Lighting columns: review of risk assessment strategy and production of a condition indicator

by R W Jordan, M G Evans and M McKenzie

UPR/ISS/29/05

PPAD 9/100/84

UNPUBLISHED PROJECT REPORT
LIGHTING COLUMNS: REVIEW OF RISK ASSESSMENT STRATEGY AND PRODUCTION OF A CONDITION INDICATOR

by R W Jordan, M G Evans and M McKenzie

Prepared for: Project Record: PPAD 9/100/84
Lighting columns: review of risk assessment strategy and production of a condition indicator
Client: County Surveyors’ Society (Mr R Elphick)

Copyright TRL Limited  September 2005

This report has been prepared for the County Surveyors’ Society (CSS) is unpublished and should not be referred to in any other document or publication without the permission of the CSS. The views expressed are those of the authors and not necessarily those of the CSS.
This report has been produced by TRL Limited, as part of a Contract placed by CSS. Any views expressed are not necessarily those of CSS.

TRL is committed to optimising energy efficiency, reducing waste and promoting recycling and re-use. In support of these environmental goals, this report has been printed on recycled paper, comprising 100% post-consumer waste, manufactured using a TCF (totally chlorine free) process.
CONTENTS

Executive summary i

1 Introduction 1

2 Background 2

3 Data obtained from highway authorities 2

4 Main findings from data analysis and feedback from authorities 5

  4.1 Variation in the failure rate with the Priority 6
    4.1.1 Steel columns that are neither Stewart and Lloyd nor British Steel 6
    4.1.2 Stewart and Lloyd and British Steel columns 7
  4.2 Consequence Scores 7
  4.3 Feedback from local authorities 8

5 Proposed changes to the risk model 9

  5.1 Factors used to calculate the Action Age 9
    5.1.1 Factor f: Environmental conditions 9
    5.1.2 Factor h: Root treatment 9
    5.1.3 Factor i: Wind exposure 9
    5.1.4 Factor n: Design standard 10
  5.2 Factors used to calculate the Consequence Score 10
    5.2.1 Factor A: Traffic flow 10
    5.2.2 Factor C: Location 10
    5.2.3 Factor D: Pedestrian density 10
    5.2.4 Factor E: Effect of failure: traffic disruption 11
  5.3 Changing the Action Age 11
    5.3.1 The significance of the Action Age 11
    5.3.2 Proposed changes to the risk model formulae and maximum Action Ages 12

6 How the risk assessment strategy should be used 16

  6.1 Visual inspections 16
  6.2 Columns with ‘unapproved’ appendages 16
  6.3 Columns with features with a history of problems 17
  6.4 What action should be taken at or beyond the Action Age 17
    6.4.1 Assess and do nothing 18
    6.4.2 Visual inspection 18
    6.4.3 Indicative testing 18
    6.4.4 Strength testing 18
    6.4.5 Removal/replacement 18
  6.5 Prioritising columns for action 18
  6.6 Changing the Priority after action has been taken 19

7 Inclusion of brackets in the risk assessment strategy 21

  7.1 Steel columns 21
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.2</td>
<td>Concrete columns</td>
<td>21</td>
</tr>
<tr>
<td>7.3</td>
<td>Summary</td>
<td>21</td>
</tr>
<tr>
<td>8</td>
<td>Production of a structural condition indicator for columns</td>
<td>22</td>
</tr>
<tr>
<td>9</td>
<td>Production of an overall condition indicator for columns</td>
<td>25</td>
</tr>
<tr>
<td>10</td>
<td>Conclusions</td>
<td>25</td>
</tr>
<tr>
<td>11</td>
<td>Acknowledgements</td>
<td>27</td>
</tr>
<tr>
<td>12</td>
<td>References</td>
<td>27</td>
</tr>
<tr>
<td>Appendix A</td>
<td>Terminology</td>
<td>29</td>
</tr>
</tbody>
</table>
Executive summary

TRL Report UPR/ISS/29/05: Lighting columns: review of risk assessment strategy and production of a condition indicator

Project Reference: Lighting columns: review of risk assessment strategy and production of a condition indicator
Project Officer: Mr R I Elphick, County Surveyors’ Society
Project Manager: Mr R W Jordan, TRL Limited

Scope of the project

In 1999, TRL was commissioned by the Highways Agency, County Surveyors’ Society and the Institution of Lighting Engineers to develop a risk assessment strategy to prioritise columns for action to determine their structural condition (McKenzie and Jordan, 2002). The strategy was incorporated into the second edition of Technical Report Number 22 – Lighting Columns and Sign Posts: Planned Inspection Regime (Institution of Lighting Engineers, 2002). Further to this, Capita Symonds developed a structural condition indicator for road lighting for the Highways Agency in April 2003 that is based on the risk model developed by TRL as part of the risk assessment strategy (Price, 2003).

In October 2004, TRL was commissioned by the Department for Transport and the County Surveyors’ Society to review the risk assessment strategy in Technical Report Number 22 and the work carried out by Capita Symonds. The main objectives of the project were to determine whether the prioritisation procedures in the risk assessment strategy are consistent with expectations and expert opinion, determine any amendments or supplementary advice needed to ensure consistency of the application of the process, determine the suitability of the condition indicator established by Capita Symonds, and determine any amendments or supplementary advice needed to allow a condition indicator process to be adopted nationally.

This report summarises the main findings of the study and recommendations for the revision of Technical Report Number 22. A separate report describes in detail the data obtained from local authorities and the analysis that was carried out during the study (Jordan, Evans and McKenzie, 2005).

Summary

The risk assessment strategy in Technical Report Number 22 assigns columns with problem features and ‘unapproved’ appendages a high priority for action. Other columns are prioritised using a risk model that calculates the age, referred to as the Action Age, at which deterioration of a column is likely and action is required to determine the effect of any deterioration on its strength. The Action Age falls within a predefined range that is specified for different column types.

The inventory data required for the risk model, which concerns the column type, the protective treatment and the environmental conditions, along with test or condition results were requested from a number of authorities, but only six authorities were able to provide both the data and the results. Where possible, the Action Age was calculated for each column, and this was compared with the Current Age. The failure rate of columns that had been tested was determined for columns of different Priority; the Priority is the difference in the Current Age (or Test Age) and the Action Age.

It was found that some columns that were younger than their Action Age had failed tests, but this was possibly because they had ‘unapproved’ appendages. Generally, however, many columns older than their Action Age had passed tests or were in a satisfactory condition. The failure rate of columns in Durham was found to increase with the Priority up to a certain Priority. The rate then decreased at high Priorities, possibly because the columns were older and had thicker sections because they were designed to a different standard. The failure rate was much higher for columns in streets in which at least one column had failed than for all columns in all streets.
In view of the data analyses, the risk model was amended to increase the Action Age of columns away from sea fronts and areas of heavy industrial pollution. The Action Age of some types of column near sea fronts and in areas of heavy industrial pollution has been decreased because of concerns about such columns.

Some authorities have experienced difficulties using the risk model because the criteria values of some factors were not well defined. Therefore, the criteria values for the factors that concern the environmental conditions, root protection, wind exposure, traffic flow, pedestrian density and the effect of a column failure on traffic disruption were amended.

Changes to the risk assessment strategy in Technical Report Number 22 were proposed that are based on the strategy developed by two authorities. Columns with features with a history of problems should be tested as a matter of urgency and on a regular basis whenever any guarantee period for the test method used has expired. Columns with ‘unapproved’ appendages should be tested as a matter of urgency. However, they may be reassessed in the same way as other columns once their strength has been proven.

Other columns should be prioritised according to their Priority. Initially, the Priority should be calculated as the difference in the Current Age and the Action Age. After testing, the Priority should be reduced by the guarantee period for the test method used, and the Priority should be increased by 1 each year. Prioritisation for testing should be reassessed each year. Further prioritisation is possible on the basis of the Consequence scores calculated by the model. Factor F, which is required to calculate the Consequence score, has been omitted from Appendix B issued by the Lighting Board. It is proposed that a new factor is included in inventories to identify the design standard. This is required for load testing and possible future refinement of the risk assessment strategy.

Any action taken will be dependent on the available resources and requires engineering judgement. Possible actions are to assess and do nothing, visual inspection, indicative testing, strength testing and removal/replacement. The risk assessment strategy should not be seen as a substitute for visual inspections. Visual inspections should be carried out throughout the life of a column, and the Action Age should be changed if defects are noted before the Action Age.

A methodology for calculating a condition indicator score for the structural condition of columns has been developed which can be used by authorities to determine the average condition of their lighting stock. It is based on the methodology proposed by Capita Symonds. It takes into account some deterioration in condition before the Action Age. The age at which the score for a column falls to zero is either twice the Action Age or 40 years, whichever is the lesser. The mean condition indicator scores for the Durham and Cornwall inventories, calculated using the revised methodology, were 5.47 and 9.05, respectively, reflecting the differences in the ages and types of column in the two authorities.

