| **Scenario 1: Do Nothing** | This Analysis Scenario is aimed at investigating the consequences of not carrying out maintenance interventions. |
| **Scenario 2: Eliminate Poor and Very Poor Assets by Year 5 and keep all assets between Fair and Very Good conditions thereafter** | This Analysis Scenario is aimed at determining the required funding level necessary to eliminate proportions of the asset in poor and very poor condition over the first five years and thereafter to keep the asset in fair to very good condition. |

## APPROACH

9.11 To implement this example in the Toolkit, the steps described in Table 9.5 may be followed. The **'Reference'** column refers to sections in this guidance document in which the steps were first described, whereas the table and figure numbers referred to in the **'Description'** column relate specifically to the worked example.

**Table 9.5: Steps for Implementing the Worked Example**

<table>
<tr><th>Steps</th><th>Description</th><th>Reference</th></tr>
<tr><td>STEP 1<br>Model Setup</td><td>Setup the Toolkit by specifying the following in the 'Input Sheet' worksheet:<br><table>
<tr><td>- Analysis Start Year:</td><td>(2012)</td></tr>
<tr><td>- Analysis Period:</td><td>(30)</td></tr>
<tr><td>- Number of Condition Bands:</td><td>(5)</td></tr>
<tr><td>- Short code for Condition Band:</td><td>(VG, G, F, P, VP)</td></tr>
<tr><td>- Number of Homogeneous Asset Groups:</td><td>(2)</td></tr>
<tr><td>- Name of Homogeneous Asset Group:</td><td>(Flags, Bituminous)</td></tr>
<tr><td>- Number of Treatments:</td><td>(2)</td></tr>
<tr><td>- Treatment Name:</td><td>(Lift and Re-lay, Replacement [Bituminous])</td></tr>
</table></td><td>Section 4</td></tr>
<tr><td>STEP 2<br>Inventory and Condition Data</td><td>Specify inventory and condition data (Table 9.1) in the 'Homogenous Asset Groups' worksheet.</td><td>Section 4</td></tr>
<tr><td>STEP 3<br>Transition Matrices</td><td>Specify the Transition Probability Matrices from Figure 9.1 in the 'Transition Matrices' worksheet by clicking on the 'View / Edit Matrix' button for each Homogenous Asset Group.</td><td>Section 4</td></tr>
<tr><td>STEP 4<br>Treatment Effects & Unit Costs</td><td>Specify Treatment Effects and unit costs (Table 9.3) in the '3 - Treatment Effects & Costs' worksheet. Note that once the data is input into the worksheet it should match the appearance of Figure 4.12 and Figure 4.14 from Section 4.</td><td>Section 4</td></tr>
<tr><td>STEP 5<br>Treatment Strategy</td><td>In the 'Treatment Strategies' worksheet, specify or modify the Treatment Strategy based on Analysis Scenarios (Table 9.4).<br><br>The Treatment Strategies used in this example are given in Figure D1 in Appendix D – Illustrations for the FOOTWAY Toolkit.</td><td>Section 4</td></tr>
<tr><td>STEP 6<br>Scenario 1: Do Nothing</td><td>In the 'Scenario' worksheet (See Figure D2 in Appendix D – Illustrations for the FOOTWAY Toolkit):<br><br>- Select the Transition Probability Matrix for each Homogeneous Asset Group for each year of analysis from the dropdown menu.<br>- Select the Treatment Strategy 'Do Nothing' for each year of analysis from the dropdown menu.<br>- The inputs for Budget Constraints and Performance Targets should be left blank to simulate a 'Do Nothing' strategy.<br><br>Run analysis to derive outputs for the 'Do Nothing' scenario. Export the</td><td>Section 5</td></tr>
</table>

| Steps | Description | Reference |
|---|---|---|
| | outputs and/or save a new version of the model. The results are discussed below. | |
| **STEP 7 Scenario 2: Eliminate VP&P by Year 5 & keep all assets between Fair and Very Good conditions thereafter** | In the **'Scenario'** worksheet assign Treatment Strategy to each Homogeneous Asset Group and year (See Figure D3 in Appendix D – Illustrations for the FOOTWAY Toolkit).<br><br>Run the Toolkit. Export the outputs and/or save a new version of the model. | Section 5 |

## OUTPUTS

9.12 The following paragraphs summarise the outputs of the analysis under the following headings:

- Predicted condition profile.
- Predicted expenditure.
- Predicted areas for Homogeneous Asset Groups.

## Predicted condition profile

9.13 The predicted condition profile for each Homogeneous Asset Group and each Analysis Scenario can be found in the **'9 - Condition Graph'** worksheet of the Toolkit. For each Analysis Scenario and asset group, the graphs obtained are as follows:

## Scenario 1 – Do Nothing

9.14 The average predicted condition profiles for the Footway network when no Treatments are applied throughout the Analysis Period (Scenario 1: Do Nothing) are shown in Figure 9.2 and Figure 9.3.

