Outline of an Asset Management System for Highways

Background
Asset management (AM) was pioneered in New Zealand and Australia in the 1980s and has been adopted by a number of businesses in the UK. In particular it has featured heavily in OFWAT's regulation of the water industry in England and Wales where systems were standardized and methodologies refined. These procedures and systems have been used in many countries across the world enabling water (and other) undertakings to produce investment programs to look after their assets in the longer term. Whilst some have access to standards for compiling an AMS in their industry or country, many do not; this paper seeks to address that problem by providing a model for highways which can be developed further.

Introduction
There is a noticeable lack of consistency involving AM practices which have become commonplace in other industries. Research into the literature for AM in the highways sector reveals that there are systems and guidance notes and some organised methodology, however, the linkage between condition assessment and levels of service is rarely made. Assessment of a widely-praised AMS for highways, developed by a reputable red-brick university in the UK, turned out to be nothing more than a condition based assessment with advice on carriageway maintenance.

This paper is about adapting the basic principles of AM, as developed by the water industry in England and Wales, so that they may be easily adopted by any government body which is responsible for the management of highways leading to a prioritized investment programme as part of an asset management strategy.

There are many ways in which AM may be implemented and consistency is notably lacking in most areas. Some businesses see it as a driver covering the replacement or refurbishment of assets nearing the end of their useful life. Others see it as an all-encompassing management system covering most aspects of the business. The merits of these contrasting approaches are discussed in:

http://felixschrodinger.wordpress.com/2010/11/13/asset-management-%E2%80%93-two-very-different-approaches/

Whichever is to be adopted is a matter for the directors.

How Asset Management Works
This is best illustrated in diagrams which show the interrelationship of the components centred on the asset inventory:

http://felixschrodinger.wordpress.com/2011/08/08/asset-management-presentation/

Slides 6 and 7 show the high level relationship of AM with other components of the management system and slide 29 shows a detailed view of how the inputs and outputs of the asset management system are centred on the inventory.

The inventory is normally a spreadsheet or simple database which includes all of the information relating to the assets to be included. The choice between databases and spreadsheets is a matter for the developer of the AMS but there are some things to consider. Spreadsheets are much easier to use especially during the data collection phase however they are not as good at selecting and sorting classes of asset for further consideration. In a database all records are locked as far as their data are concerned; if the order of the records is changed then all of the associated data will move with each relevant record automatically. This is not necessarily so for a spreadsheet and an unwary user can easily break the link between an asset and its associated data by moving things around in a table.

In the case of highways it is likely that separate tables will be required for differing types of asset, even though the processes will be the same. The inventory will normally consist of inputs including:

- Asset data
- Condition grades
- Performance grades based on 'levels of service'
- Asset lives
- Cost data

And will enable outputs:

- Ad hoc reports
- Prioritization for the investment program
- Current valuation

Each of these aspects will be discussed in some detail in the sections which follow.

Level of detail
Fundamental to the success of an AMS is the level of detail. We could choose to take a whole highway as a single asset but this would militate against any system of practical management. On the other hand including too much detail takes excessive effort and can create confusion through lack of clarity.

A highway must be assessed in two aspects: its sections by length (links) and features which exist at junctions (nodes). It difficult to design a single data table to suit both types of data so careful consideration must be given to how they are set up. A 'link' is a linear section of highway and a 'node' is a junction or other point along the highway where it is split into manageable sections. This concept is common to utilities which manage pipelines and cables but not so much in respect of highways management. It is likely, due to differing data needs that that they will be best managed in separate inventories.

Components of a highway (links)
First a highway must be defined in general (high level) terms and then split into manageable lengths which are based on any change in the basic properties. A change in construction or surfacing is often selected as a node, however, it is suggested that links should not exceed 1km in length and where not otherwise divided, existing route markers should be used. The following data is required in respect of each 'link' and 'node':

- Name
- Unique identifier and/or descriptor (e.g. A562 + detail)
- 'Link' or 'node'*
- Type of highway – e.g. motorway, A road, B road, unclassified, primary estate/distributor, local access/cul de sac
- Start and end points
- Construction – paved, unpaved etc
- Number of lanes
- Builder/constructor
- Capacity

- Average and peak throughput
- Speed limit
- Owner
- Maintainer

Having constructed the main headers for the data table, we now need to input the components of the highway which, for links, will comprise:

- Carriageway formation (CF)
- Carriageway base course (BC)
- Carriageway surface (CS)
- Kerbs and channels (KC)
- Surface water drainage Pipes, ancillaries, ponds etc. (SW)
- Guard rails (GR)
- Lane and edge lines plus reflectors (WL)
- Boundary fencing (BF)
- Lighting (LG)
- Footpath/cycleway base (FB)
- Footpath/cycleway surface (FS)

Each section of highway and component should have a unique identifier which should be self evident, e.g.: A607/17E/BC would be the base course of the eastbound carriageway on section 17 of the A607.