Recommendations have been made concerning the development of condition indicators for the electrical integrity and energy consumption, and the optical performance of columns. These could be used to derive an overall condition indicator each column and help engineers determine when it is appropriate to test, upgrade/refurbish or replace a column.

To summarise, the risk model has been amended so it is easier to use and reflects the findings from the data provided by authorities. The risk assessment strategy developed by two authorities for prioritising columns for testing has been proven and should be adopted by all authorities. There is an urgent need for authorities to populate their inventories with the data required to use the risk model and risk assessment strategy described in Technical Report Number 22 and to calculate the mean condition indicator score of their lighting column stock.

**Implementation**

The recommendations from this study should be included in the next revision of Technical Report Number 22. The methodology for calculating a condition indicator score for the structural condition of columns, and the mean score for the stock owned by an authority should be included in LTP2 guidance notes.
1 Introduction

There are over 6.5 million lighting columns on highways in the UK of different ages ranging from brand new to over 50 years old. The limited funding available to highway authorities for regular replacement has resulted in deterioration in the structural condition of the lighting column stock due to corrosion and fatigue cracking. Many columns have deteriorated to the point where it is not known if they can withstand the in-service loading. Although column collapses are infrequent, some have resulted in fatalities and significant compensation payments to victims from highway authority budgets with inevitable increases in insurance premiums. The type and amount of deterioration of some columns have been attributable to design defects, such as internal corrosion at hot-swaged joints and cracking at square cornered door openings. Other columns have deteriorated because of the ineffectiveness of their protective treatments and the harshness of their environment. Therefore, the condition of each column is dependent on its design, its protective treatment and its environment.

In 1999, TRL was commissioned by the Highways Agency, County Surveyors’ Society and the Institution of Lighting Engineers to identify suitable non-destructive testing methods for determining the structural condition of columns (Jordan, McKenzie, Vassie and Ofori-Darko, 2001) and to develop a risk assessment strategy that was designed to prioritise columns for further action (McKenzie and Jordan, 2002). The strategy was to serve two purposes. Firstly, it was to identify the columns that were most at risk of collapse. Secondly, by using it and acting on its recommendations, it was to enable highway authorities to demonstrate that they had exercised due care in reducing the risk of lighting column failure to as low a level as is reasonably practicable.

The risk assessment strategy was incorporated into the second edition of Technical Report Number 22 – Lighting Columns and Sign Posts: Planned Inspection Regime (Institution of Lighting Engineers, 2002), and highway authorities have been encouraged to use it. However, few authorities appear to be using the strategy either because they prefer to use an alternative approach or because they do not have the inventory data required for the model that is specified in Appendix B issued by the Lighting Board and referred to in ‘Well-lit Highways’ (Roads Liaison Group, 2004). Further to this, Capita Symonds developed a structural condition indicator for road lighting for Highways Agency in April 2003 that is based on the risk model developed by TRL (Price, 2003). It is anticipated that highway authorities will be required to derive an overall condition indicator for their stock from the year 2006/07 as part of LTP2.

In view of the above, in October 2004, TRL was commissioned by the Department for Transport and the County Surveyors’ Society to review the risk assessment strategy in Technical Report Number 22 and to review the work carried out by Capita Symonds. The main objectives of the project were to:

- obtain data required to assess the risk model from local authorities;
- set up a programme to analyse the data and determine whether the prioritisation procedures in the risk assessment strategy are consistent with expectations and expert opinion;
- determine any amendments or supplementary advice needed to ensure consistency of the application of the process and the results;
- determine the suitability of the condition indicator established by the Symonds Group;
- determine any amendments or supplementary advice needed to allow a condition indicator process to be adopted nationally; and
- recommend further research necessary on the risk assessment of lighting column condition and to establish an overall road lighting condition indicator.

A separate report describes in detail the data obtained from local authorities, the analysis of the data and the effect of proposed changes to the risk model and the method of calculating the condition indicator scores (Jordan, Evans and McKenzie, 2005). This report summarises the main findings and recommendations for inclusion in a revision of Technical Report Number 22.

The terminology used throughout this report is defined in Appendix A.
2 Background

Technical Report Number 22 describes a risk assessment strategy that was developed to help prioritise when, under normal circumstances, action should be taken to establish the condition of lighting columns. The strategy, which is shown in Figure 1, recommends that columns with certain features such as right-angled door openings, hot swaged joints, and ‘unapproved’ appendages should be first priority for action. An ‘unapproved appendage is an attachment or luminaire that is greater or heavier than that for which a column was designed, or a height extension for which a column was not designed (see Appendix A). Other columns should be prioritised as first or second priority using a risk model that processes inventory data and calculates an Action Age for each column. The Action Age is the age when deterioration of the column is likely. Columns older than their Action Age should be first priority. Columns less than their Action Age but more than 24 years old should be second priority for action. The risk model also calculates a Consequence Score for each column that is indicative of the consequences of a column failure. The Score can be used to further prioritise columns within the first and second priority categories. The priority of all columns should be assessed on an annual basis.

The inventory data required for the model concerns the column type, the protective treatment and the environmental conditions. The Action Age falls within a predefined range that is specified for each of the following column types:

- steel columns with external protection only;
- steel columns with galvanising;
- steel columns with galvanising and additional external protection; and
- concrete columns.

A steel column with galvanising and additional external protection can be classed as such only if the additional external protection was applied while the galvanising was still providing protection.

Technical Report Number 22 indicates what action can be taken at the Action Age, and gives some guidance on how columns could be prioritised if there are insufficient funds to test all columns that are above their Action Age. However, there is no guidance on what action should be taken once columns have been tested and, in particular, after any guarantee that the column is structurally sound has expired.

3 Data obtained from highway authorities

The inventory data required for the risk model were requested from a number of authorities so the Action Age and Consequence Score could be calculated for comparison with the Current Age. Six authorities provided inventory data that were sufficiently complete for the calculation of the Action Age for most, but not all, columns. The reason why other authorities could not provide the data appears to be because they have not populated their databases.

Table 1 and Table 2 summarise the data provided on columns whose condition has been determined from tests or assessments.

Two authorities, Durham and Cornwall, provided their complete inventory, and the other four provided representative samples. None of the authorities provided data on one of the factors required to calculate the consequence score, namely factor F concerning where a column is sited and the effect that failure may have on traffic and pedestrians. This is because the factor was omitted in error from Appendix B issued by the Lighting Board, although it is listed in Technical Report Number 22. However, information on factor F was provided subsequently by Durham and Cornwall.

Durham and Cornwall had used the risk model to prioritise columns for testing. The other four authorities appear to have used other means of prioritisation, e.g. column type, age, group, although this was not significant to the findings of this project.
Where test data were available, the age at test was compared with the Action Age. Some columns would have been tested irrespective of their age as required by the model because they had ‘unapproved’ appendages or have features with a history of problems (Table 3). It was not possible to separate those with and without ‘unapproved’ appendages and problem features, but it was possible to analyse all the Stewart and Lloyd and British Steel columns separately, some of which may have had problem features.

It was not possible to tell from current inventories what percentage of columns had failed tests because data on such columns are normally archived when the columns have been removed or replaced. However, to enable the failure rate to be determined, Durham provided details of columns that had been replaced because they had failed tests.

Figure 1  Original risk assessment strategy shown in Technical Report Number 22
Table 1  Data for columns not manufactured by British Steel or Stewart and Lloyd

<table>
<thead>
<tr>
<th>Authority</th>
<th>Column material</th>
<th>Protective coating</th>
<th>Number of records</th>
<th>Number of records with Action Age</th>
<th>Number of test results/condition scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cornwall</td>
<td>Steel</td>
<td>Galvanised + External</td>
<td>32885</td>
<td>32885</td>
<td>781</td>
</tr>
<tr>
<td>Durham</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sheet steel</td>
<td>External</td>
<td>5212</td>
<td>4342</td>
<td>614</td>
</tr>
<tr>
<td></td>
<td>Tubular Steel</td>
<td>External</td>
<td>22532</td>
<td>17775</td>
<td>4159</td>
</tr>
<tr>
<td></td>
<td>Tubular Steel</td>
<td>Galvanised + External</td>
<td>7389</td>
<td>5660</td>
<td>248</td>
</tr>
<tr>
<td>Staffordshire</td>
<td>Concrete Steel</td>
<td>-</td>
<td>21093</td>
<td>18345</td>
<td>21093</td>
</tr>
<tr>
<td></td>
<td></td>
<td>External</td>
<td>4707</td>
<td>3243</td>
<td>4707</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Galvanised</td>
<td>17075</td>
<td>4256</td>
<td>17075</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Galvanised + External</td>
<td>803</td>
<td>344</td>
<td>803</td>
</tr>
<tr>
<td>Suffolk</td>
<td>Steel</td>
<td>External</td>
<td>354</td>
<td>343</td>
<td>301</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Galvanised</td>
<td>2027</td>
<td>2027</td>
<td>1902</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Galvanised + External</td>
<td>859</td>
<td>855</td>
<td>777</td>
</tr>
</tbody>
</table>