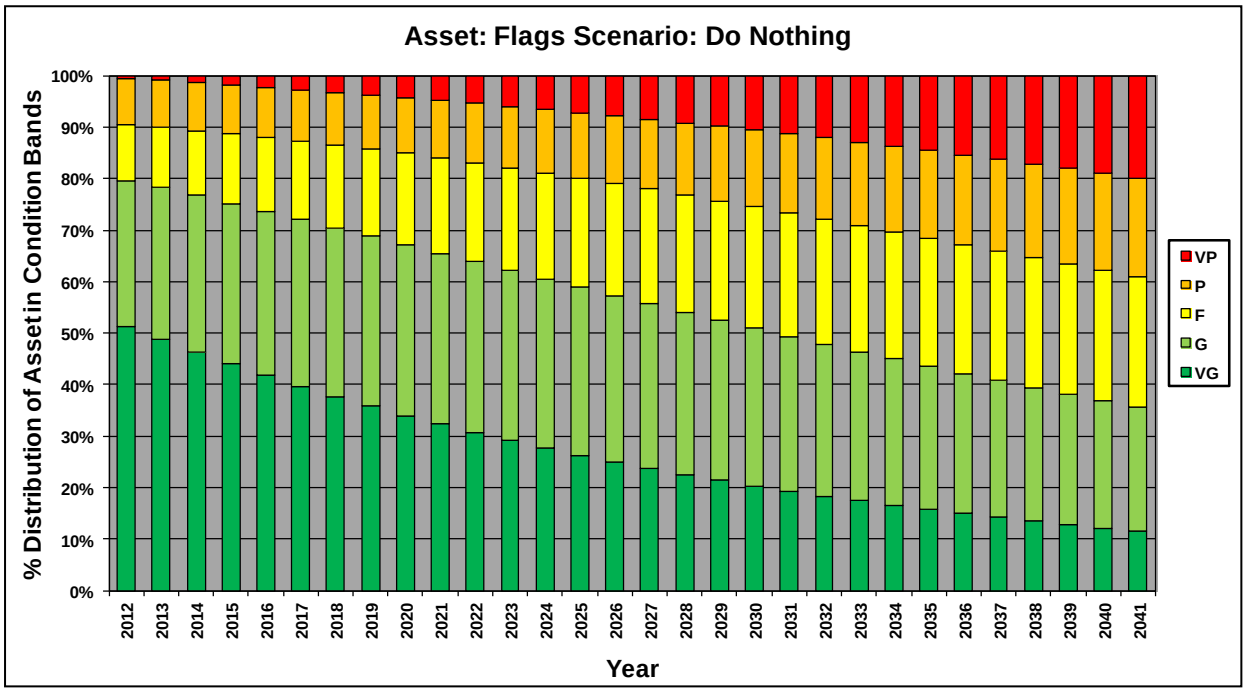



**Figure 9.2: Scenario 1 (Do Nothing) Predicted Condition Profile for 'Flags' Asset Group**

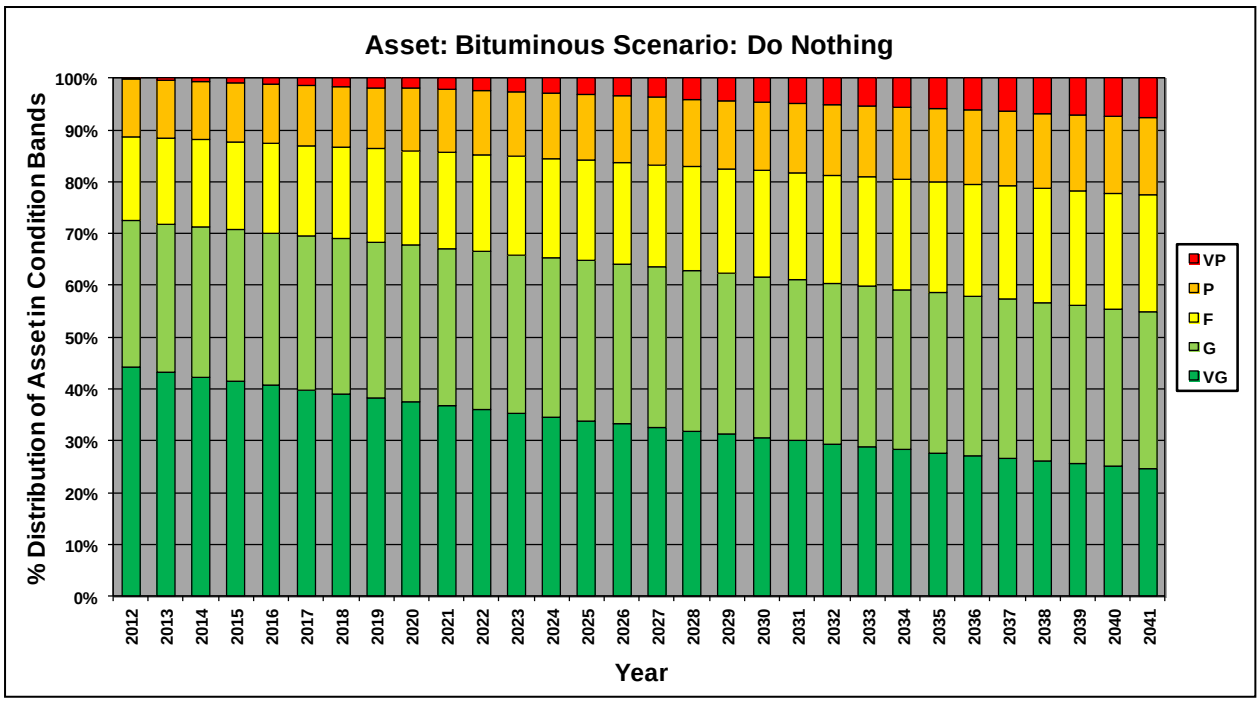



**Figure 9.3: Scenario 1 (Do Nothing) Predicted Condition Profile for 'Bituminous' Asset Group**

## Scenario 2 – Eliminate VP&P by Year 5 and keep all assets between Fair and Very Good conditions thereafter

9.15 The average predicted condition profiles for the Footway network under Scenario 2 are illustrated in Figure 9.4 and Figure 9.5, from which it can be observed that the population of Very Poor and Poor assets is eliminated within 5 years and maintained null thereafter, as specified in Table 9.4.

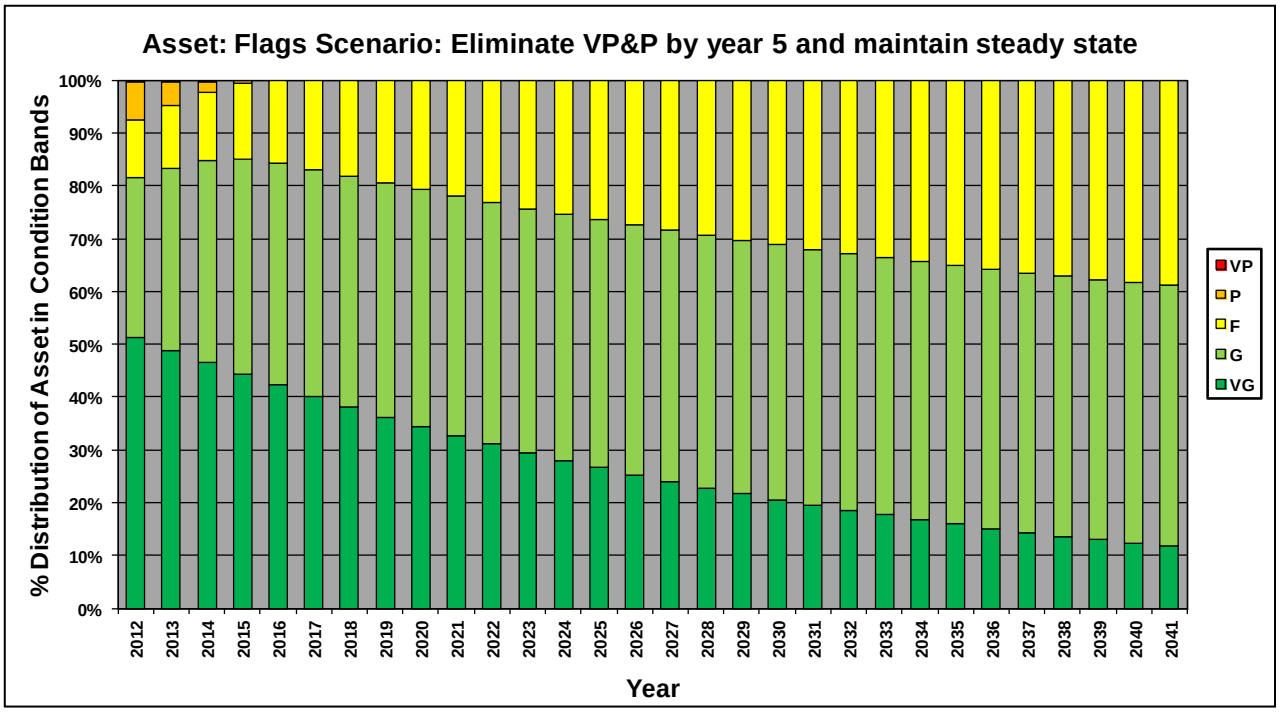



**Figure 9.4: Scenario 2 Predicted Condition Profile for 'Flags' Asset Group**

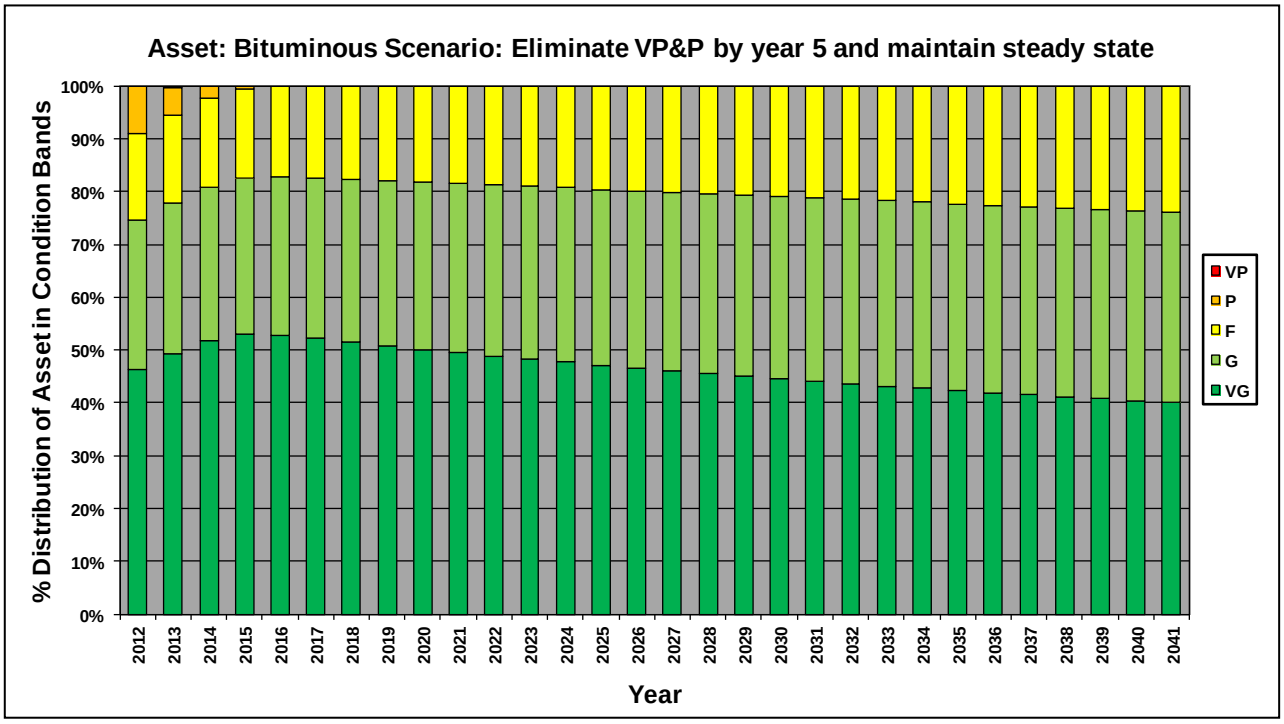



**Figure 9.5: Scenario 2 Predicted Condition Profile for 'Bituminous' Asset Group**

## Predicted Expenditure

9.16 Predicted annual expenditure profile for the Footway network by Treatment Type for each Analysis Scenario can be found in the **'15 – Exp by Treat Graph'** worksheet. Results for Scenario 2 are shown below.