Components of a highway (nodes)
Information about nodes, which may be junctions or intermediate points along the length of the road:

- Bridges (which may be split into components)
- Retaining walls
- Embankments
- Culverts and subways

Major junctions generally come in three types:

- Roundabouts (traffic islands)
- Light controlled junctions
- Uncontrolled junctions

The information concerning these types of junction will vary but must include all of the components (kerbs, base, surface, etc.) as for the main carriageway but will reflect the manner in which the highway has been split. Reference to a map will be essential to show where the carriageway (link) ends and the junction (node) begins.

Ancillaries
It is a matter of judgement about how to include ancillaries; however, their inclusion in the main data tables can lead to over complication. It is suggested, therefore that the following be placed in a separate table:

- Warning and direction signs
- Gantries
- Bus shelters

The following information is then added for each individual asset:

- Asset status - in use or not (code: AB, NW, OP, UC)
- Condition grade (1-5)
- Performance grade (1-5)
- Year of construction/installation
- Asset life (in years)
- MEAV ($ replacement cost)
- Criticality (optional)
- Remarks

Status
Some inventories contain only assets which are in use. This is not quite right as even an abandoned asset has some value if only the residual land on which it resides. Codes are normally used: AB = abandoned; NW = not working; OP = operational/in use; UC = under construction. It is good practice to annotate anything which is not working with a comment in the 'remarks' column.

Condition Data
Condition grading is based on what you see rather than how well the asset performs. It is not dependent upon how well it does its job from the occupier's point of view which is the role of the performance grade. A standard set of condition grades is contained in APPENDIX 1. Generalized definitions can be applied to most assets but not all. Some types of asset have their own defined condition descriptions such as road surfacing which may have a defined set of numerical grades. In this case, the specific asset grades much be converted to the standard 1-5 grading system.

Performance Grading
Performance grades will again, be set but are based on defined levels of service criteria. This can lead to some confusion with the condition grade especially where the road surface in concerned. This can be simplified if physical issues are contained under condition and non-physical things (such as congestion) are placed under performance. Some sample PGs are contained in APPENDIX 2.

Constructed and Asset Life
Each type of asset is accorded an asset life which is based on that experienced by typical assets in a similar environment. A set of standard asset lives is attached in APPENDIX 3. The year of construction/installation is also required as a baseline for the asset life. Age is not used as it changes every year and is not, therefore, stable.

Replacement cost
There are many variations on the definition of the replacement cost but this will tend to be the cost of construction at the time of the survey. Some businesses use the 'Modern Equivalent Asset Value' (MEAV) concept which recognises that the replacement asset may be different from that originally built. Whichever is used, the replacement cost must be the full cost including all contract and administrative overheads. This can often increase the unit rate shown in a bill of quantities by a factor of more than two. The costing MUST be in a stable currency i.e. one with an inflation rate less than 10%.

Criticality
Many systems include a measure of risk assessment, often referred to as 'criticality'. Whilst useful this may not be essential as, in general, the bigger the asset, the more critical it will be. Obviously motorways and A roads will be more critical than B roads or unclassified and this sort of crude assessment may suffice. If a more sophisticated system is required see:

http://felixschrodinger.wordpress.com/2013/11/14/criticality/

Remarks
A remarks field is essential so that any data which is not normal can be explained.

Output - RAL
The first output will be a calculation of the 'remaining asset life' (RAL). Some systems use simple percentages or even life in years based on the condition grade. This fails to recognise that performance is just as important; an undersized asset in perfect condition may require replacement because it is now under capacity. A typical 'look-up' table combining condition and performance is shown below. The RAL is calculated as the percentage RAL times the original asset life.

	Condition Grade				
Performance Grade	1	2	3	4	5
1	100	87	75	62	50
2	87	75	62	50	37
3	75	62	50	37	25
4	62	50	37	25	12
5	50	37	25	12	1

Look-up Table showing the percentage remaining asset life (%RAL).

Output – Valuation
If the replacement cost (MEAV) is multiplied by the percentage remaining asset life, divided by 100 then we have the current asset value (CAV). This gives the current value of the asset but it is unlikely to include the value of the land on which it stands. This should be considered separately.

Prioritization
It remains to examine the asset, in areas or in groups, to determine which have the highest priority. This will include those with the shortest RAL and the highest criticality score. This is a task best done by human inspection and assessment based on the output from the AMS. Computers are not noted for their judgement in these matters. A set of projects, based on either area or asset type, can now be compiled and input to the capital investment program (CIP). Obviously this first attempt will not conform with the available funding profile or practical timescales. The program, which must also contain all new schemes, is then smoothed to take out peaks and troughs whilst allowing for available funding.