Table 2  Data for columns manufactured by British Steel and Stewart and Lloyd or manufacturer unknown

<table>
<thead>
<tr>
<th>Authority</th>
<th>Column material</th>
<th>Protective coating</th>
<th>Number of records</th>
<th>Number of records with Action Age</th>
<th>Number of test results/condition scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cornwall</td>
<td>Steel</td>
<td>Galvanised + External</td>
<td>1764</td>
<td>1764</td>
<td>196</td>
</tr>
<tr>
<td>Durham</td>
<td>Tubular steel</td>
<td>External</td>
<td>1455</td>
<td>1390</td>
<td>1390</td>
</tr>
<tr>
<td>Gloucestershire</td>
<td>Steel</td>
<td>External</td>
<td>2500</td>
<td>2500</td>
<td>226</td>
</tr>
<tr>
<td>Staffordshire</td>
<td>Steel</td>
<td>External</td>
<td>8</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Galvanised</td>
<td>799</td>
<td>92</td>
<td>799</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Galvanised + External</td>
<td>36</td>
<td>8</td>
<td>36</td>
</tr>
<tr>
<td>Suffolk</td>
<td>Steel</td>
<td>External</td>
<td>656</td>
<td>656</td>
<td>559</td>
</tr>
<tr>
<td>Worcestershire</td>
<td>Concrete Steel</td>
<td></td>
<td>1217</td>
<td>1217</td>
<td>1217</td>
</tr>
<tr>
<td>(manufacturer unknown by TRL)</td>
<td>Steel</td>
<td>External</td>
<td>953</td>
<td>953</td>
<td>953</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Galvanised</td>
<td>846</td>
<td>846</td>
<td>846</td>
</tr>
</tbody>
</table>
### Table 3  Column types with features that require urgent action

<table>
<thead>
<tr>
<th>Column Type</th>
<th>Defective Feature</th>
<th>Problem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel (Cohen)</td>
<td>Right-angled door opening</td>
<td>Fatigue cracks from corners of door opening</td>
</tr>
<tr>
<td>Steel with hot-swaged joint</td>
<td>Brackets with missing bolts or sealing gaskets that enable</td>
<td>Internal corrosion particularly if there is no internal protection</td>
</tr>
<tr>
<td>(Stewart and Lloyd, older British Steel)</td>
<td>water to enter the shafts</td>
<td></td>
</tr>
<tr>
<td>Prestressed concrete</td>
<td>Sealing plugs poorly fitted or not present</td>
<td>Shrinkage of sealing plugs allows ingress of contaminants and water</td>
</tr>
<tr>
<td>(5m Stanton and Staveley Types 1805 and 2005)</td>
<td></td>
<td>which corrode the prestressing wires</td>
</tr>
<tr>
<td>All types</td>
<td>‘Unapproved’ appendages</td>
<td>Wall thickness may be too low to withstand design loading even if there is no corrosion or fatigue cracking</td>
</tr>
</tbody>
</table>

### 4  Main findings from data analysis and feedback from authorities

Full details of the data analysis are given in Jordan, Evans and McKenzie (2005). Only the main findings are described in this report.

The following distributions were calculated for each authority from the data provided (see Appendix A):

- Current Age;
- Action Age;
- Priority at the present time (i.e. the Current Priority); and
- Priority when a column was tested (i.e. the Test Priority).

If the Current Age of a column is 25 years and its Action Age is 20 years, the Priority at the present time, the Current Priority, is 5 (i.e. 25 minus 20). If the same column was tested at 23 years, the Priority when the column was tested, the Test Priority, was 3 (i.e. 23 minus 20). Throughout the report, when test results are discussed, the Priority referred to is the Test Priority. When column ages are discussed, the Priority referred to is the Current Priority. The Priority increases by 1 each year. As discussed in section 6.6, the Priority can be reduced after testing, but the results in this section concern the Priority of columns when they were tested, not those after they were tested with any reductions included.

Although there appeared to be inconsistencies in some data with some column types and their age, the key points regarding the test data can be summarised as follows:

- most of the columns owned by Cornwall were steel columns with galvanising and additional external protection which were younger than their Action Age, but some had been load tested;
- most of the columns tested by Durham were steel columns with external protection only;
- Gloucestershire had ultrasonically tested some columns with hot-swaged joints;
- Staffordshire had assessed the structural condition of columns as good, reasonable, fair or poor;
- Suffolk had load tested all types of steel column; and
• Worcestershire had assigned the same condition score to all columns for which data were provided.

4.1 Variation in the failure rate with the Priority

To gauge the effectiveness of the risk model, the failure rate in load tests was determined for a number of column types in different authorities.

4.1.1 Steel columns that are neither Stewart and Lloyd nor British Steel

The results for columns with external protection only and without hot-swaged joints in Durham are shown in Table 4 for all columns in all streets, and in Table 5 for columns in streets in which at least one column had failed a test. The populations were too small in some cases to make reliable comparisons. However, Table 4 and Table 5 show an increasing trend in the failure rate for Priorities from 0 to 15 and 5 to 20, respectively, and then a decrease in the failure rate at higher Priorities.

One would expect the failure rate to increase with the Priority (Test Priority). Ideally, the risk assessment strategy should identify columns for testing or replacement such that the failure rate is neither too low (e.g. <2 per cent), because that would mean that most of the testing was unnecessary, nor too high (e.g. > 5 per cent), because that would mean that an unacceptably high number of columns are below strength. The trends at higher Priorities in Table 4 and Table 5 could be influenced by changes in the design specification that resulted in the wall thickness of the old columns being greater than that of the newer columns. Although Table 4 and Table 5 show that the failure rate was higher for columns in streets in which at least one column had failed, the Action Ages were similar for columns in such streets and those in streets where there had been no failures.

Table 4 Durham non British Steel or Stewart and Lloyd: Variation in failure rate with Priority for steel columns with external protection only

<table>
<thead>
<tr>
<th>Priority</th>
<th>Population</th>
<th>Percentage failed</th>
</tr>
</thead>
<tbody>
<tr>
<td>-5 to 0</td>
<td>41</td>
<td>2.4</td>
</tr>
<tr>
<td>0 to 5</td>
<td>135</td>
<td>0.7</td>
</tr>
<tr>
<td>5 to 10</td>
<td>302</td>
<td>3.0</td>
</tr>
<tr>
<td>10 to 15</td>
<td>1539</td>
<td>3.7</td>
</tr>
<tr>
<td>15 to 20</td>
<td>1498</td>
<td>2.7</td>
</tr>
<tr>
<td>&gt; 20</td>
<td>770</td>
<td>1.7</td>
</tr>
</tbody>
</table>

Table 5 Durham non British Steel or Stewart and Lloyd: Variation in failure rate with Priority for steel columns with external protection only in streets with at least one failed column

<table>
<thead>
<tr>
<th>Priority</th>
<th>Population</th>
<th>Percentage failed</th>
</tr>
</thead>
<tbody>
<tr>
<td>-5 to 0</td>
<td>3</td>
<td>66.7</td>
</tr>
<tr>
<td>0 to 5</td>
<td>2</td>
<td>50.0</td>
</tr>
<tr>
<td>5 to 10</td>
<td>120</td>
<td>7.5</td>
</tr>
<tr>
<td>10 to 15</td>
<td>372</td>
<td>14.2</td>
</tr>
<tr>
<td>15 to 20</td>
<td>192</td>
<td>21.4</td>
</tr>
<tr>
<td>&gt; 20</td>
<td>77</td>
<td>16.9</td>
</tr>
</tbody>
</table>
In Suffolk, the failure rate of columns with external protection only of Priority greater than 20 was 5.9 per cent. The failure rate of galvanised columns of Priority from 10 to 15 was 1.8 per cent. There had been no failures of columns of lower Priority.

Some columns had been tested that were younger than their Action Age, but this may be because they had ‘unapproved’ appendages. In Durham, the failure rate of galvanised columns with additional external protection of Priority less than -10 was 1.3 per cent. In Cornwall, the failure rate of columns of the same type of Priority less than -10 was 1.4 per cent. In Suffolk, there were no failures of columns of the same type of Priority less than -10.

4.1.2 Stewart and Lloyd and British Steel columns

The results for columns with external protection only and with hot-swaged joints in Durham and Suffolk are shown in Table 6 and Table 7, respectively. The high failure rate in Durham of columns of Priority 5 to 10 may be because these columns had brackets that are not the cap type and had the problem features given in row 2 of Table 3. If so, this would demonstrate the need to test such columns as a matter of urgency.