## Scenario 2 – Eliminate VP&P by Year 5 and maintain steady state

9.17 The predicted annual expenditure profile for the Footway network by Treatment Type for Scenario 2 is illustrated in Figure 9.6.

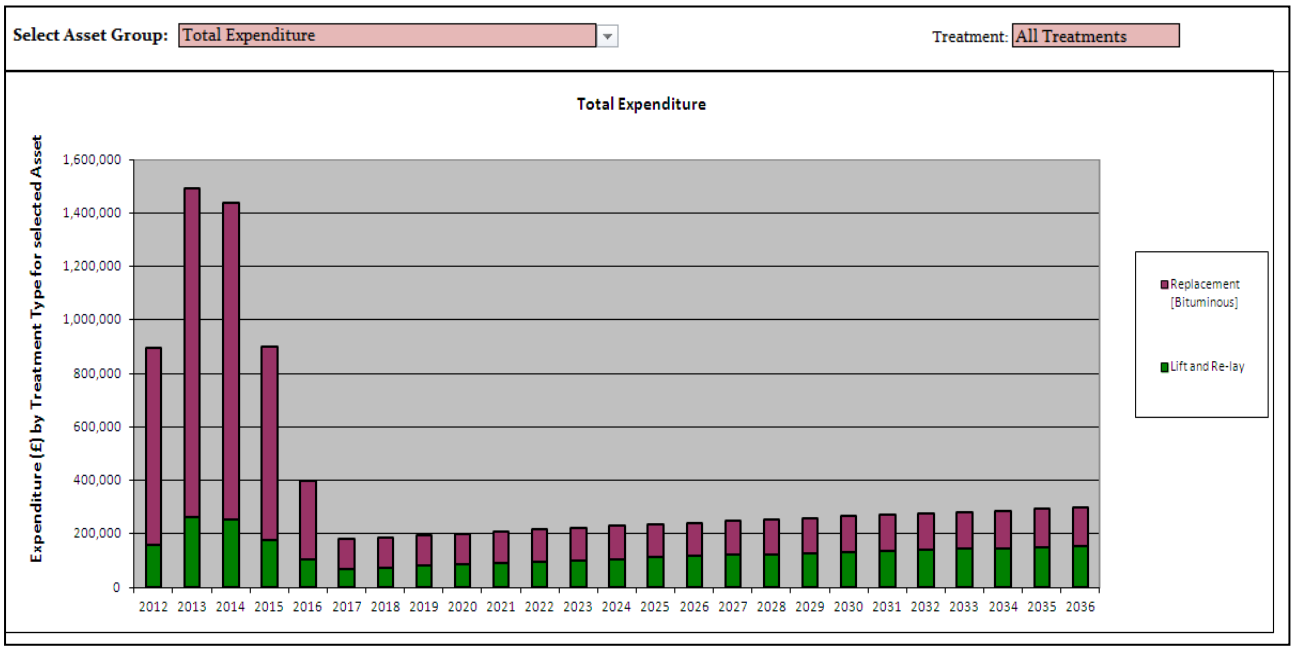



**Figure 9.6: Scenario 2 Predicted Expenditure Profile by Treatment Type**

## Predicted areas for Homogeneous Asset Groups

9.18 As mentioned in Section 1, the areas covered by each asset group are changing over the period of analysis. This is due to the fact that the Treatment **'Replacement [Bituminous]'** moves the Flags assets to the Bituminous asset group.

9.19 The areas covered by each asset group over the Analysis Period are shown in Figure 9.7. This output can be found in the **'16 – Area by Year'** worksheet of the Toolkit.

| Asset Group | No. | Cond | Initial Distribution (m²) 2012 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|
| Flags S1 | 1 | VG | 256,824 | 243,983 | 231,784 | 220,194 | 209,185 | 198,726 | 188,789 | 179,350 |
| | 2 | G | 128,412 | 143,441 | 162,585 | 179,800 | 191,250 | 197,758 | 201,487 | 204,844 |
| | 3 | F | 47,560 | 51,603 | 56,195 | 61,514 | 67,428 | 73,619 | 79,826 | 85,909 |
| | 4 | P | 42,804 | 34,433 | 21,175 | 9,170 | 2,358 | 0 | 0 | 0 |
| | 5 | VP | 0 | 1,712 | 2,060 | 1,248 | 341 | 0 | 0 | 0 |
| Bituminous S1 | 1 | VG | 728,190 | 750,690 | 797,770 | 841,535 | 861,252 | 858,775 | 847,175 | 835,890 |
| | 2 | G | 453,096 | 458,598 | 464,440 | 471,106 | 478,515 | 486,170 | 493,622 | 500,693 |
| | 3 | F | 258,912 | 262,796 | 266,712 | 270,666 | 274,675 | 278,752 | 282,900 | 287,115 |
| | 4 | P | 178,002 | 143,696 | 87,647 | 36,491 | 8,235 | 0 | 0 | 0 |
| | 5 | VP | 0 | 2,848 | 3,433 | 2,074 | 561 | 0 | 0 | 0 |

**Figure 9.7: Asset Group Area by year under Scenario 2**

9.20 In addition, the graphs shown in Figure 9.8 and Figure 9.9 were produced manually (using the Export function of the Toolkit) to illustrate the changes in areas over the period of analysis. The area covered by the Flags asset group decreases over the years whilst the area covered

by the Bituminous asset group increases by the same amount; this is due to the fact that some footways constructed of flags were reconstructed as bituminous footways as part of the Treatment Strategy.

