Risk-based investment planning and delivery – Sewerage networks

DCWW case study

Kar Yee Li PhD, MSc, DIC, BEng, Principal Consultant (Strategic Consultancy) . Ewan Group plc.

Abstract

This paper presents a case study application of risk-based prioritisation of sewer maintenance. It addresses the issue of why sewer maintenance planning should be risk based and how this should be linked to strategic investment planning. A proof of concept was demonstrated using data from DCWW.

A concise method (IPaD matrix) for structuring the use of data and their linkages with asset service and performance is also presented.

The results from this study clearly show how maintenance planners could potentially target maintenance in a way that is consistent with the UKWIR Capital Maintenance Planning – A Common Framework. It is proactive rather than reactive in the way that it looks to pre-empt future performance problems that are linked to service.

To allow the approach to have further-reaching benefits, a more in-depth and robust regression style analysis needs to be carried out which deals with

- the data issues encountered as part of this study
- the linkage between service and performance to be established mathematically

In addition, to fully complete the risk assessment, the inclusion of a measure of severity of consequence is needed.

1 BACKGROUND

1.1 Why do we need to invest in sewerage networks?

Water and sewerage companies (WASCs) have a statutory duty to maintain serviceability to customers (Ofwat letter to Managing Directors MD161). This means that it is not enough to demonstrate that the service is being provided, but they must also show that the ability of the assets in continuing to provide that service is maintained.

Companies can choose to invest in their assets either reactively as the assets fail or proactively to prevent future asset failure. To do this requires an understanding of how assets deteriorate in condition over time, how this could give rise to failures in asset performance but more importantly how this change in performance affects the ability of the asset to serve customers. There are stakeholders other than customers that are affected by the way companies invest in their assets. These include:

- Company shareholders or financiers
- The environment
- Staff
- General public

To operate successfully, companies must balance the needs of all the stakeholders. This culminates in the overarching need to manage the assets in a sustainable way that ensures social and economic stability within the corporate and legal framework.

1.2 Why should investment planning be risk-based?

The phrase "maintain sustainability" indicates that companies need to understand how the ability of assets to serve customers might change with time. Unfortunately, the future cannot be predicted with certainty and we must therefore assess the likelihood of failures and their associated consequences. In essence, the two parameters of likelihood and associated consequence give us a measure of expected consequence or what the industry frequently term "risk".

The element of investment planning that relates to understanding how the future is different from what we have observed from the past allows us to demonstrate changes in maintenance investment needs to the Regulator. In 2002, the industry adopted an approach known as the UKWIR Common Framework – Maintenance Investment Planning (CF). The CF addresses the need for companies to be forward-looking in their plans and explicitly includes a forecasting stage to estimate the likelihood of asset failures and their effect on service and costs. This framework has been used by Ofwat to assess the robustness of companies' PR04 capital maintenance investment plans.

Companies were penalised to varying degrees by Ofwat for lack of adherence to the CF in the form of cuts to the companies' proposed plans. As we now embark on AMP4, companies will be required to demonstrate that they can deliver what they have promised for the investment agreed with Ofwat.

This gives us two issues to deal with during this AMP period:

1. how do we ensure that we invest in the right assets?
2. how can we ensure that we put into place the right process and collect the appropriate data to ensure that we can demonstrate the need for capital maintenance for a deteriorating underground asset?

The simple answer to this is to embed the principles of the CF in the investment delivery process. In doing so, capital and operational solutions that are delivered in AMP4 will tie in with the principles adopted in the planning process for PR04, but more importantly, there will be a consistent set of data and analysis tools that will be essential for a less painful and hopefully more successful investment plan for PR09. However, embedding the CF into "business as usual" processes during AMP4 is easier said than done. The CF concepts and processes need to be assimilated by all internal stakeholders to the investment process. In some circumstances, the tools and data to support the processes may not always be available and would therefore need to be developed and collected.