Table 6 Durham British Steel or Stewart and Lloyd: Variation in failure rate with Priority for steel columns with external protection only

<table>
<thead>
<tr>
<th>Priority</th>
<th>Population</th>
<th>Percentage failed</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 5</td>
<td>42</td>
<td>0</td>
</tr>
<tr>
<td>5 to 10</td>
<td>56</td>
<td>50.0</td>
</tr>
<tr>
<td>10 to 15</td>
<td>195</td>
<td>2.1</td>
</tr>
<tr>
<td>15 to 20</td>
<td>417</td>
<td>1.7</td>
</tr>
<tr>
<td>&gt; 20</td>
<td>621</td>
<td>1.3</td>
</tr>
</tbody>
</table>

Table 7 Suffolk British Steel or Stewart and Lloyd: Variation in failure rate with Priority for steel columns with external protection only

<table>
<thead>
<tr>
<th>Priority</th>
<th>Population</th>
<th>Percentage failed</th>
</tr>
</thead>
<tbody>
<tr>
<td>-5 to 0</td>
<td>48</td>
<td>0</td>
</tr>
<tr>
<td>0 to 5</td>
<td>107</td>
<td>0.9</td>
</tr>
<tr>
<td>5 to 10</td>
<td>117</td>
<td>4.3</td>
</tr>
<tr>
<td>10 to 15</td>
<td>128</td>
<td>0</td>
</tr>
<tr>
<td>15 to 20</td>
<td>92</td>
<td>1.1</td>
</tr>
</tbody>
</table>

4.2 Consequence Scores

Table 8 shows the Consequence Scores for the full inventories of Durham and Cornwall, respectively. As expected, the Scores tended to be higher for Group A than Group B columns. The Scores for Durham mainly fell in the range 1 to 3 because the criteria values for many of the factors were generally low. Therefore, because many Consequence Scores were similar, it would have been difficult to use them to prioritise action. Whereas there were many Scores in Cornwall in the range 2 to 3, there were significant numbers above this range, so prioritisation on the basis of the Consequence Scores would have been possible.
Table 8 Durham and Cornwall Consequence Scores for Group A and Group B columns

<table>
<thead>
<tr>
<th>Consequence Score</th>
<th>Durham Groups A and B</th>
<th>Durham Group A</th>
<th>Durham Group B</th>
<th>Cornwall Groups A and B</th>
<th>Cornwall Group A</th>
<th>Cornwall Group B</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 1</td>
<td>822</td>
<td>40</td>
<td>782</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 to 2</td>
<td>8823</td>
<td>2801</td>
<td>6022</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 to 3</td>
<td>24513</td>
<td>7778</td>
<td>16735</td>
<td>18320</td>
<td>683</td>
<td>17637</td>
</tr>
<tr>
<td>3 to 4</td>
<td>871</td>
<td>864</td>
<td>7</td>
<td>5086</td>
<td>1661</td>
<td>3425</td>
</tr>
<tr>
<td>4 to 5</td>
<td>202</td>
<td>199</td>
<td>3</td>
<td>7690</td>
<td>4366</td>
<td>3324</td>
</tr>
<tr>
<td>5 to 6</td>
<td>617</td>
<td>536</td>
<td>81</td>
<td>1480</td>
<td>25</td>
<td>1455</td>
</tr>
<tr>
<td>6 to 7</td>
<td>20</td>
<td>20</td>
<td>0</td>
<td>6</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>7 to 8</td>
<td>27</td>
<td>27</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 to 9</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 to 10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.3 Feedback from local authorities

Several local authorities that have used or considered how they would use the risk assessment strategy in Technical Report Number 22 commented on some deficiencies in the strategy and the risk model (Williams and Smith, 2004).

The main areas of concern were as follows:

- The risk model should take account of further root treatments;
- Some of the criteria values in the risk model are not well defined, including those for:
  - Factor f: Environmental conditions;
  - Factor h: Root protection;
  - Factor i: Wind exposure;
  - Factor n: Design standard (new factor for future use)
  - Factor A: Traffic flow;
  - Factor C: Location;
  - Factor D: Pedestrian density;
  - Factor E: Effect of failure: traffic disruption;
- Guidance on how columns with problem features should be included in the strategy after testing (see section 6.3);
- Guidance is required on what action should be taken at the Action Age (see sections 6.4 and 6.5);
- Guidance is required on how the Priority should be changed after action has been taken (see section 6.6).
5 Proposed changes to the risk model

Following analysis of the data and feedback obtained from authorities, a number of changes to the risk model are proposed.

5.1 Factors used to calculate the Action Age

5.1.1 Factor f: Environmental conditions

The protective treatment of a column can deteriorate at a higher rate near a sea front where there is exposure to salt spray and abrasion by sand. Similarly, columns in areas of heavy industrial pollution can deteriorate prematurely. Rather than be too prescriptive about how near a sea front should be or how heavy the industrial pollution, the criteria values should be changed as follows:

Criteria value 4: Near sea front or in area of on-going heavy industrial pollution where there is a history of premature deterioration;
Criteria value 2: Inland urban or industrial; and
Criteria value 1: Inland rural.

The Zinc Millenium Map (Galvanizers’ Association, 2000) could be used for further guidance.

5.1.2 Factor h: Root treatment

Technical Report Number 26 – A Practical Guide to the Painting of Lighting Columns and Brackets (Institution of Lighting Engineers, 2003) recommends that steel lighting columns be hot dip galvanised to BS EN ISO 1461 (British Standards Institution, 1999) as the primary means of protection and that consideration be given to applying a protective paint system in the factory under controlled conditions at the time of manufacture in order to preserve and extend the life of the galvanising. The section on root treatments states that a bitumen coating generally applied to the exterior of the root does not perform well in the ground, and that there are known environmental problems with its use. Alternative treatments are recommended for the inner and outer surfaces of the root to a height of 250mm above ground level. Three of these treatments are suggested where a tougher and more resistant finish to abrasion is required, namely:

Option R1 – a four coat Epoxy MIO system that requires mordant solution;
Option R2 – a four coat vinyl/vinyl copolymer MIO system that requires mordant solution; and
Option R3 – a two coat epoxy glass flake system that requires mordant solution.

To take account of this information, the criteria values for Factor h (Root Protection) should be changed as follows:

Criteria value 4: Columns with no additional protection or a thin bituminous coating
Criteria value 2: Columns with a thick and durable bituminous coating, or columns with alternative treatments except options R1, R2 and R3.
Criteria value 1: Columns with full depth foundations that extend above ground level, or columns with alternative treatments R1, R2 and R3.

5.1.3 Factor i: Wind exposure

The European Standard EN 40-3-1 (British Standards Institution, 1996) that specifies design loads for lighting columns requires the wind pressure at any height above ground to be calculated from the product of the reference wind pressure, a factor dependent on the column size, a factor dependent on the dynamic behaviour of the column, a topography factor and a factor dependent on the local terrain and the height above ground. Therefore, the magnitude of the wind loading should be taken into account in the design of columns. However, factor i is intended to allow for how frequently wind
loading may occur. For consistency with EN 40-3-1, the criteria values should be changed so they correspond to those for terrain categories I to IV in Table 1 of the Standard, as follows:

Criteria value 4: Near sea front or lakeshore or in open country with few obstacles (equivalent to categories I and II);
Criteria value 2: Suburban or industrial areas and permanent forests (equivalent to category III); and
Criteria value 1: Urban areas with at least 15 per cent of surface covered with buildings (equivalent to category IV).

5.1.4 **Factor n: Design standard**

It is proposed that a new factor is included to identify the design standard. Possible standards are BS 1840 (British Standards Institution, 1960), BS 5649 (British Standards Institution, 1982), EN 40 (British Standards Institution, 2000), Departmental Standards BD 26: *Design of lighting columns* (Highways Agency, 1986; 1992; 1994; 1999). Information on the design standard is required for load testing (see section 6.4.4) and possible future refinement of the risk assessment strategy.

5.2 **Factors used to calculate the Consequence Score**

5.2.1 **Factor A: Traffic flow**

The criteria values for traffic density should be changed so they are based on categories in Well-maintained Highways (Roads Liaison Group, 2005a):

Criteria value 4: Road Category 1 (motorways) and Category 2 (strategic routes);
Criteria value 2: Road Category 3a (main distributors) and Category 3b (secondary distributors); and
Criteria value 1: Road Category 4a (link roads) and Category 4b (local access roads), and residential roads.

A possible alternative would be to use the HAUC road categories, with Type 0 and 1 roads carrying over 10 million standard axles (msa), Type 2 roads carrying from over 2.5 to 10 msa, and Type 3 and 4 roads carrying no more than 2.5 msa.

5.2.2 **Factor C: Location**

The criteria values for Factor C should be changed so they include bridges over waterways.

Criteria value 4: On a bridge over a trunk road or mainline railway;
Criteria value 2: On a bridge over a principal road or passenger railway or major (busy) waterway;
Criteria value 1: On a bridge over a minor road or minor railway or minor waterway;
Criteria value 0: Not on a bridge or on a bridge over open land or rarely used waterway.

5.2.3 **Factor D: Pedestrian density**

The criteria values for pedestrian density should also be changed so they are based on categories in Well-maintained Highways, and cycle tracks should be included.