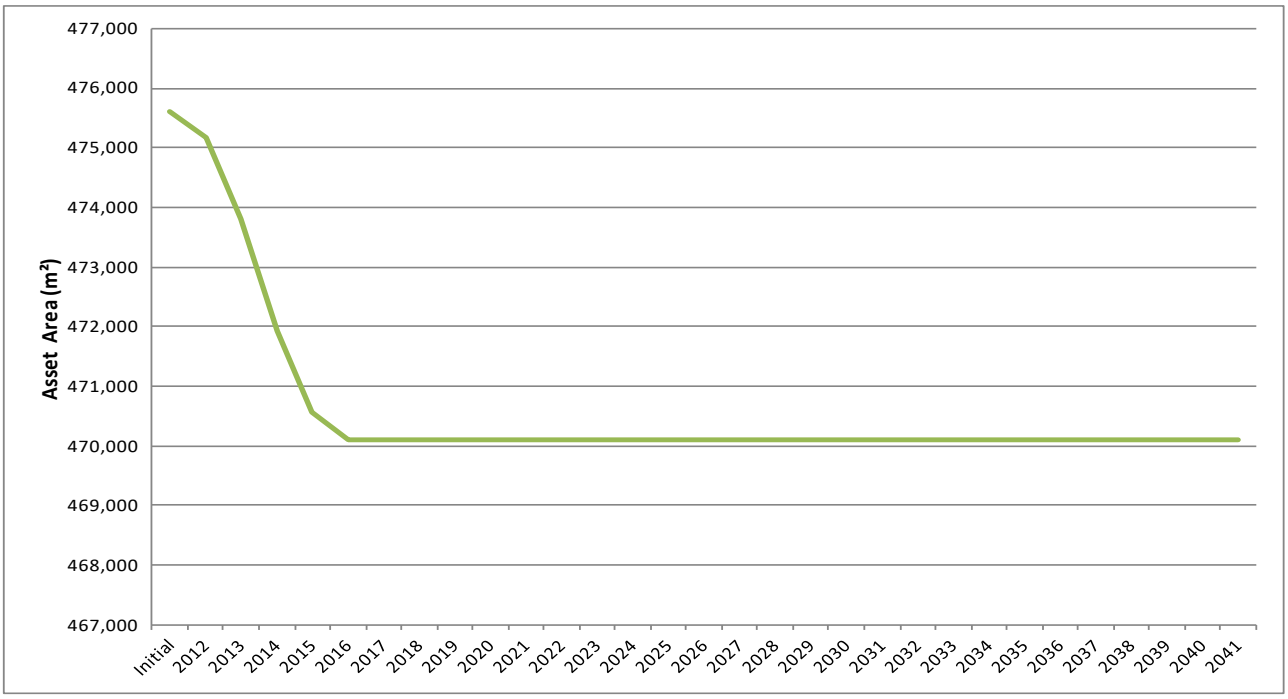



**Figure 9.8: Area by Year for Asset Group 'Flags'**

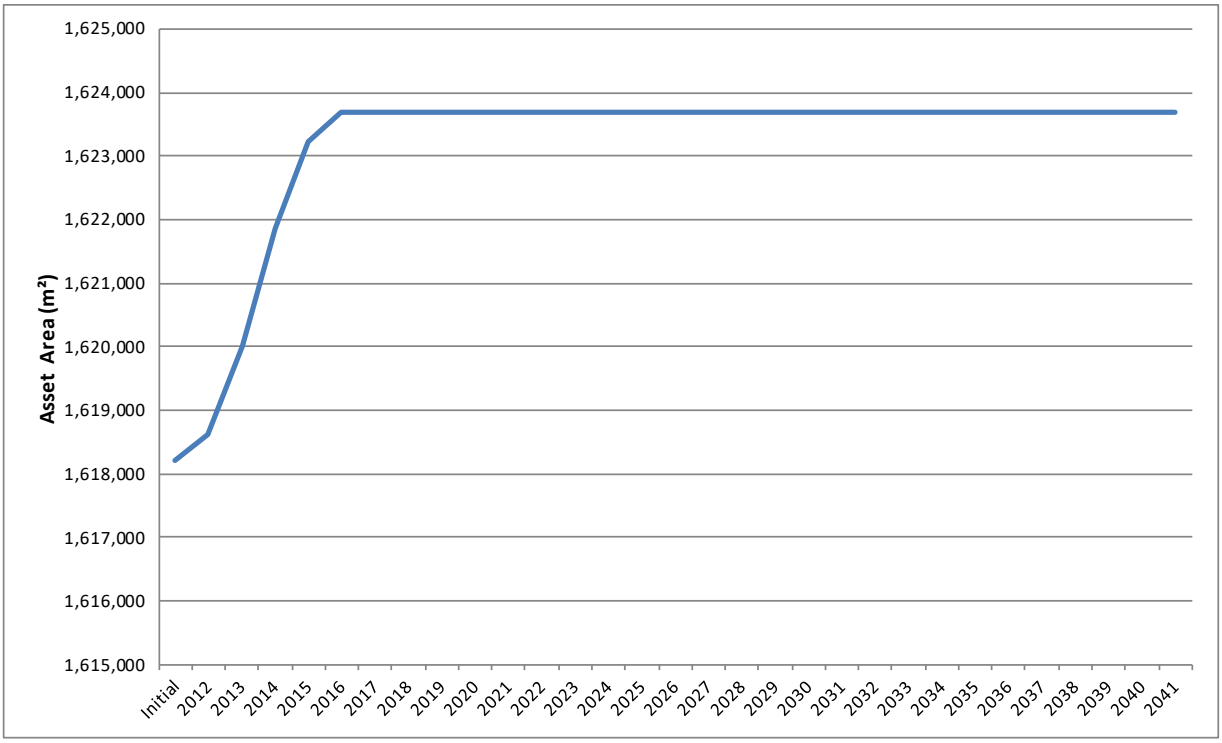



**Figure 9.9: Area by Year for Asset Group 'Bituminous'**

# 10 REFERENCES

Derivation of Transition Probability Matrices for Pavement Deterioration Modelling, Journal of Transportation Engineering ASCE, February 2006

Hierarchical asphalt pavement deterioration model for climate impact studies, International Journal of Pavement Engineering, M. Anyala, J.B. Odoki and C.J. Baker, May 2012

Technical Note 46 - Part 1 - Financial Information to support Asset Management (Carriageways), PCIS Support Contract, July 2011

# 11 GLOSSARY

| | |
|---|---|
| **After-Treatment Asset Group** | User defined input used to model the change of Homogeneous Asset Group following a Treatment (see Section 4). |
| **Analysis Period** | User specified duration (in years) of the lifecycle analysis (see Section 4). |
| **Analysis Scenario** | A combination of the following input attributes that should be selected by the user for each homogeneous asset group before running an analysis: transition probability matrix (deterioration model), treatment strategy, performance target, and budget constraints (see Section 5). |
| **Asset Service Life** | The average time (in years) it takes an asset to move from the best (as new) condition band or state to the worst condition band or state. |
| **Budget Constraint** | Annual budget figure, which can be user-defined for each Treatment Type (see Section 4). Budget Constraints are assigned to Homogeneous Asset Groups from the Scenarios worksheet (see Section 5). |
| **Carriageway Toolkit** | The version of the Lifecycle Planning Toolkit (also referred to in this document as 'Carriageway Lifecycle Planning Toolkit') used for strategic level lifecycle modelling of road carriageways. |
| **Condition Band** | Used to categorise the condition of assets that are being modelled. Condition bands would normally range from an excellent state (e.g. Very Good) to a critical state or failed state (e.g. Very Poor). See Table 2.1 and Section 4. |
| **Deterioration Model** | Is defined in the Toolkit in terms of Transition Probability Matrices (TPMs). A TPM embodies the proportion of asset that will remain in a given condition band and the proportion that would move to a worst condition state after one deterioration cycle. |
| **Footway Toolkit** | The version of the Lifecycle Planning Toolkit (also referred to in this document as 'Footway Lifecycle Planning Toolkit') used for strategic level lifecycle modelling of footways and dedicated cycle ways. |
| **Homogeneous Asset Group** | A grouping of assets which are similar in terms of deterioration related criteria. See Table 2.1 and Section 4. |
| **Other Asset Toolkit** | The version of the Lifecycle Planning Toolkit (also referred to in this document as Other Highway Asset Lifecycle Planning Toolkit') used for strategic level lifecycle modelling of highway assets such as: road signs, bollards, vehicle restraint systems, street lighting, traffic signals, road markings and kerbs. |
| **Performance Target** | Annual condition target specified by the user and assigned to homogeneous asset groups (see Sections 4 and 5). |
| **Transition Probability Matrix** | A Transition Probability Matrix embodies all information necessary to model the annual deterioration of a particular homogeneous asset group (see Section 4). |
| **Treatment Effect** | The effects (change in asset condition or homogeneous asset group) of applying a specific treatment to particular asset group as specified by the user (see Section 4). |
| **Treatment Strategy** | A Treatment Strategy comprises the following user defined attributes: a ranked list of Treatment Types, the condition band to which each Treatment Type is applicable, and the maximum percentage of assets that can be treated (see Section 4). Treatment Strategies are assigned annually to Homogeneous Asset Groups (see Section 6). |

# APPENDIX A – DEFAULT CARRIAGEWAY DETERIORATION MODELS

## INTRODUCTION

This appendix describes generic default carriageway deterioration models for local highway road networks. The default deterioration models presented in this appendix are intended as a starting point for local highway authorities who may not immediately have deterioration models that would allow them to develop sensible lifecycle plans immediately or do not have data appropriate for developing such deterioration models. Local highway authorities may adjust (calibrate) these default models so that predictions from the Lifecycle Planning Toolkit closely match recent local observed trends. The default models may also be used to benchmark existing models.

The default carriageway deterioration models presented in this appendix are compatible with the carriageway Lifecycle Planning Toolkit described in this document. No changes to the deterioration matrices were made in the 2019 update of the toolkit. The methodology for deriving the matrices in the initial version is described in this section. The deterioration models, in conjunction with the Lifecycle Planning Toolkit, will support local highway authorities to implement an approach based on asset management principles that deliver demonstrable efficiencies. The principal uses of deterioration models are to predict how asset condition will change over time and, in conjunction with treatment options, to allow practitioners to determine the most cost-effective timing of treatments.

The appendix is structured under the following headings:

- **Transition Probability Matrix**: introduces the concept of the deterioration modelling embodied in the Lifecycle Planning Toolkit.
- **Condition Bands for Carriageways:** provides the definition of five carriageway condition states used in developing the default deterioration models.
- **Homogeneous Carriageway Asset Groups:** describes ten homogeneous carriageway groups. Deterioration models were developed for each of these homogeneous groups.
- **Default Carriageway Deterioration Models**: provides a set of default carriageway deterioration models derived from SCANNER (Surface Condition Assessment for the National Network of Roads) data and another set of models derived from CVI (Coarse Visual Inspection) data.
- **Developing TPMs from Data**: describes a standard approach which may be used by local highway authorities to develop models that reflect local observed deterioration trends.