This paper presents an approach which was tested at Welsh Water (DCWW) for prioritising sewer capital maintenance in AMP4. It follows from the original study to develop the PR04 submission for sewer capital maintenance using a strategic investment planning tool called GA*asset*. A brief overview of the linkages between sewer investment prioritisation and strategic business planning is given. This is followed by an outline of work carried out for DCWW as an initial proof of concept with suggestions for future improvements.

2 INVESTMENT DELIVERY – PRIORITISING SEWERS

2.1 Level of application

Following the Final Determination from Ofwat for PR04, investment budgets to varying degrees of detail have been identified for each asset group. In general, companies have identified capital maintenance budgets for groups of catchments and need annual plans of how and where to concentrate their efforts first. Many companies have already pulled together their year 1 and 2 plans. It is essential that companies develop these in line with the CF principles to avoid investing inappropriately and risk non-delivery of promised performance and levels of service.

This work concentrates on the initial prioritisation of sewer catchments for capital maintenance consideration by targetting those catchments where risk reduction is maximised most cost effectively. It aims to provide a ranked list of catchments for further detailed investigations and scheme definition.

This top-down approach is crucial for achieving company level service targets within the resources that have been made available following PR04.

2.2 Criteria for good investment prioritisation

2.2.1 Common Framework compliant

The process for implementing the CF is illustrated in Figure 2.1. The key aspects of these are:

A. Historic analysis – to understand the review maintenance expenditure and historic levels of service
B. Forward-looking analysis – to forecast future service by predicting future service or risk of failure; and assessing the impact of maintenance on forecasted service or risk of failure.
C. Conclusions – to explain any differences in the level of maintenance between historic spend and forecasted spend; and identify any opportunities for further efficiencies.

By being CF compliant, companies will be able to manage their investment programmes to deliver what has been promised in the company business plans. Furthermore, it is widespread belief that the CF is here to stay. Therefore, collection and analysis of data during AMP4 that is in line with the principles of the CF will significantly support preparation for PR09 and beyond.