Criteria value 4: Footway Category 1a (prestige walking zones) and Category 1 (primary walking routes), bus station, place of entertainment where people gather;
Criteria value 2: Footway Category 2 (secondary walking routes) and Cycle Track; and
Criteria value 1: Footway Category 3 (link footways) and Category 4 (local access footways).
5.2.4 Factor E: Effect of failure: traffic disruption
Factor E has a low weighting factor and, therefore, has a small effect on the consequence score. However, users of the model should determine the extent of the disruption caused by a column failure and its replacement taking into account:

- The traffic flow and the number of traffic lanes
- The presence of alternative routes
- The effect of delays on routes to ferries and airports.

5.3 Changing the Action Age
The overriding conclusion from the analysis of the test results and condition assessments is that many columns have passed a static load test or are in acceptable condition although they are considerably older than their Action Age. Therefore, possible refinement of the risk model to increase the Action Age was investigated that took into account the significance of the Action Age and the variation in the failure rate with the Priority shown in section 4.1.

5.3.1 The significance of the Action Age
The risk model is intended to identify the age when deterioration of a column is likely to start, not the age when deterioration is likely to be sufficient to weaken a column to the point of failure. Steel columns corrode when their protective treatment is no longer effective and their environment is conducive to corrosion. The protective treatment may be damaged by mechanical effects, such as abrasion and impact, prior to, during and after installation. It may be damaged by chemical effects, such as those due to de-icing salt, dog urine and environmental pollution, over a period of time.

Once the protective treatment has been damaged, corrosion can occur at a rate that will be dependent on the presence of oxygen, water and the corrosive agents that may occur in the ground or the atmosphere.

As will be well known to all lighting engineers, columns may suffer significant loss of section due to corrosion before they are below strength. What loss is possible before they are below strength is dependent on how the column was designed and where the corrosion occurs.

The wall thickness and diameter of each section of a column must be such that the strength of the section is sufficient to withstand the design wind loading. Because the bending moment induced by wind loading increases with nearness to the ground, the locations which are of most interest during design are those near the ground and those where there are changes in section. The base of the shaft is one such location for columns with a larger diameter base section. The bottoms of door openings are critical for columns with unreinforced door openings. Both the bottoms of door openings and/or ground level may be critical for columns with reinforced doors.

A column with unreinforced door openings can suffer significant loss of section near ground level away from the door opening. For example, it can have sufficient strength with a hole in its base section that is slightly less wide than the door opening.

Furthermore, most columns are manufactured from tubular or sheet steel of a standard stock size. The wall thickness and section width or diameter may be varied, but the stock size chosen is normally the one with the lowest strength that will satisfy the design requirements. In most cases, therefore, the wall thickness will be higher than is needed to satisfy the design requirements.

Another factor that cannot be overlooked is the change in the design Standard from BS 1840 (British Standards Institution, 1960) to BS 5649 (British Standards Institution, 1982), and from BS 5649 to EN 40 (British Standards Institution, 2000). In general, columns designed to BS 1840 have more substantial sections than those designed to BS 5649. Similarly, wall thickness will have changed with changes to Departmental Standards BD 26: Design of lighting columns (Highways Agency, 1986; 1992; 1994; 1999) since 1986.
The above demonstrates that it is not unduly surprising that columns may have sufficient strength when they are significantly greater than their Action Age. However, some columns could be below strength with little corrosion if that corrosion is at the critical sections.

5.3.2 Proposed changes to the risk model formulae and maximum Action Ages

Although there is scope to increase the Action Age for most columns, comments from lighting engineers suggest that columns in coastal areas, that are subjected to salt spray and sand erosion, and columns in areas with heavy industrial pollution may deteriorate at a faster rate than allowed for in the risk model.

The factor in the probability formulae that concerns these environmental conditions is factor f. As indicated above, changes to the criteria values for this factor are required. Furthermore, the factor should be given greater importance in the model by raising the factor to the power 2 in the relevant formulae. This necessitates other changes to the formulae so the scaling factors cover the range 1 to 2.

The proposed revisions to the model have been incorporated into Table 9 to Table 11. It is proposed that the maximum Action Age for columns with external protection only is increased from 16 years to 20 years, as shown in Table 12. It is considered inappropriate to increase the maximum Action Age of the other steel column types until more test data are available on newer columns designed to BS 5649. Most of those for which test data were provided were designed to BS 1840.
### Table 9 Derivation of Action Ages for steel columns

<table>
<thead>
<tr>
<th>Code</th>
<th>Factor</th>
<th>Criteria value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>b</td>
<td>Column height</td>
<td>&gt; 9m</td>
</tr>
<tr>
<td>c</td>
<td>Ground conditions</td>
<td>poorly drained, clay</td>
</tr>
<tr>
<td>d</td>
<td>Salting of road</td>
<td>precautionary salting</td>
</tr>
<tr>
<td>e</td>
<td>External influences: dog urine, strimmers, herbicide</td>
<td>residential</td>
</tr>
<tr>
<td>f</td>
<td>Environmental conditions</td>
<td>near sea front or in area of ongoing heavy industrial pollution</td>
</tr>
<tr>
<td>h</td>
<td>Root protection</td>
<td>no additional protection or thin bituminous coating</td>
</tr>
<tr>
<td>i</td>
<td>Wind exposure</td>
<td>near seafront or lakeshore, or in open country with few obstacles</td>
</tr>
<tr>
<td>l</td>
<td>Attachments or height extension</td>
<td>yes</td>
</tr>
<tr>
<td>m</td>
<td>Flange plate</td>
<td>buried flange plate</td>
</tr>
</tbody>
</table>

Scaling factor for corrosion of planted column = \[
\frac{[(b+i+l+2h^{1/2}(c+d+e+2f^2))/13.0]^{0.259}}{13.0}\]

Scaling factor for corrosion of flanged column = \[
\frac{[(b+i+l+4m^{1/2}(m-1)(m-2)c/3+d+e+4f^2))/27.0]^{0.217}}{27.0}\]

Scaling factor for fatigue of column not designed for fatigue = \[
\frac{[(b+i+l)/3.0]^{0.5}}{3.0}\]

Action Age = (Age when action is recommended for most favourable conditions from Table 12)/Scaling factor

If data are not available for a factor, the worst case criteria value is assumed. If data are not available for more than three factors, the risk analysis cannot be used.
Table 10 Derivation of Action Ages for concrete columns

<table>
<thead>
<tr>
<th>Code</th>
<th>Factor</th>
<th>Criteria value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>b</td>
<td>Column height</td>
<td>&gt; 9m</td>
</tr>
<tr>
<td>c</td>
<td>Ground conditions</td>
<td>poorly drained, clay</td>
</tr>
<tr>
<td>d</td>
<td>Salting of road</td>
<td>precautionary salting</td>
</tr>
<tr>
<td>e</td>
<td>External influences: dog urine, strimmers,</td>
<td>residential</td>
</tr>
<tr>
<td></td>
<td>herbicide</td>
<td></td>
</tr>
<tr>
<td>f</td>
<td>Environmental conditions</td>
<td>near sea front or in area of ongoing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>heavy industrial pollution</td>
</tr>
<tr>
<td>h</td>
<td>Root protection</td>
<td>no additional protection or thin bituminous coating</td>
</tr>
<tr>
<td>i</td>
<td>Wind exposure</td>
<td>near seafront or lakeshore, or in open</td>
</tr>
<tr>
<td></td>
<td></td>
<td>country with few obstacles</td>
</tr>
<tr>
<td>l</td>
<td>Attachments</td>
<td>yes</td>
</tr>
</tbody>
</table>

Scaling factor = \([(b+i+l+2h^{\frac{3}{2}}\{c+d+e+2f^2\})/17.1]^{0.289}\)

Action Age = (Age when action is recommended for most favourable conditions from Table 12)/Scaling factor

If data are not available for a factor, the worst case criteria value is assumed. If data are not available for more than three factors, the risk analysis cannot be used.
Table 11 Derivation of Consequence Scores

<table>
<thead>
<tr>
<th>Code</th>
<th>Factor</th>
<th>Weighting factor</th>
<th>Criteria value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>A</td>
<td>Traffic flow</td>
<td>5</td>
<td>road category 1 (motorways) and category 2 (strategic routes)</td>
</tr>
<tr>
<td>B</td>
<td>Traffic speed</td>
<td>5</td>
<td>&gt; 50 mph</td>
</tr>
<tr>
<td>C</td>
<td>Location</td>
<td>5</td>
<td>on a bridge over a trunk road or mainline railway</td>
</tr>
<tr>
<td>D</td>
<td>Pedestrian density</td>
<td>6</td>
<td>footway category 1a (prestige walking routes) and category 1 (primary walking routes), bus station, place of entertainment where people gather</td>
</tr>
<tr>
<td>E</td>
<td>Effect of failure: traffic disruption</td>
<td>1</td>
<td>major disruption</td>
</tr>
<tr>
<td>F</td>
<td>Effect of location on probability of collapse causing accident or injury</td>
<td>1</td>
<td>sited on central reserve</td>
</tr>
</tbody>
</table>

Consequences of failure for column near a road = \(F \times (A + B + C + D + E)\)  
Normalising factor = 25.6 (see Note)

Consequences of failure for column in a public area away from road = \(D\)  
Normalising factor = 2.4

1. Calculate weighting factor x criteria value score for each factor.
2. Enter scores in formula and calculate consequence score.
3. Normalise by dividing consequence score by normalising factor to give a value in the range 0 to 10.