## TRANSITION PROBABILITY MATRIX

The Lifecycle Planning Toolkit makes use of Transition Probability Matrices (TPMs) to model the deterioration of each Homogeneous Asset Group annually. The general form of the matrix denoted by P is given by:

$$P = \begin{bmatrix} p_{11} & p_{12} & \dots & p_{1n} \\ p_{21} & p_{22} & \dots & p_{2n} \\ \vdots & & & \vdots \\ p_{n1} & p_{n2} & \dots & p_{nn} \end{bmatrix} \quad \text{(A1)}$$

This matrix contains all the information necessary to model the deterioration of the Homogeneous Group. The transition probabilities, $p_{ij}$, indicate the probability of the portion of the asset group in condition *i* moving to condition *j* in one year due to the damaging effects of traffic, environment and/or other factors, as applicable.

For every TPM, the sum of the entries in each row is equal to one and all entries are non-negative. Two more conditions apply to the process when used to simulate asset deterioration. Firstly $p_{ij} = 0$ for $i>j$, signifying the general belief that assets cannot improve in condition without first receiving some form of treatment; the bottom half of the matrix, as shown in equation (A2). Secondly $p_{nn} = 1$, signifying a holding state whereby assets that have reached their worst condition cannot deteriorate further. Consequently, the general form of the transition matrix $P$ implemented in the Toolkit is denoted by:

$$P = \begin{bmatrix} p_{11} & p_{12} & p_{13} & \dots & p_{1n} \\ 0 & p_{22} & p_{23} & \dots & p_{2n} \\ 0 & 0 & p_{33} & \dots & p_{3n} \\ : & : & : & & : \\ 0 & 0 & 0 & \dots & 1 \end{bmatrix} \quad \text{(A2)}$$

The Lifecycle Planning Toolkit allows the user to define deterioration models by specifying the elements ($p_{ij}$) of the TPM. Default carriageway deterioration models for each Homogeneous Group are given below. A standard approach for developing TPMs from data is also described later in this appendix.

## CONDITION BANDS FOR CARRIAGEWAYS

The Carriageway Condition Index (CCI) is a measure of road pavement performance and can be calculated from SCANNER, CVI or DVI (Detailed Visual Inspection) data. Only SCANNER and CVI data were used in developing the default carriageway deterioration models. Guidance on the calculation of CCI from SCANNER and CVI carriageway defects is provided in UKPMS Technical Note 46 – Part 1 (UKPMS Technical Note).

Table A1 describes five CCI based condition bands used to develop the default carriageway deterioration models. The condition bandings were defined to ensure that the default carriageway deterioration models given adequate scope within the intermediate bands to carry out preventative maintenance treatments.

**Table A1: CCI Condition Bands by Road Hierarchy**

| Description | Code | CCI Condition Bands | | | |
|---|---|---|---|---|---|
| | | Strategic Route & Main Distributors | Secondary Roads | Link Roads | Local Access Roads |
| Carriageway in **Very Good** condition | VG | 0 – 3.0 | 0 – 4.0 | 0 – 6.0 | 0 – 7.0 |
| Carriageway in **Good** condition | G | 3.1 - 10 | 4.1 – 13.0 | 6.1 – 17.0 | 7.1 – 18.0 |
| Carriageway in **Fair** condition | F | 10.1 – 25.0 | 13.1 – 30.0 | 17.1 – 35.0 | 18.1 – 38.0 |
| Carriageway in **Poor** condition | P | 25.1 – 61.0 | 30.1 – 65.0 | 35.1 – 72.0 | 38.1 – 76.0 |
| Carriageway in **Very Poor** condition | VP | 61.1 - 100 | 65.1 – 100.0 | 72.1 – 100.0 | 76.1 – 100.0 |

Data from a variety of local highway authorities in England were used to test these bands. The testing has confirmed that the bandings give TPMs with meaningful transition from the Very Good condition state to the Very Poor condition state, with adequate scope within the intermediate bands to for example carry out preventative maintenance treatments.

## HOMOGENEOUS CARRIAGEWAY ASSET GROUPS

At the strategic level, carriageway sections are defined in the Lifecycle Planning Toolkit by aggregating individual road sections known to have similar performance (in terms of deterioration) and reporting requirements to form Homogeneous Carriageway Asset Groups. Each group normally represents a large number of physical road sections each of which have similar characteristics and are distributed over the road network. Instead of each road section being analysed separately, just the homogeneous group is analysed. The advantage of this approach is the fast turn-around that it facilitates, and hence the ability to use the Lifecycle Planning Toolkit to iterate to a preferred solution/strategy relatively quickly.

Default carriageway deterioration models were developed for each of the Homogeneous Asset Groups defined by road hierarchy and environment (Table A2). In some cases, the same deterioration models are provided for more than one group

**Table A2: Homogeneous Carriageway Groups**

| Description of Homogenous Group | Road Hierarchy | Environment |
|---|---|---|
| **Urban Strategic Route** | 2 – Strategic Route | Urban |
| **Rural Strategic Route** | 2 – Strategic Route | Rural |
| **Urban Main Distributor** | 3a – Main Distributor | Urban |
| **Rural Main Distributor** | 3a – Main Distributor | Rural |
| **Urban Secondary Distributor** | 3b – Secondary Distributor | Urban |
| **Rural Secondary Distributor** | 3b – Secondary Distributor | Rural |
| **Urban Link Road** | 4a – Link Road | Urban |
| **Rural Link Road** | 4a – Link Road | Rural |
| **Urban Local Access Road** | 4b – Local Access Road | Urban |
| **Rural Local Access Road** | 4b – Local Access Road | Rural |

The homogeneous groups shown in Table A2 could be subdivided further by pavement type (e.g. flexible, flexible composite, rigid, etc) and road type (e.g. single, dual etc) as appropriate. However, it is important to note that, as the number of homogeneous groups grows it becomes increasingly cumbersome to set up the Toolkit and interpret the outputs.

## DEFAULT CARRIAGEWAY DETERIORATION MODELS

The default models presented here were derived using local highway authority data comprising: SCANNER, CVI and maintenance history. Data used were obtained from several local highway authorities in England including: Worcestershire, Hertfordshire, Cornwall and Peterborough. It should be noted that these models are defaults only. The user should use models that better reflect local deterioration trends if such models are available.

Two sets of the default carriageway deterioration models are presented:

- TPMs from SCANNER data; and
- TPMs from CVI data

## DEFAULT TRANSITION PROBABILITY MATRICES DERIVED USING SCANNER DATA

The default carriageway deterioration models in the form of TPMs derived from local highway authorities' SCANNER data are given from Figure A1 to Figure A7.

| | | | | | |
|---|---|---|---|---|---|
| **VG** | 0.924 | 0.076 | 0.000 | 0.000 | 0.000 |
| **G** | - | 0.828 | 0.172 | 0.000 | 0.000 |
| **F** | - | - | 0.797 | 0.203 | 0.000 |
| **P** | - | - | - | 0.868 | 0.132 |
| **VP** | - | - | - | - | 1.000 |

**Figure A1: Deterioration model for SCANNER: Urban Strategic Routes and Urban Main Distributors**

| | | | | | |
|---|---|---|---|---|---|
| **VG** | 0.910 | 0.090 | 0.000 | 0.000 | 0.000 |
| **G** | - | 0.714 | 0.279 | 0.007 | 0.000 |
| **F** | - | - | 0.681 | 0.318 | 0.001 |
| **P** | - | - | - | 0.771 | 0.229 |
| **VP** | - | - | - | - | 1.000 |

**Figure A2: Deterioration model for SCANNER: Rural Strategic Routes and Rural Main Distributors**

| | | | | | |
|---|---|---|---|---|---|
| **VG** | 0.929 | 0.071 | 0.000 | 0.000 | 0.000 |
| **G** | - | 0.814 | 0.186 | 0.000 | 0.000 |
| **F** | - | - | 0.775 | 0.225 | 0.000 |
| **P** | - | - | - | 0.846 | 0.154 |
| **VP** | - | - | - | - | 1.000 |