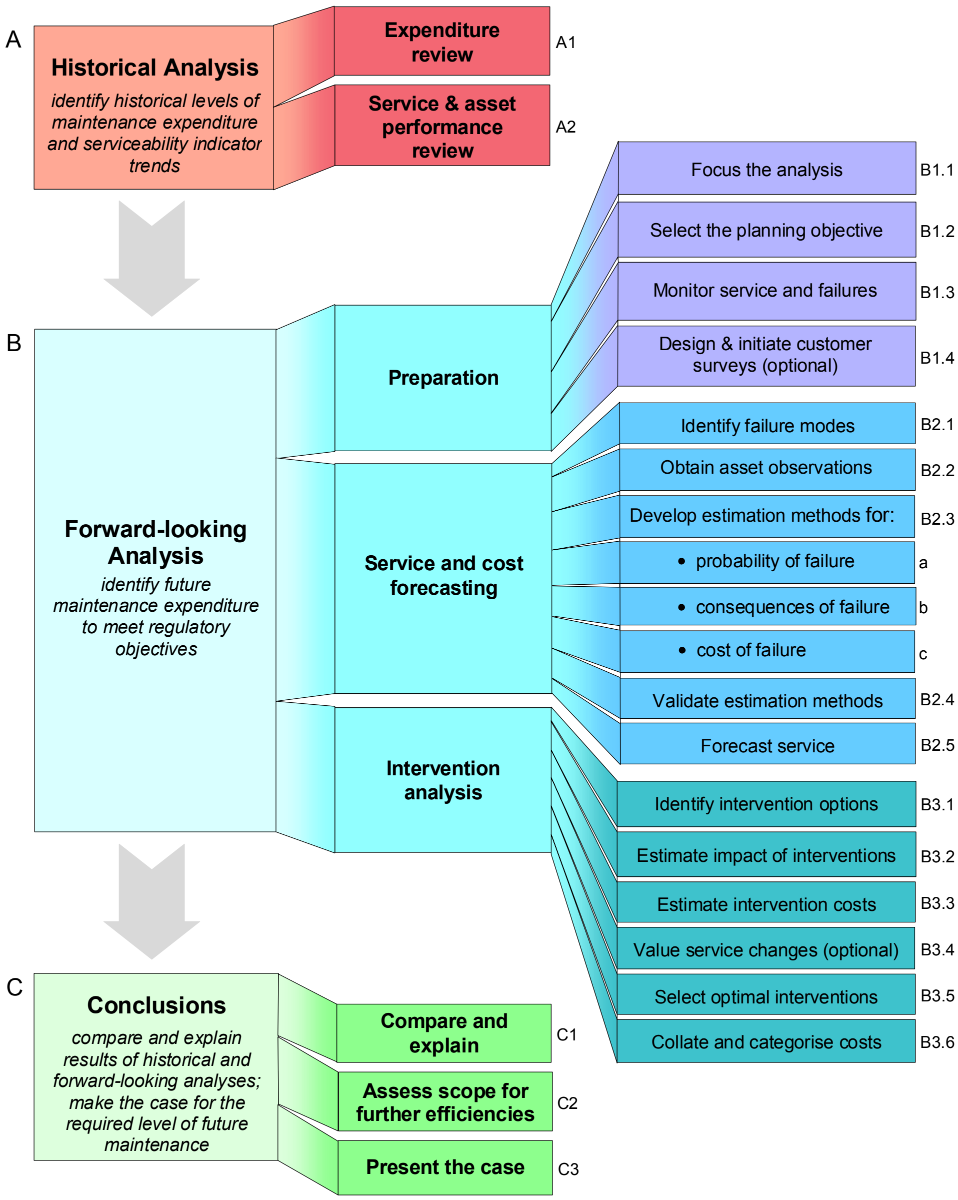

Figure 2.1 UKWIR: Capital Maintenance Planning – A Common Framework Process for implementing the Common Framework

2.2.2 Service driven

Maintenance agreed with Ofwat is generally based on agreed levels of service and investment to maintain the ability of assets to serve customers and the environment. When prioritising catchments for investment, maintenance managers must ensure that the approach is consistent with the company business plan and as a result it must be service driven.

This does not mean that companies should only concentrate on those areas where service has been observed historically to have significant failures. Instead, companies need to understand how asset performance, e.g. collapses, is linked to service, e.g. flooding. In doing so, companies can determine what needs to be tackled in order to manage service.

2.2.3 Forward looking

Where companies ask for capital maintenance that exceeds historic expenditure, they are required to explain why the future requirement is predicted to be different from the past. A robust analysis would be based on sewer performance predictive or deterioration models linked to service and performance of the assets.

The predictive models can be used to give 2 types of measures:

- expected number of performance and service failures
- probability of performance and service failures

Both are measures of likelihood and can be used interchangeably. For example, if the expected number of flooding incidents in a catchment in any one year is predicted to be 2, the equivalent probability of failure is 2 in 365 (or 0.0055).

To calculate risk of failure, the severity (or consequence) of the service failure must be ascertained. For example, given that a service failure (flooding incident) has occurred, the severity of the incident depends on the extent of the consequence. This could be related to the number of properties affected and whether there has been damage to internal or external property. A common currency for calculating the extent of consequences across all asset types is helpful and ideally should be monetised. This allows companies to balance expenditure priorities more objectively. For example, the direct and indirect costs associated with internal and external flooding of properties is a consequential cost and can be combined with likelihood of flooding (service failure) to give risk of failure. In the absence of monetised consequence, a structured approach to assessing the extent of consequences using scores will suffice, but cannot immediately be used to compare one asset type against another.

2.2.4 Cost effective

The priority of maintenance should be targetted at those catchments which offer the highest return for every £ of investment, i.e. what DCWW call “the most bangs for bucks!” The measure “bangs” is inextricably linked to service and the risk reduction associated with the expenditure.

The primary measure for cost effectiveness is:

Risk reduction per £.

This is a measure that reflects the level of benefit generated for every pound. By ranking the highest values as top priority, companies can concentrate on the gaining achieving as much cost effectiveness earlier on in their investment programmes. However, sense-checking of this list is important as certain schemes which are necessary for achieving regulatory and company service targets may require significant lead-in times.