Data must be available for all factors to get a reliable score. Hence, if any data are missing, the risk analysis table for consequences should not be used.

Note: The normalising factor for ‘Consequences of failure for column near a road’ has been calculated assuming that there can be no pedestrians on a central reserve, i.e. when the criteria value for factor \(F = 4\), the criteria value for factor \(D = 0\).
Table 12  Age when there is a likelihood of corrosion or fatigue cracking

<table>
<thead>
<tr>
<th>Influencing factors</th>
<th>Corrosion of steel columns</th>
<th>Fatigue cracking of steel columns not designed for fatigue</th>
<th>Concrete columns</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Protective treatment</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>External protective coating only</td>
<td>Galvanised and external protective coating</td>
<td></td>
</tr>
<tr>
<td>Most favourable conditions</td>
<td>20</td>
<td>32</td>
<td>40</td>
</tr>
<tr>
<td>Least favourable conditions</td>
<td>10</td>
<td>16</td>
<td>20</td>
</tr>
</tbody>
</table>

The net effect of the changes to the risk model on the Action Age was investigated using Durham’s full inventory. It was found that, on average, the change in the Action Age should be:

- Increase of 1 year for steel columns with external protection only near a sea front or in heavy industrial pollution
- Increase of 4 years for steel columns with external protection only away from a sea front or heavy industrial pollution
- Decrease of 4 years for galvanised steel columns with or without additional external protection near a sea front or in heavy industrial pollution
- Increase of 3 years for galvanised steel columns with or without additional external protection away from a sea front or heavy industrial pollution
- Decrease of 2 years for concrete columns near a sea front or in heavy industrial pollution
- Increase of 3 years for concrete columns away from a sea front or heavy industrial pollution

Therefore, the changes to the risk model have the desired effect.

6  How the risk assessment strategy should be used

6.1  Visual inspections

The risk assessment strategy requires visual inspections to be carried out at regular intervals after the installation date whenever a column is visited for maintenance. This is because the risk assessment strategy does not take into account deterioration due to unusual service conditions, vandalism, impact damage, manufacturing defects, or material deficiencies. Such defects that are noted before the Action Age should result in a change in the Action Age to the age at the date the defect was identified, and appropriate action should be taken, as indicated in section 6.4.

6.2  Columns with ‘unapproved’ appendages

Action should be taken on columns with ‘unapproved’ appendages to demonstrate that they can withstand the design wind loading, whatever the Current Age. In most cases this will require some form of load testing. However, if the material properties and geometry of the column are known, and the likelihood of premature deterioration is low, the strength could be assessed by design calculations.
Generally, the supplier or manufacturer of the column would be best able to confirm the material properties, determine the geometry, and carry out the calculations. Once the strength of such columns has been proven, they can be included in the risk assessment strategy with the Action Age calculated by the risk model.

If either the strength is assessed by design calculations or a column is tested before its Action Age, the Priority should be calculated as the Current Age minus the Action Age. If a column is tested after its Action Age, the Priority should be made equal to the Current Age minus the Action Age minus the guarantee period in years for the test carried out. The significance of the Priority is discussed further in sections 6.5 and 6.6.

6.3 Columns with features with a history of problems

The risk assessment strategy requires urgent action on columns with features with a history of problems.

Columns with square cornered door openings can suffer cracking at the door openings. Because its extent may not be determined by visual inspection, some form of testing is normally required. As indicated above, on a small loss of section may be needed at door openings before a column is below strength, hence the need for urgent action.

Water can accumulate at the hot-swaged joints of certain Stewart and Lloyd and British Steel columns and cause corrosion on the internal surfaces of columns with external protection only where it cannot be detected visually. Significant corrosion has been attributed to leakage through brackets that are not of the cap type where grub screws or gaskets have been omitted when the bracket was fitted to the shaft, or where grub screw have corroded.

Columns with features with a history of problems can be included in the risk assessment strategy after their strength has been proven. If a column is tested before its Action Age, the Priority could be calculated as the Current Age minus the Action Age. If a column is tested after its Action Age, the Priority could be made equal to the Current Age minus the Action Age minus the guarantee period in years for the test carried out. Subsequent testing could then be determined as outlined in section 6.5. However, it is recommended that such columns are tested on a regular basis as soon as the guarantee period for the test carried out has expired.

6.4 What action should be taken at or beyond the Action Age

The risk assessment strategy in Technical Report Number 22 gives some guidance on how columns should be prioritised for action, but a process has been developed by a number of Authorities that can be recommended to others.

When the risk model has been run on columns not covered by sections 6.2 and 6.3, the Priority of each column should be calculated and the need for action considered when the Priority is 0 or greater.

Possible actions are:

- assess and do nothing;
- visual inspection;
- indicative testing;
- strength testing; and
- removal/replacement.

Any action taken will be dependent on the available resources.
6.4.1 **Assess and do nothing**

It may be appropriate to do nothing where previous visual inspections have shown a column to be in good condition and there are no concerns about any hidden deterioration.

6.4.2 **Visual inspection**

Although visual inspections should have been carried out previously (section 6.1), a more detailed visual inspection could be carried out to identify columns with obvious defects that should be replaced or tested without delay. However, deterioration below ground and on the internal surfaces of columns cannot be detected visually. Therefore, visual inspection cannot determine whether a column is in good condition and it should not be the only action taken if there are concerns about any hidden deterioration. Visual inspections above the Action Age should be in accordance with the detailed inspection described in Well-lit Highways (Roads Liaison Group, 2004).

6.4.3 **Indicative testing**

Indicative testing such as loss of section monitoring or ultrasonic testing can determine the presence of corrosion at some locations both above and below ground. If no significant loss of section is detected, no further action is required. However, if corrosion is detected, the strength of the column should be determined in a strength test.

Where loss of section has been identified on some columns and not others, it may be preferable to strength test all of the columns in a street at the same time.

Indicative testing is likely to be most effective on columns with features with a history of problems which are below or just above their Action Age (see section 6.3).

6.4.4 **Strength testing**

When a column is showing signs of structural deterioration, a strength test should be carried out to determine whether the column has sufficient strength to withstand the design wind loading.

The design standard has changed from BS 5649 (British Standards Institution, 1982) to EN 40 (British Standards Institution, 2000) in recent years, so it is appropriate to strength test columns in accordance with test requirements based on EN 40.

Strength testing that guarantees that a column is structurally sound and should not fail within the guarantee period is recommended.

6.4.5 **Removal/replacement**

If a column has a defect such as a large hole that seriously compromises its strength and makes it poor aesthetically, it should be removed and replaced.

6.5 **Prioritising columns for action**

Possible methods of prioritisation are as follows:

- highest Priority; and
- highest Consequence Score for columns of Priority \( \geq 0 \).

Because of limited resources, most Authorities will have many columns of Priority \( \geq 0 \) and will need to prioritise them for the different actions described above taking into account the Consequence Score.

Authorities should determine the most appropriate method of prioritisation, dependent on the age and condition of their stock. One way to prioritise that takes into account the Consequence Score is to calculate a Risk Score. A Probability Score of, say, 1 could be assigned to columns with a Priority in...
the range from 0 to 5, a Score of 2 to columns with a Priority in the range from 5 to 10 etc. The Probability Score could then be multiplied by the Consequence Score to produce a Risk Score.

As indicated in section 6.3, columns with features with a history of problems should be tested on a regular basis as soon as the guarantee period for the test carried out has expired.

Some lighting engineers consider that, even when there is no leakage through the brackets, corrosion can occur at hot-swaged joints and at the internal steps of columns which are assembled in sections because of condensation on their inside surfaces. Corrosion is more likely on columns which are not galvanised than those that are. However, until more is known about whether corrosion can occur on the inner surfaces of galvanised columns, possible corrosion at the internal steps of all column types must be investigated at regular intervals above the Action Age, whatever their Priority. Possible test methods to detect the presence of such corrosion are loss of section monitoring and ultrasonic testing, but if corrosion is detected, the strength of the column should be determined by testing or the column should be removed or replaced.

6.6 Changing the Priority after action has been taken

The recommended approach is that when action has been taken, the Priority should be reduced by a fixed amount that is equal to length of the guarantee period in years for the test carried out. This means that the Priority of a column that has been tested may remain higher than the Priority of columns that have not been tested. Therefore, checks must be made to prevent further action until the end of the guarantee period.