**Figure A3: Deterioration model for SCANNER: Urban Secondary Distributors**

| | | | | | |
|---|---|---|---|---|---|
| **VG** | 0.928 | 0.072 | 0.000 | 0.000 | 0.000 |
| **G** | - | 0.811 | 0.189 | 0.000 | 0.000 |
| **F** | - | - | 0.777 | 0.223 | 0.000 |
| **P** | - | - | - | 0.839 | 0.161 |
| **VP** | - | - | - | - | 1.000 |

**Figure A4: Deterioration model for SCANNER: Rural Secondary Distributors**

| | | | | | |
|---|---|---|---|---|---|
| **VG** | 0.937 | 0.063 | 0.000 | 0.000 | 0.000 |
| **G** | - | 0.796 | 0.202 | 0.002 | 0.000 |
| **F** | - | - | 0.756 | 0.244 | 0.000 |
| **P** | - | - | - | 0.880 | 0.120 |
| **VP** | - | - | - | - | 1.000 |

**Figure A5: Deterioration model for SCANNER: Urban Link Roads**

| | | | | | |
|---|---|---|---|---|---|
| **VG** | 0.933 | 0.067 | 0.000 | 0.000 | 0.000 |
| **G** | - | 0.773 | 0.225 | 0.002 | 0.000 |
| **F** | - | - | 0.722 | 0.278 | 0.000 |
| **P** | - | - | - | 0.836 | 0.164 |
| **VP** | - | - | - | - | 1.000 |

**Figure A6: Deterioration model for SCANNER: Rural Link Roads**

| | | | | | |
|---|---|---|---|---|---|
| **VG** | 0.963 | 0.037 | 0.000 | 0.000 | 0.000 |
| **G** | - | 0.898 | 0.102 | 0.000 | 0.000 |
| **F** | - | - | 0.897 | 0.103 | 0.000 |
| **P** | - | - | - | 0.933 | 0.067 |
| **VP** | - | - | - | - | 1.000 |

**Figure A7: Deterioration model for SCANNER: Local Roads (Urban and Rural)**

## DEFAULT TRANSITION PROBABILITY MATRICES DERIVED USING CVI DATA

The default carriageway deterioration models in the form of Transition Probability Matrices derived from local highway authorities' CVI data are given in Figure A8 to Figure A17.

| | | | | | |
|---|---|---|---|---|---|
| **VG** | 0.911 | 0.088 | 0.001 | 0.000 | 0.000 |
| **G** | - | 0.727 | 0.265 | 0.008 | 0.000 |
| **F** | - | - | 0.688 | 0.310 | 0.002 |
| **P** | - | - | - | 0.775 | 0.225 |
| **VP** | - | - | - | - | 1.000 |

**Figure A8: Deterioration model for CVI: Urban Strategic Routes**

| | | | | | |
|---|---|---|---|---|---|
| **VG** | 0.913 | 0.087 | 0.000 | 0.000 | 0.000 |
| **G** | - | 0.741 | 0.254 | 0.005 | 0.000 |
| **F** | - | - | 0.710 | 0.289 | 0.001 |
| **P** | - | - | - | 0.788 | 0.212 |
| **VP** | - | - | - | - | 1.000 |

**Figure A9: Deterioration model for CVI: Rural Strategic Routes**

| | | | | | |
|---|---|---|---|---|---|
| **VG** | 0.880 | 0.119 | 0.001 | 0.000 | 0.000 |
| **G** | - | 0.740 | 0.251 | 0.009 | 0.000 |
| **F** | - | - | 0.706 | 0.292 | 0.002 |
| **P** | - | - | - | 0.780 | 0.220 |
| **VP** | - | - | - | - | 1.000 |

**Figure A10: Deterioration model for CVI: Urban Main Distributors**

| | | | | | |
|---|---|---|---|---|---|
| **VG** | 0.913 | 0.086 | 0.001 | 0.000 | 0.000 |
| **G** | - | 0.752 | 0.242 | 0.006 | 0.000 |
| **F** | - | - | 0.714 | 0.285 | 0.001 |
| **P** | - | - | - | 0.796 | 0.204 |
| **VP** | - | - | - | - | 1.000 |

**Figure A11: Deterioration model for CVI: Rural Main Distributors**

| | | | | | |
|---|---|---|---|---|---|
| **VG** | 0.932 | 0.068 | 0.000 | 0.000 | 0.000 |
| **G** | - | 0.831 | 0.169 | 0.000 | 0.000 |
| **F** | - | - | 0.797 | 0.203 | 0.000 |
| **P** | - | - | - | 0.853 | 0.147 |
| **VP** | - | - | - | - | 1.000 |

**Figure A12: Deterioration model for CVI: Urban Secondary Distributors**

| | | | | | |
|---|---|---|---|---|---|
| **VG** | 0.932 | 0.068 | 0.000 | 0.000 | 0.000 |
| **G** | - | 0.834 | 0.166 | 0.000 | 0.000 |
| **F** | - | - | 0.797 | 0.203 | 0.000 |
| **P** | - | - | - | 0.856 | 0.144 |
| **VP** | - | - | - | - | 1.000 |

**Figure A13: Deterioration model for CVI: Rural Secondary Distributors**

| | | | | | |
|---|---|---|---|---|---|
| **VG** | 0.940 | 0.060 | 0.000 | 0.000 | 0.000 |
| **G** | - | 0.815 | 0.184 | 0.001 | 0.000 |
| **F** | - | - | 0.781 | 0.219 | 0.000 |
| **P** | - | - | - | 0.862 | 0.138 |
| **VP** | - | - | - | - | 1.000 |

**Figure A14: Deterioration model for CVI: Urban Link Roads**

| | | | | | |
|---|---|---|---|---|---|
| **VG** | 0.941 | 0.059 | 0.000 | 0.000 | 0.000 |
| **G** | - | 0.815 | 0.184 | 0.001 | 0.000 |
| **F** | - | - | 0.788 | 0.212 | 0.000 |
| **P** | - | - | - | 0.864 | 0.136 |
| **VP** | - | - | - | - | 1.000 |

**Figure A15: Deterioration model for CVI: Rural Link Roads**

| | | | | | |
|---|---|---|---|---|---|
| **VG** | 0.942 | 0.058 | 0.000 | 0.000 | 0.000 |
| **G** | - | 0.829 | 0.170 | 0.001 | 0.000 |
| **F** | - | - | 0.795 | 0.205 | 0.000 |
| **P** | - | - | - | 0.872 | 0.128 |
| **VP** | - | - | - | - | 1.000 |

**Figure A16: Deterioration model for CVI: Urban Local Roads**

| | | | | | |
|---|---|---|---|---|---|
| **VG** | 0.943 | 0.057 | 0.000 | 0.000 | 0.000 |
| **G** | - | 0.832 | 0.168 | 0.001 | 0.000 |
| **F** | - | - | 0.795 | 0.205 | 0.000 |
| **P** | - | - | - | 0.874 | 0.126 |
| **VP** | - | - | - | - | 1.000 |

**Figure A17: Deterioration model for CVI: Rural Local Roads**

## DEVELOPING TRANSITION PROBABILITY MATRICES FROM DATA

It should be noted that these models given above are defaults only. When suitable data is available, then TPMs can be developed that better reflect the deterioration trend of the road network from which the data were measured.

The standard approach is to observe, from historic data, the way in which a Homogeneous Group deteriorates over time and use this to estimate the probability $p_{ij}$ using equation A3 below. $N_{ij}$ is the number of assets in the Homogenous Group that moved from condition $i$ to condition $j$ during one year and $N_i$ is the total number of assets that started the year in condition state $i$.

$$p_{ij} = \frac{N_{ij}}{N_i} \qquad \text{(A3)}$$

The proportions are likely to vary from year to year thereby requiring an average to be determined over time for each $p_{ij}$ to ensure accuracy in the model.