2.2.5 Opportunities for efficiencies

Capital maintenance is only one of the investment activities associated with sewerage. Other investment streams include to flooding due to hydraulic overload (enhancement) and CSO schemes (quality).

By identifying areas of overlap for capital maintenance and other investment schemes, potential efficiencies can be gained. Typically, this might be where maintenance can be carried out at the same time as a CSO or flooding scheme offering maintenance benefits at a lower unit cost of intervention. The overlap of schemes is an important consideration as Ofwat would have taken this into account when setting efficiency targets.

2.2.6 Linked to planning

The benefits of linking the investment programme for delivery with the planning process are far-reaching. Ultimately, this could mean PR09 “at the press of a button.” The other key benefits are:

- Consistent purpose for investment to avoid inappropriate targetting of investment
- Alignment with CF which is considered to be best practice for capital maintenance planning
- Continual updating and learning from ongoing analysis of data that is common to delivery and planning

Figure 2.2 shows a framework for linking the planning process to the delivery process and is a concept known as IPaD (Investment Planning and Delivery) and developed by Ewan Group.

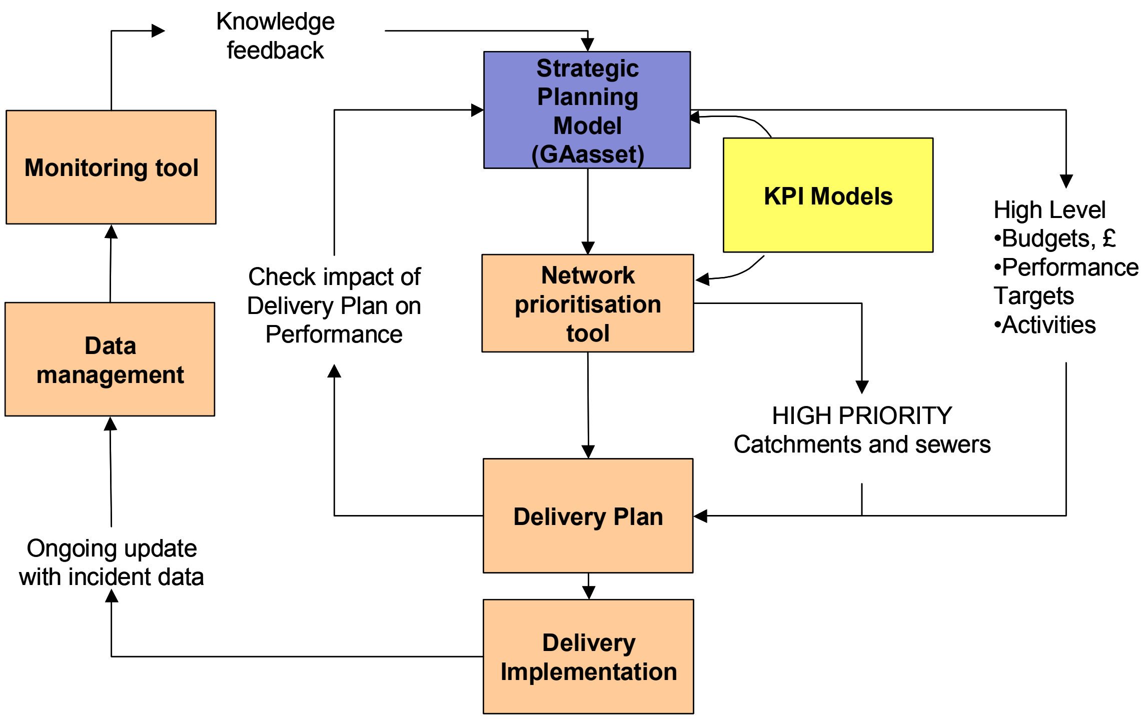

Figure 2.2 Ewan IPaD (Investment Planning and Delivery) framework

The blue box - Strategic Planning Model (GAasset) - represents the model used to develop the strategic business plan. This gives the high level budgets for groups of catchments together with the expected performance targets and associated levels of maintenance activity. To determine these values requires the development of KPI (key performance indicator) models which are used to predict the change in performance over time of the grouped catchments under the following scenarios

1. no intervention or capital maintenance – i.e. " do-nothing"
2. specified mix of interventions or capital maintenance

The GAasset strategic planning model uses the KPI models together with (proactive) intervention and reactive costs to determine the most cost effective (optimal) plan over a 15 year planning horizon.