In the years that columns are not strength tested, their Priority should increase by 1.

It is possible that the Priority of two columns that are identical structurally will be different if one is tested more than the other, but this is not a serious issue.

Of more concern is that newer columns that have a low Priority at the present time may not be so readily identified for testing until their Priority is similar to that of columns with a high Priority that are currently being tested. An example of this is shown in Table 13. Because of changes in lighting column design over the years, new, galvanised columns, although they have better corrosion protection than columns with external protection only, tend to be manufactured from material of lower thickness. Therefore, they can suffer less corrosion than older non-galvanised columns before they are below strength. Some columns designed to BS 5649 may fail before the Priority is as high as the Priority of columns designed to BS 1840 (British Standards Institution, 1960) that are being tested now. It should be noted that the risk assessment strategy requires action to be taken when a column has a Priority of zero or greater.

<table>
<thead>
<tr>
<th>Time</th>
<th>Priority of column being tested</th>
<th>Priority of newer column not yet tested</th>
</tr>
</thead>
<tbody>
<tr>
<td>Now</td>
<td>15 → 10 after strength test</td>
<td>-5</td>
</tr>
<tr>
<td>Now + 5 years</td>
<td>15 → 10 after strength test</td>
<td>0</td>
</tr>
<tr>
<td>Now + 10 years</td>
<td>15 → 10 after strength test</td>
<td>5</td>
</tr>
<tr>
<td>Now + 15 years</td>
<td>15 → 10 after strength test</td>
<td>10</td>
</tr>
<tr>
<td>Now + 20 years</td>
<td>15 → 10 after strength test</td>
<td>15 → 10 after strength test</td>
</tr>
</tbody>
</table>

The revised risk assessment strategy is shown in Figure 2.
Reassessments should be carried out annually to determine what action is required, irrespective of what action has been taken in the previous year.

**Figure 2 Revised risk assessment strategy**
7 Inclusion of brackets in the risk assessment strategy

7.1 Steel columns

Deterioration of column brackets can cause them to collapse, although in most case there will not be the same catastrophic collapse of a bracket as that caused by deterioration of the base or shaft of column. Weld failure can lead to the separation of the bracket arm from the spigot and separation of the luminaire spigot from the bracket arm. In some cases, the internal wiring may support detached items and prevent them from falling to the ground, but this should not be a reason for inaction.

Deterioration of the bracket arm can be noted during routine lamp changes and enable a report to be made for the determination of action. In most cases, the bracket arm can be changed before failure from severe deterioration has become likely. The replacement of bracket arms is a simple operation and relatively inexpensive to undertake. Consequently the risks are far more manageable than the risks associated with the deterioration of the base or shaft of the column near to or below ground level.

Other bracket failures include the loss of the keyway that is provided to prevent bracket rotation or the loss of security due to loose or missing grub screws. This is unlikely to lead to any catastrophic failure but would allow the bracket to rotate and create a misalignment of the luminaire optics resulting in poor lighting performance.

Some flange-mounted brackets have been known to have missing bolts and, in this type of junction, any missing bolt has the potential for catastrophic failure. In practice the factor of safety is fairly high and normally allows the bracket to remain secure without incident. Generally the bolt is missing because it is not possible to replace the bolt for some reason. Either the thread has stripped or the bolt has sheared and cannot be extracted from the socket.

7.2 Concrete columns

It is well known that concrete columns suffer from ‘spalling’ particularly at the junction of the bracket to the column shaft. This quite often affects the bracket and shaft simultaneously. As the column or bracket joint includes a steel insert, this provides additional strength where the concrete loss occurs. This will reduce the risk of catastrophic failure where concrete loss occurs at this point. However, there is a high risk of personal injury when fragments of concrete become detached and fall to the ground.

Provided the base compartment and shaft are in good condition, most lighting engineers will consider cutting off the shaft and bracket and fitting an adaptor bracket. This will generally be economic where the expected remaining life of the shaft is in excess of 5 years. However this approach will be governed by local policy and dependent on the condition of columns generally in the area and the future plans of any redevelopment or refurbishment within the area. It is normally seen as an interim solution to get the most life out of an existing asset.

7.3 Summary

The above indicates that the action needed to prevent the failure or collapse of a bracket can, in most cases, be determined during visual inspections. It is recommended that these inspections are more detailed above the Action Age so the specified defects identified above are noted.

An example of what could be included in an inspection sheet is shown in Table 14. The scores could be summed to indicate the overall condition. Action would be required if any feature had a score of 4.

The Institution of Lighting Engineers and the Lighting Board are considering further the visual inspection of columns, including brackets.
Table 14 Possible inspection sheet for brackets

<table>
<thead>
<tr>
<th>Feature</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Security of bracket fixing to shaft</td>
<td>Extensive cracking of structure around bolts or grub screws</td>
</tr>
<tr>
<td>Security of luminaire attachment to bracket arm</td>
<td>Luminaire fixing loose from hand pressure</td>
</tr>
<tr>
<td>Cracking</td>
<td>Extensive cracking or spalling of structure</td>
</tr>
<tr>
<td>Corrosion</td>
<td>Extensive corrosion with or without loss of surface protection</td>
</tr>
</tbody>
</table>

8 Production of a structural condition indicator for columns

On behalf of the Highways Agency, Capita Symonds (Price, 2003) proposed a methodology for calculating a condition indicator score for lighting columns that is based on the Action Age derived by the risk model in Technical Report Number 22. The function used to calculate the score is shown in Figure 3.
Capita Symonds proposed that the coordinates of P and Q be (0.8, 10) and (1.5, 0). When this function was applied to Durham’s lighting stock (Smith, 2004), it was found that most columns had a score of 10 or 0, and there were few scores in between. It was thought that a change in condition up to point P was more representative than no change, and it was thought that the score should be modified when more was known about the condition of columns after they had been tested.

It is recommended that the change in the condition in the early years is reflected in a change in the y coordinate of point P to 8 (as shown in Figure 4). This is because, generally, there is steady deterioration of the protective treatment of columns below their Action Age, but there should be little material degradation of columns aged 0.8 times their Action Age or less.

Attempts to incorporate test data into the methodology proved to be difficult and several options were considered. One option was to move point Q from (1.5, 0) to (2.0, 0) when a column is within the guarantee period after a strength test. Outside the guarantee period, point Q would revert back to (1.5, 0). Another option was to reduce the effective age of the column by the guarantee period after a strength test, and adopt the score for the effective age. Both these options increase the score when a column has passed a test. However, any options that increase the score were considered to be inappropriate because nothing would have been done to improve the condition of a column.

Depreciation models often assume a linear depreciation with time (Roads Liaison Group, 2005b), but the rate of deterioration can be non-linear. The condition of a column changes slowly when the protective treatment is effective and then decreases more rapidly when the treatment becomes less effective and corrosion occurs. However, just as it is inappropriate to increase the score after testing when nothing has been done to improve the condition of a column, it is inappropriate to reduce the score after it has passed a strength test. Therefore, it was concluded that the profile in Figure 4 should be retained, but that point Q be moved to give a larger range of scores.

Table 15 shows the condition indicator scores for the full Durham inventory assuming different coordinates for point Q. The final two cases assume that the x-coordinate of Q in Figure 4 is adjusted so the score cannot exceed zero when a column is aged 40 or 50 years. The second case gives the lowest mean score, but the third, fourth and fifth cases give similar means that are not much higher than the mean for the first case proposed by Capita Symonds.

![Figure 4 Preferred function for calculating condition indicator scores](attachment:figure4.png)
The preferred function is the fourth case, i.e. \( P \) at \((0.8, 8)\), \( Q \) at \((2, 0)\) or \((x, 0)\) so the product of \(x\) and the Action Age does not exceed 40 years. This is shown in Figure 4. The score should be zero for a column that has failed a test. Forty years is now considered to be the maximum practical life of a column.

For the fourth case, the mean score for the Durham inventory is 5.47, and Table 16 shows that the mean score for the Cornwall inventory is 9.05. These figures reflect the differences in the ages and types of column in the two authorities.