# APPENDIX B – ILLUSTRATIONS FOR THE CARRIAGEWAY TOOLKIT

| Serial | Name | Step | Treatment | Condition Band | % Treated | VG | G | F | P | VP |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Do Nothing | 1 | None | | | | | | | |
| | | 2 | None | | | | | | | |
| | | 3 | None | | | | | | | |
| | | 4 | None | | | | | | | |
| | | 5 | None | | | | | | | |
| | | 6 | None | | | | | | | |
| | | 7 | None | | | | | | | |
| 2 | Strat. & Main | 1 | Surface Dressing | F | 10% | | | 10% | | |
| | | 2 | Micro Asphalt | F | 10% | | | 10% | | |
| | | 3 | Moderate Overlay | F | 5% | | | 5% | | |
| | | 4 | Moderate Inlay | P | 35% | | | | 35% | |
| | | 5 | Deep Inlay | P | 15.00% | | | | 15% | |
| | | 6 | Deep Inlay | VP | 35.00% | | | | | 35% |
| | | 7 | Reconstruction | VP | 5.00% | | | | | 5% |
| 3 | Secondary | 1 | Surface Dressing | F | 15% | | | 15% | | |
| | | 2 | Micro Asphalt | F | 15% | | | 15% | | |
| | | 3 | Moderate Overlay | F | 5% | | | 5% | | |
| | | 4 | Moderate Inlay | P | 10% | | | | 10% | |
| | | 5 | Deep Inlay | P | 5.00% | | | | 5% | |
| | | 6 | Deep Inlay | VP | 10.00% | | | | | 10% |
| | | 7 | Reconstruction | VP | 5.00% | | | | | 5% |
| 4 | Link | 1 | Surface Dressing | F | 5% | | | 5% | | |
| | | 2 | Micro Asphalt | F | 5% | | | 5% | | |
| | | 3 | Moderate Overlay | F | 2% | | | 2% | | |
| | | 4 | Moderate Inlay | P | 20% | | | | 20% | |
| | | 5 | Deep Inlay | P | 5.00% | | | | 5% | |
| | | 6 | Deep Inlay | VP | 10.00% | | | | | 10% |
| | | 7 | Reconstruction | VP | 15.00% | | | | | 15% |
| 5 | Local | 1 | Surface Dressing | F | 4% | | | 4% | | |
| | | 2 | Micro Asphalt | F | 4% | | | 4% | | |
| | | 3 | Moderate Overlay | F | 2% | | | 2% | | |
| | | 4 | Moderate Inlay | P | 3% | | | | 3% | |
| | | 5 | Deep Inlay | P | 3.00% | | | | 3% | |
| | | 6 | Deep Inlay | VP | 5.00% | | | | | 5% |
| | | 7 | Reconstruction | VP | 2.00% | | | | | 2% |

**Figure B1: Treatment Strategies**

| Run Analysis ... | Clear selected row(s) | Copy selected cell(s) | Paste copied cell(s) |
|---|---|---|---|

| | | | | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|
| No. | Homogeneous Group | Scenario Name | Criteria | 2012 | 2013 | 2014 | 2015 | 2016 |
| 1 | Strategic & Main | Do Nothing | Transition matrix | Strategic & Main | Strategic & Main | Strategic & Main | Strategic & Main | Strategic & Main |
| | | | Treatment strategy | Do Nothing | Do Nothing | Do Nothing | Do Nothing | Do Nothing |
| | | | Budget constraint | | | | | |
| | | | Performance target | | | | | |
| 2 | Secondary | Do Nothing | Transition matrix | Secondary | Secondary | Secondary | Secondary | Secondary |
| | | | Treatment strategy | Do Nothing | Do Nothing | Do Nothing | Do Nothing | Do Nothing |
| | | | Budget constraint | | | | | |
| | | | Performance target | | | | | |
| 3 | Link | Do Nothing | Transition matrix | Link | Link | Link | Link | Link |
| | | | Treatment strategy | Do Nothing | Do Nothing | Do Nothing | Do Nothing | Do Nothing |
| | | | Budget constraint | | | | | |
| | | | Performance target | | | | | |
| 4 | Local | Do Nothing | Transition matrix | Local | Local | Local | Local | Local |
| | | | Treatment strategy | Do Nothing | Do Nothing | Do Nothing | Do Nothing | Do Nothing |
| | | | Budget constraint | | | | | |
| | | | Performance target | | | | | |

**Figure B2: Illustration of 'Scenario' worksheet under the 'Do Nothing' scenario (Scenario 1)**

| Serial | Name | Treatment | Budget constraints (£ 000s) | Roll Over | Total (£ 000s) |
|---|---|---|---|---|---|
| 1 | £404k/year | Surface Dressing | 35 | N | 404 |
| | | Micro Asphalt | 54 | N | |
| | | Moderate Overlay | 43 | N | |
| | | Moderate Inlay | 133 | N | |
| | | Deep Inlay | 129 | N | |
| | | Reconstruction | 11 | N | |
| 2 | £75k/year | Surface Dressing | 11 | N | 75 |
| | | Micro Asphalt | 18 | N | |
| | | Moderate Overlay | 9 | N | |
| | | Moderate Inlay | 10 | N | |
| | | Deep Inlay | 18 | N | |
| | | Reconstruction | 8 | N | |
| 3 | £46k/year | Surface Dressing | 2 | N | 46 |
| | | Micro Asphalt | 4 | N | |
| | | Moderate Overlay | 2 | N | |
| | | Moderate Inlay | 16 | N | |
| | | Deep Inlay | 10 | N | |
| | | Reconstruction | 11 | N | |
| 4 | £62k/year | Surface Dressing | 5 | N | 62 |
| | | Micro Asphalt | 8 | N | |
| | | Moderate Overlay | 6 | N | |
| | | Moderate Inlay | 8 | N | |
| | | Deep Inlay | 26 | N | |
| | | Reconstruction | 9 | N | |

**Figure B3: Budgets**

| Run Analysis ... | Clear selected row(s) | Copy selected cell(s) | Paste copied cell(s) |
|---|---|---|---|

| | | | | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|
| No. | Homogeneous Group | Scenario Name | Criteria | 2012 | 2013 | 2014 | 2015 | 2016 |
| 1 | Strategic & Main | Scenario 3 (25% Budget Cut) | Transition matrix | Strategic & Main | Strategic & Main | Strategic & Main | Strategic & Main | Strategic & Main |
| | | | Treatment strategy | Strat. & Main | Strat. & Main | Strat. & Main | Strat. & Main | Strat. & Main |
| | | | Budget constraint | £404k/year | £404k/year | £404k/year | £404k/year | £404k/year |
| | | | Performance target | | | | | |
| 2 | Secondary | Scenario 3 (25% Budget Cut) | Transition matrix | Secondary | Secondary | Secondary | Secondary | Secondary |
| | | | Treatment strategy | Secondary | Secondary | Secondary | Secondary | Secondary |
| | | | Budget constraint | £75k/year | £75k/year | £75k/year | £75k/year | £75k/year |
| | | | Performance target | | | | | |
| 3 | Link | Scenario 3 (25% Budget Cut) | Transition matrix | Link | Link | Link | Link | Link |
| | | | Treatment strategy | Link | Link | Link | Link | Link |
| | | | Budget constraint | £46k/year | £46k/year | £46k/year | £46k/year | £46k/year |
| | | | Performance target | | | | | |
| 4 | Local | Scenario 3 (25% Budget Cut) | Transition matrix | Local | Local | Local | Local | Local |
| | | | Treatment strategy | Local | Local | Local | Local | Local |
| | | | Budget constraint | £62k/year | £62k/year | £62k/year | £62k/year | £62k/year |
| | | | Performance target | | | | | |

**Figure B4: Illustration of 'Scenario' worksheet under the 'Budget Constraint' scenario (Scenario 3)**

| No. | Name | Performance Indicator | Expression | Performance Target (%) |
|---|---|---|---|---|
| 1 | VP&P<=5.7% | VP & P | <= | 6% |
| 2 | VP&P<=9.3% | VP & P | <= | 9% |
| 3 | VP&P<=6.8% | VP & P | <= | 7% |
| 4 | VP&P<=27% | VP & P | <= | 27% |

**Figure B5: Performance Target**

| Run Analysis ... | Clear selected row(s) | Copy selected cell(s) | Paste copied cell(s) |
|---|---|---|---|

| | | | | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|
| No. | Homogeneous Group | Scenario Name | Criteria | 2020 | 2021 | 2022 | 2023 | 2024 |
| 1 | Strategic & Main | Scenario 4 (Budget Constraint and Performance Target) | Transition matrix | Strategic & Main | Strategic & Main | Strategic & Main | Strategic & Main | Strategic & Main |
| | | | Treatment strategy | Strat. & Main | Strat. & Main | Strat. & Main | Strat. & Main | Strat. & Main |
| | | | Budget constraint | £404k/year | £404k/year | | | |
| | | | Performance target | | | VP&P<=5.7% | VP&P<=5.7% | VP&P<=5.7% |
| 2 | Secondary | Scenario 4 (Budget Constraint and Performance Target) | Transition matrix | Secondary | Secondary | Secondary | Secondary | Secondary |
| | | | Treatment strategy | Secondary | Secondary | Secondary | Secondary | Secondary |
| | | | Budget constraint | £75k/year | £75k/year | | | |
| | | | Performance target | | | VP&P<=9.3% | VP&P<=9.3% | VP&P<=6.8% |
| 3 | Link | Scenario 4 (Budget Constraint and Performance Target) | Transition matrix | Link | Link | Link | Link | Link |
| | | | Treatment strategy | Link | Link | Link | Link | Link |
| | | | Budget constraint | £46k/year | £46k/year | | | |
| | | | Performance target | | | VP&P<=6.8% | VP&P<=6.8% | VP&P<=6.8% |
| 4 | Local | Scenario 4 (Budget Constraint and Performance Target) | Transition matrix | Local | Local | Local | Local | Local |
| | | | Treatment strategy | Local | Local | Local | Local | Local |
| | | | Budget constraint | £62k/year | £62k/year | | | |
| | | | Performance target | | | VP&P<=27% | VP&P<=27% | VP&P<=27% |