Once the high level budgets and performance targets for the groups of catchments have been determined, a sewer prioritisation exercise is necessary to establish a programme for targetting the investment at the catchment level.

The prioritisation exercise also depends on KPI models. These should be built up from detailed analysis of asset attributes and their relationship with asset service and performance. Ideally, to avoid misalignment of the "top-down" strategic model outputs with the expected performance from the "bottom-up" sewer investment prioritisation, the KPI models should be the same.

Having prioritised the catchments within their strategic level groups to identify the high priority catchments, the next step would be to determine indicative levels of intervention for each catchment by drilling-down to sewer level and examining the predicted likelihood for asset performance problems. This analysis, combined with the high level budgets and performance targets, can then be used to define a first-cut investment programme.

The intention of the first-cut plan is to target detailed investigations to obtain a better understanding of the potential problems in the high priority catchments and sewers, thereby providing more accurate costs and estimates of impact of interventions. As knowledge is improved, it is essential to re-run the strategic model with updated information to check that the overall company targets can still be satisfied. This feedback of information should continue throughout the delivery stage through purposeful and focussed monitoring of the investments and their beneficial impacts to ensure that the planning models are reflective of latest knowledge.

3 APPLICATION TO DCWW – PROOF OF CONCEPT

3.1 Separating performance and service measures

To justify investments to Ofwat, companies are required to demonstrate that service is at risk should the investment not be available. The driver for investment is therefore asset service (e.g. flooding) and not asset performance (e.g. collapses). However, using service alone to prioritise investment only helps us to identify *where* to invest. To know *how* to invest, we need to understand the underlying failure mode or asset performance failure that has given rise to the service failure. Taking this further still, if we can forecast any likely changes in asset performance failure by looking at *why* asset performance failures occur and linking these to explanatory factors, we can determine the future risk to asset service.

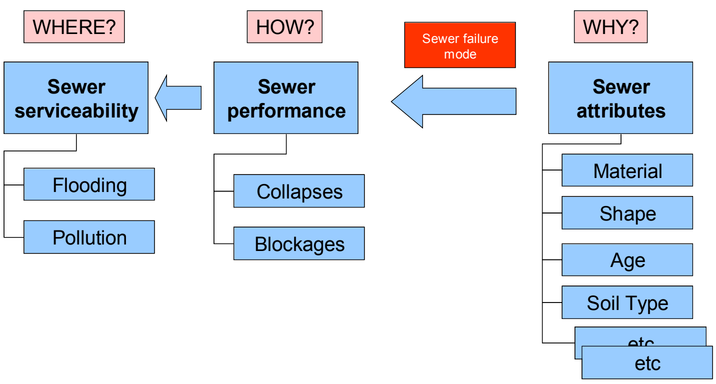

Figure 3.1 illustrates the concept of separating asset service, asset performance and explanatory factors.

Figure 3.1 Separating service from performance

An example of the linkages between service, performance and explanatory factors are shown in the IPaD matrix below (Figure 3.2). The IPaD matrix is a highly visual and simple means for structuring the data required for modelling asset service and performance by clearly establishing causal links.

SERVICE MEASURES						FAILURE MODES	EXPLANATORY VARIABLES																	
REGULATORY				FINANCIAL																				
Flooding		Pollution		Opex																				
Flooding (Other)	Flooding HO	Pollution (sewers)	Pollution (CSOs)	Reactive	Preventative	Performance measure	Age	installation	Size	Material	Shape	Function	Joint type	type/density	Urban	Pipe gradient	Depth	frequency	Soil type	Tree cover	Traffic	Mining	level mode	Pumping station
✔		✔		✔	✔	Sewer blockage	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔			✔	✔				✔
✔		✔		✔	✔	Sewer collapse	✔	✔		✔		✔					✔	✔	✔	✔	✔	✔	✔	

Figure 3.2 Example application: Sewerage IPaD matrix

This matrix has been used to structure the risk based modelling approach for prioritising maintenance of DCWW sewer. The process for the modelling approach is shown in Figure 3.3.