Table 15  Condition indicators scores for Durham inventory calculated using revised risk model and different methodologies

<table>
<thead>
<tr>
<th>Condition indicator score</th>
<th>Number of columns</th>
<th>Number of columns</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( P ) at ((0.8, 10)) ( Q ) at ((1.5, 0))</td>
<td>( P ) at ((0.8, 8)), ( Q ) at ((1.5, 0))</td>
</tr>
<tr>
<td>---------------------------</td>
<td>-------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>0 exactly</td>
<td>10431</td>
<td>10431</td>
</tr>
<tr>
<td>0 to 1</td>
<td>1677</td>
<td>1735</td>
</tr>
<tr>
<td>1 to 2</td>
<td>1637</td>
<td>2406</td>
</tr>
<tr>
<td>2 to 3</td>
<td>1389</td>
<td>5760</td>
</tr>
<tr>
<td>3 to 4</td>
<td>5245</td>
<td>552</td>
</tr>
<tr>
<td>4 to 5</td>
<td>505</td>
<td>356</td>
</tr>
<tr>
<td>5 to 6</td>
<td>272</td>
<td>523</td>
</tr>
<tr>
<td>6 to 7</td>
<td>312</td>
<td>1131</td>
</tr>
<tr>
<td>7 to 8</td>
<td>877</td>
<td>725</td>
</tr>
<tr>
<td>8 to 9</td>
<td>731</td>
<td>8338</td>
</tr>
<tr>
<td>9 to 10</td>
<td>16876</td>
<td>7995</td>
</tr>
<tr>
<td>Mean</td>
<td>5.31</td>
<td>4.67</td>
</tr>
</tbody>
</table>

Table 16  Condition indicators scores for Cornwall inventory calculated using revised risk model

<table>
<thead>
<tr>
<th>Condition indicator score</th>
<th>Number of columns with ( P ) at ((0.8, 8)), ( Q ) at ((2, 0)) or ((x, 0)) so (x) times Action Age (\leq 40)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 to 9</td>
<td>15497</td>
</tr>
<tr>
<td>9 to 10</td>
<td>19161</td>
</tr>
<tr>
<td>Mean</td>
<td>9.05</td>
</tr>
</tbody>
</table>
9 Production of an overall condition indicator for columns

The condition indicator methodology described above concerns only the structural condition of columns because that is the main concern at present. Condition indicators for the other components could be used to derive an overall condition indicator for each column and help engineers determine when it is appropriate to test, refurbish, upgrade or replace a column. The other indicators should concern the:

1. Electrical integrity and energy consumption; and
2. Optical performance and light pollution.

The factors that should be included in an electrical condition indicator are:
- Luminaire type – integral gear or remote gear;
- Ballast type – conventional or electronic (efficiency);
- Capacitor (conventional ballast only);
- Lamp type, rating, efficacy;
- Dimming controls and photocell;
- Power consumption – undimmed and dimmed;
- Connectors;
- Mains supply connection;
- Internal wiring;
- Circuit fuse or Mains circuit breaker;
- Electricity supply cut-out; and
- Feeds to illuminated signs or other street furniture.
- Security for the prevention of unauthorised access.
- Presence of asbestos containing components – rare but possible
- Presence of capacitors containing PCB – rare but possible

The factors that should be included in an optical condition indicator are:
- Lamp type;
- Colour rendering index;
- Lighting standard;
- Illuminance (pedestrian and mixed areas);
- Luminance and specularity (traffic areas);
- Cut-off angle of luminaire (index);
- Overall uniformity;
- Longitudinal uniformity; and
- Lumen maintenance factor.
- Presence of asbestos – rare but possible

Note: Asbestos can still be found in rewirable fuses; around the door openings of old cast-iron feeder pillars and pole mounted cut-out fuse housings. Polychlorinated Biphenyl (PCB) may be present in old capacitors manufactured before 1974.

10 Conclusions

1. There is an urgent need for authorities to populate their inventories with the data required to use the risk model and risk assessment strategy described in Technical Report Number 22, and to calculate the mean condition indicator score of their lighting column stock.

Risk assessment strategy

2. The risk assessment strategy developed by two authorities for prioritising columns for testing has been proven and should be adopted by all authorities.
3. Minor changes have been made to the flow diagram shown in Technical Report Number 22 to reflect best practice.

4. Columns with features with a history of problems should be tested as a matter of urgency and whenever any guarantee period for the test method used has expired.

5. Columns with features with ‘unapproved’ appendages should be tested as a matter of urgency. However, they may be reassessed as other columns once their strength has been proven.

6. Other columns should be prioritised according to their Priority. Initially, the Priority should be calculated as the difference in the Current Age and the Action Age. After testing, the Priority should be reduced by the guarantee period for the test method used, and the Priority should be increased by 1 each year. Prioritisation for testing should be reassessed each year.

7. The risk assessment strategy is not a substitute for visual inspections. Visual inspections should be carried out throughout the life of a column, and the Action Age should be changed if defects are noted before the Action Age.

8. Test results from Durham showed that the failure rate of columns of Priority greater than zero increased with the Priority before decreasing at high Priorities. The failure rate was much higher for columns in streets in which at least one column had failed than for all columns in all streets. The variation in the failure rate with Priority appeared to be dependent on the design code - older columns tend to have thicker sections.

9. Some columns that were younger than their Action Age had failed tests, possibly because they had ‘unapproved’ appendages.

10. Because many columns older than their Action Age had passed tests, the risk model has been amended to increase the Action Age of columns away from sea fronts and areas of heavy industrial pollution. The Action Age of some types of column near sea fronts and in areas of heavy industrial pollution has been decreased.

11. The criteria values of some factors in the risk model have been changed to simplify the use of the model.

12. Analysis of Consequence scores has shown that the range of scores may be lower in some authorities than others. Where the range is reasonably high, it should be possible to prioritise for testing columns of similar Priority on the basis of the Consequence score. Factor F, which is required to calculate the Consequence score, has been omitted from Appendix B issued by the Lighting Board.

13. A means of including brackets in the risk assessment strategy has been proposed.

14. It is proposed that a new factor is included in inventories to identify the design standard. This is required for load testing and possible future refinement of the risk assessment strategy.

**Condition indicators**

15. A methodology for calculating a condition indicator score for columns has been developed which is based on the methodology proposed by Capita Symonds. This can be used by authorities to determine the average condition of their lighting stock.

16. The methodology takes into account some deterioration in condition before the Action Age. The age at which the score for a column falls to zero is twice the Action Age or 40 years, whatever is the lesser. The number of columns with a zero score is lower for the revised methodology than that proposed by Capita Symonds.

17. The mean condition indicator scores for the Durham and Cornwall inventories, calculated using the revised methodology, are 5.47 and 9.05, respectively, reflecting the differences in the ages and types of column in the two authorities.

18. The factors that should be considered when calculating condition indicators for other components of lighting columns have been identified. They concern the electrical integrity and energy
consumption, and the optical performance and light pollution. An overall condition indicator taking into account the structural, electrical and optical condition would help engineers determine when it is appropriate to test, refurbish, upgrade or replace a column.

11 Acknowledgements

The work described in this report was carried out in the Infrastructure and Environment Division of TRL Limited. The Project Manager is Richard Jordan and the Quality Audit and Review Officer is Malcolm McKenzie.

The authors wish to thank the following members of the Steering and Working Groups for their significant contributions to the project:

**Steering Group**
- Edward Bunting  Department for Transport (Chairman)
- Dave Coatham  Institution of Lighting Engineers
- Roger Elphick  Durham County Council
- Mike Rawlings  Consultant
- Glyn Williams  Cornwall County Council

**Working Group**
- Glyn Williams  Cornwall County Council (Chairman)
- Alan Beckett  Highways Agency
- Tony Price  Capita Symonds
- Mike Rawlings  Consultant
- Anthony Smith  Durham County Council

The authors also wish to thank the following Local Authorities that provided data, without which the project could not have been completed:
- Cornwall
- Durham
- Gloucestershire
- Staffordshire
- Suffolk
- Worcestershire

12 References


Appendix A. Terminology

**Action Age**
The age when deterioration of a column is likely and action is required to determine the effect of any deterioration on its strength. It is calculated from data on the column type and its protective treatment and environmental conditions.

**Consequence Score**
A score that is related to the consequences of a column failure on road traffic and pedestrians. It is dependent on the traffic flow and speed, the pedestrian density and location of the column.

**Current Age**
The age of a column at the present time.

**Current Priority**
The Current Age minus the Action Age.

**Guarantee period**
The period after a column has been strength tested during which it should not fail due to structural deterioration.

**Priority**
The Priority used to prioritise columns for action.

If a column has not been tested, the Priority is the Current Priority. The Priority increases by 1 each year, but is decreased by the guarantee period each time a column is strength tested. For example, assuming the following parameters:

- Year installed = 1980
- Action Age = 20 years
- Year of first strength test = 2005
- Year of second strength test = 2011
- Guarantee period = 5 years

Priority in 2004 = Current Age – Action Age = 4
Priority in 2005 before first strength test = Current Age – Action Age = 5
Priority in 2005 after first strength test = Priority before first strength test – Guarantee period = 0
Priority in 2011 before second strength test = Current Age – Action Age – Guarantee period = 6
Priority in 2011 after second strength test = Priority before second strength test – Guarantee period = 1

**Strength test**
A test on a column that guarantees that it is structurally sound and should not fail within a specified guarantee period.

**Test Priority**
The age when a column was first tested minus the Action Age.

**‘Unapproved’ appendage**
An attachment (e.g. sign, hanging basket, banner or decoration) that is larger or heavier than that for which the column was designed.

A luminaire that is larger or heavier than that for which the column was designed.
A height extension for which the column was not designed.