**Figure B6: Illustration of 'Scenario' worksheet under the 'Performance Target' scenario (Scenario 4)**

# APPENDIX C – ILLUSTRATIONS FOR THE OTHER ASSETS TOOLKIT

| Serial | Name | Step | Treatment | Condition Band | % Treated | VG | G | F | P | VP |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Replace on fail | 1 | Asset Replacement | VP | 100% | | | | | 100% |
| | | 2 | None | | | | | | | |

**Figure C1: Treatment Strategy**

Run Analysis ... | Clear selected row(s) | Copy selected cell(s) | Paste copied cell(s)

| | | | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|
| No. | Homogeneous Group | Scenario Name | Criteria | 2012 | 2013 | 2014 | 2015 |
| 1 | Traffic Signs - Matrix and VMS | Replace on fail | Transition matrix | TSM&V | TSM&V | TSM&V | TSM&V |
| | | | Treatment strategy | Replace on fail | Replace on fail | Replace on fail | Replace on fail |
| | | | Budget constraint | | | | |
| | | | Performance target | | | | |
| 2 | Lighting Columns | Replace on fail | Transition matrix | LC | LC | LC | LC |
| | | | Treatment strategy | Replace on fail | Replace on fail | Replace on fail | Replace on fail |
| | | | Budget constraint | | | | |
| | | | Performance target | | | | |

**Figure C2: Illustration of 'Scenario' worksheet under the 'Replace on fail' scenario (Scenario 1)**

| Serial | Name | Treatment | Budget constraints (£ 000s) | Roll Over | Total (£ 000s) |
|---|---|---|---|---|---|
| 1 | Budget - Signs | Asset Replacement | 100 | N | 100 |
| | | None | | N | |
| 2 | Budget - Lighting | Asset Replacement | 10 | N | 10 |
| | | None | | N | |

**Figure C3: Illustration of 'Budgets' worksheet under the 'Budget Constraint' scenario (Scenario 2)**

Run Analysis ... | Clear selected row(s) | Copy selected cell(s) | Paste copied cell(s)

| | | | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|
| No. | Homogeneous Group | Scenario Name | Criteria | 2012 | 2013 | 2014 | 2015 |
| 1 | Traffic Signs - Matrix and VMS | Replace on fail | Transition matrix | TSM&V | TSM&V | TSM&V | TSM&V |
| | | | Treatment strategy | Replace on fail | Replace on fail | Replace on fail | Replace on fail |
| | | | Budget constraint | Budget - Signs | Budget - Signs | Budget - Signs | Budget - Signs |
| | | | Performance target | | | | |
| 2 | Lighting Columns | Replace on fail | Transition matrix | LC | LC | LC | LC |
| | | | Treatment strategy | Replace on fail | Replace on fail | Replace on fail | Replace on fail |
| | | | Budget constraint | Budget - Lighting | Budget - Lighting | Budget - Lighting | Budget - Lighting |
| | | | Performance target | | | | |

**Figure C4: Illustration of 'Scenario' worksheet under the 'Budget Constraint' scenario (Scenario 2)**

# APPENDIX D – ILLUSTRATIONS FOR THE FOOTWAY TOOLKIT

| Serial | Name | Step | Treatment | Condition Band | % Treated | VG | G | F | P | VP |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Do Nothing | 1 | None | | | | | | | |
| | | 2 | None | | | | | | | |
| 2 | FLAGS&BITUM[20%] | 1 | Lift and Re-lay | P | 20% | | | | 20% | |
| | | 2 | Replacement (Bituminous) | VP | 20% | | | | | 20% |
| 3 | FLAGS&BITUM[40%] | 1 | Lift and Re-lay | P | 40% | | | | 40% | |
| | | 2 | Replacement (Bituminous) | VP | 40% | | | | | 40% |
| 4 | FLAGS&BITUM[60%] | 1 | Lift and Re-lay | P | 60% | | | | 60% | |
| | | 2 | Replacement (Bituminous) | VP | 60% | | | | | 60% |
| 5 | FLAGS&BITUM[80%] | 1 | Lift and Re-lay | P | 80% | | | | 80% | |
| | | 2 | Replacement (Bituminous) | VP | 80% | | | | | 80% |
| 6 | FLAGS&BITUM[100%] | 1 | Lift and Re-lay | P | 100% | | | | 100% | |
| | | 2 | Replacement (Bituminous) | VP | 100% | | | | | 100% |
| 7 | BITUM[20%] | 1 | Replacement (Bituminous) | P | 20% | | | | 20% | |
| | | 2 | Replacement (Bituminous) | VP | 20% | | | | | 20% |
| 8 | BITUM[40%] | 1 | Replacement (Bituminous) | P | 40% | | | | 40% | |
| | | 2 | Replacement (Bituminous) | VP | 40% | | | | | 40% |
| 9 | BITUM[60%] | 1 | Replacement (Bituminous) | P | 60% | | | | 60% | |
| | | 2 | Replacement (Bituminous) | VP | 60% | | | | | 60% |
| 10 | BITUM[80%] | 1 | Replacement (Bituminous) | P | 80% | | | | 80% | |
| | | 2 | Replacement (Bituminous) | VP | 80% | | | | | 80% |
| 11 | BITUM[100%] | 1 | Replacement (Bituminous) | P | 100% | | | | 100% | |
| | | 2 | Replacement (Bituminous) | VP | 100% | | | | | 100% |

**Figure D1: Treatment Strategies**

Run Analysis ... | Clear selected row(s) | Copy selected cell(s) | Paste copied cell(s)

| | | | | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|
| No. | Homogeneous Group | Scenario Name | Criteria | 2012 | 2013 | 2014 | 2015 | 2016 |
| 1 | Flags | Do Nothing | Transition matrix | Flags | Flags | Flags | Flags | Flags |
| | | | Treatment strategy | Do Nothing | Do Nothing | Do Nothing | Do Nothing | Do Nothing |
| | | | Budget constraint | | | | | |
| | | | Performance target | | | | | |
| 2 | Bituminous | Do Nothing | Transition matrix | Bituminous | Bituminous | Bituminous | Bituminous | Bituminous |
| | | | Treatment strategy | Do Nothing | Do Nothing | Do Nothing | Do Nothing | Do Nothing |
| | | | Budget constraint | | | | | |
| | | | Performance target | | | | | |

**Figure D2: Illustration of 'Scenario' worksheet under the 'Do Nothing' scenario (Scenario 1)**

| Run Analysis ... | Clear selected row(s) | Copy selected cell(s) | Paste copied cell(s) |
|---|---|---|---|

| | | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|---|
| Homogeneous Group | Scenario Name | Criteria | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
| Flags | Eliminate VP&P by year 5 and maintain a steady state | Transition matrix | Flags | Flags | Flags | Flags | Flags | Flags |
| | | Treatment strategy | FLAGS&BITUM[20%] | FLAGS&BITUM[40%] | FLAGS&BITUM[60%] | FLAGS&BITUM[80%] | FLAGS&BITUM[100%] | FLAGS&BITUM[100%] |
| | | Budget constraint | | | | | | |
| | | Performance target | | | | | | |
| Bituminous | Eliminate VP&P by year 5 and maintain a steady state | Transition matrix | Bituminous | Bituminous | Bituminous | Bituminous | Bituminous | Bituminous |
| | | Treatment strategy | BITUM[20%] | BITUM[40%] | BITUM[60%] | BITUM[80%] | BITUM[100%] | BITUM[100%] |
| | | Budget constraint | | | | | | |
| | | Performance target | | | | | | |

**Figure D3: Illustration of 'Scenario' worksheet under Scenario 2**

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