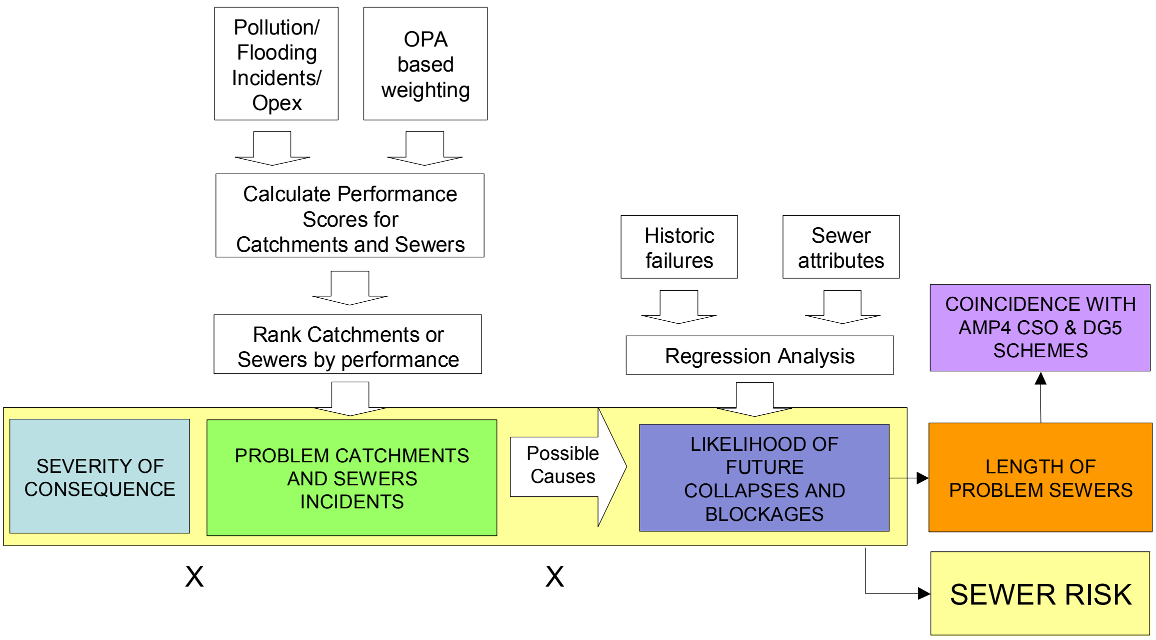

Figure 3.3 Risk based prioritisation of sewerage maintenance

The green box (Problem catchments and sewers incidents) identifies where service problems have been observed in the past. This was derived by combining historic service incidents for each sewer using weightings based on the Ofwat OPA scoring method to give an overall service score. The catchment scores were then generated by aggregating sewer scores and were ranked to identify the worst catchments. However, this only shows where, historically, service problems have been observed.

The following step involved the identification of those catchments that also had a high likelihood of asset performance failure. This was based on an analysis of historic performance failures for blockages and collapses and generating regression relationships with sewer attributes in order to calculate, for the whole asset stock, the likelihood or expected number of collapses and blockages.

The change in likelihood of collapses and blockages occurring in the future were calculated using the regression relationships by simply increasing the age (asset attribute) by 5 years. This gave an indication of the rate at which sewers were deteriorating and helped to identify catchments that would present a problem in the near future.

Finally, additional parameters to aid the maintenance planning process were generated including the length of sewers that exhibited high likelihood of collapses and blockages together with the coincidence with other investment schemes, i.e. CSOs and flooding HO. The former gives an indication of the extent of the problem and the latter identifies those areas that could benefit from additional efficiencies through combining maintenance and quality or enhancement schemes.

3.2 Generating relationships for blockages and collapses

A simple multi-linear regression approach was adopted for this initial proof of concept study, although it is believed that other modelling approaches more suited to the behaviour of sewer performance should eventually be applied.

The regression study identified the following factors as having a statistically significant effect on blockages and collapses.

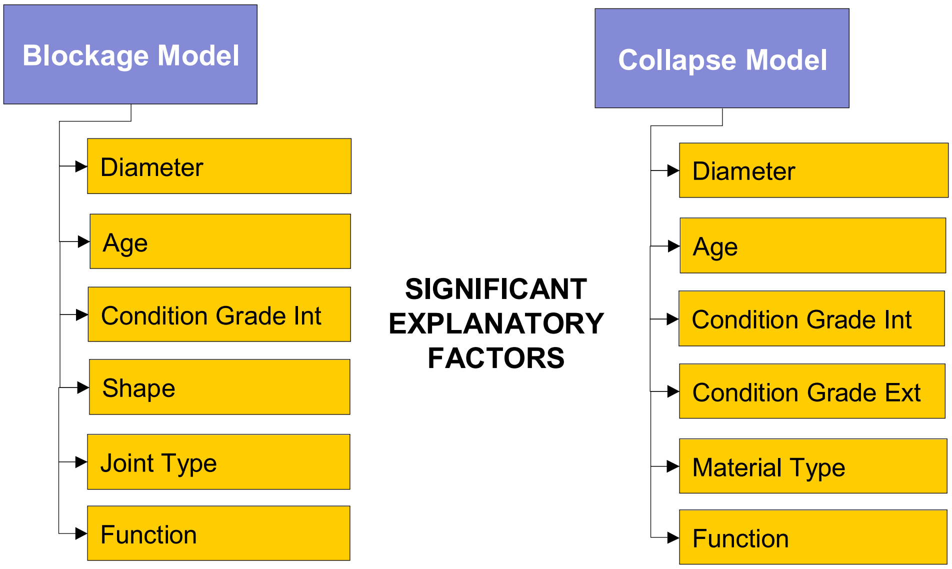

Figure 3.4 Significant explanatory factors of asset performance failures

Although the relationships were not strong, it is believed that this was due to the following factors

- limited data cleansing (within the time available)
- nonlinearity of the relationships
- lack of environmental type data (soil, traffic, groundwater, etc)
- normalisation issues – i.e. the use of sewer lengths to determine appropriate rates of performance problems did not always give a true reflection of the performance of the sewer.

3.3 Illustrative results

Figure 3.5 shows illustrative results based on the regression relationships generated in this proof of concept study. The results show that the majority of historic service problem catchments (red) are most likely to be linked to sewer blockages. However, there are some service problem areas that are associated with high likelihood of blockages and collapses.

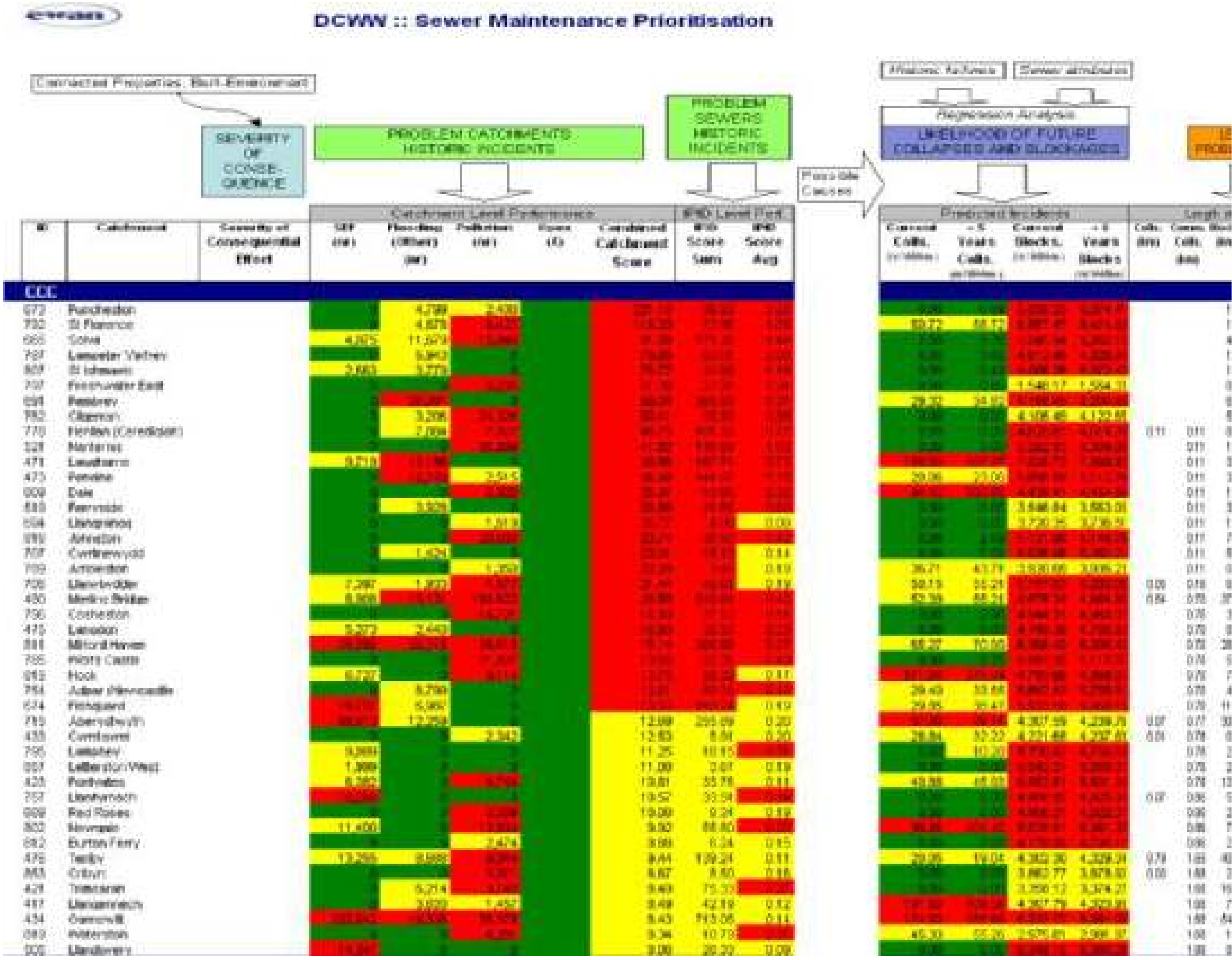

Figure 3.5 Illustrative results for DCWW risk-based sewer maintenance prioritisation

Maintenance planners would be able use these results to target further investigations by concentrating on those areas with high coincidence of service problems and both blockages and collapses. The final columns in Figure 3.5 highlight the lengths of sewer mains that are coincident with mains that are within 500m of CSO and flooding HO schemes. This allows maintenance planners to look for further efficiencies when planning whole catchment solutions.

4 CONCLUSIONS AND FURTHER STUDY

The results from this study clearly show how maintenance planners could potentially target maintenance in a way that is consistent with the CF. It is proactive rather than reactive in the way that it looks to pre-empt future performance problems that are linked to service.

To allow the approach to have further-reaching benefits, a more in-depth and robust regression style analysis needs to be carried out. This needs to allow for

- the nonlinear relationship between explanatory factors and asset performance
- the data issues encountered during the course of this study, and
- the linkage between service and performance to be established mathematically.

In addition, to fully complete the risk assessment, the inclusion of a measure of severity of consequence is needed. The current proof of concept shows only the visual linkage of asset performance to asset service.

Eventually, the approach should include data relating to the typical costs of dealing with the likely asset performance problems and the associated benefits. This allows an assessment of the cost effectiveness of schemes ensuring that companies can additionally target on the basis of “most bangs for bucks”.