APPENDIX 1 –Condition Grades

There are a number of number of numerical grading systems available for use and these may be applied subjectively or objectively based on actual measurements. Amongst these are:

- Surface Distress Index (SDI)
- Ride Comfort Index (RCI)
- Pavement Quality Index (PQI)
- Structural Quality Index (SQI)

Whether one of these, or other, numerical system is adopted is a matter for local consideration and the degree of effort that the asset owner wishes to invest. Whilst such systems will undoubtedly provide a clear unambiguous system of grading, most highway managers will be aware intuitively of the grades and hence their priorities. It is arguable whether the RCI is a 'condition' issue or a 'performance' one. In this scenario it is restricted to condition.

Specific Condition Grade - Formation

The purpose of the formation is to provide a stable and regular support to the base course. Thus the frequency of failure and the regularity of the surface of the formation are pertinent.

Grade	Description
1 – excellent	Stable in all respects with no history of failure; no deviation greater than 20mm
2 – good	Stable in all respects with only very infrequent failure; no deviation greater than 35mm
3 – adequate	Stable in all respects with only occasional failure; no deviation greater than 50mm
4 – poor	Some areas of instability with occasional failures; no deviation greater than 100mm
5 - awful	Unstable with frequent failures; deviation frequently greater than 100mm

Many roads have no surfacing ('sealing' in some countries) and hence the formation also provides the running surface. In this case 'corrugation' and 'rutting' should be taken into account.

Specific Condition Grade - Base Course

The purpose of the base course is to smooth out imperfections in the formation and provide a stable base for the wearing course. The grade could be based on the same system used for the wearing course (below) or it could be related to the performance of the base alone.

Grade	Description
1 – excellent	Stable in all respects with no history of failure; no deviation greater than 10mm
2 – good	Stable in all respects with only very infrequent failure; no deviation greater than 15mm
3 – adequate	Stable in all respects with only occasional failure; no deviation greater than 20mm
4 – poor	Some areas of instability with frequent failures; no deviation greater than 30mm
5 - awful	Unstable with frequent failures; deviation frequently greater than 40mm

Specific Condition Grade - Wearing Course

The grade for the wearing course may be objectively based on a defined methodology or it may subjectively use generic grades. The advantage of an objective system is that it will take both severity and frequency into account in arriving at a combined score which is converted into a grade. An objective system, based on the Pavement Condition Index (PCI)* from Canada might look like this:

Severity	Extent	Value	Score
	none	0	8
Very slight	few	0.5	7
Slight	intermittent	1	6
Moderate	frequent	2	5
Severe	extensive	3	4
Very severe	throughout	4	3

*Establishment of Network Trigger Values for Pavement Management Rehabilitation (Donaldson R MacLeod, 2008)

Grade	Description
1 – excellent	PCI score 8 or better
2 – good	PCI score 7
3 – adequate	PCI score 6
4 – poor	PCI score 5
5 - awful	PCI score 4 or worse

If the country or locality has another available scheme then this should be used as appropriate.

Generic Condition Grades

The grades for other assets can be developed for them specifically or generic definitions can be used:

Grade	Description
1 – excellent	In ‘as new’ condition without minor defects
2 – good	Minor defects only apparent with finishes etc. but no major problems
3 – adequate	Significant minor problems which do not affect overall performance and only occasional major problems
4 – poor	Significant major issues on a regular basis which affect performance but do not affect safety overall
5 - awful	Significant problems which affect performance; unsafe

These grades are applicable, in general terms to most (non mechanical/electrical) assets and may be extended or replaced to deal with particular components where they already have specified condition grades. Where electrical components are present then the grades may be extended by adding a reference to electrical safety.

APPENDIX 2 – Performance Grades

Carriageway Performance Grades
The performance grades for all of the components of the carriageway are based on safety, speed and the capacity of the highway according to its ability to meet the needs of the users (customers). There are many ways to do this; the UK system is based on hourly capacity whereas in the US it is based on peak hourly flow. Whilst the assessments shown below may not accurately reflect either, they provide a basis for consideration whilst consideration is given to any local standards. Where a local standard does exist, this is used to define grade 3.

Capacity/congestion

Grade	Description
1 – excellent	Meets daily and peak hour flows with at least 20% spare capacity
2 – good	Meets daily and peak hour flows with at least 10% spare capacity
3 – adequate	Meets daily flows with some spare capacity but peak hour flows will suffer some delay
4 – poor	Just meets daily flow requirements but significant delays during peak hours
5 - awful	Fails to meet daily and peak hour flows leading to significant delays even outside of peak hours

Safety

Grade	Description
1 – excellent	No reportable accidents ever
2 – good	Only occasional reportable accidents and none serious
3 – adequate	Less than one serious accident in five years
4 – poor	More than one serious accident in five years
5 - awful	More than two serious accidents in five years

The problem with this grading is in defining the length under consideration; is a complete section of highway considered, just the asset length or should the incidents be apportioned per kilometre of length? The latter approach is the most objective, however, most accidents tend to occur at junctions.

Speed
Speed performance should always be related to the speed limit pertaining to the road.

Grade	Description
1 – excellent	Always able to travel at the speed limit
2 – good	Able to approach speed limit for in excess of 95% of time
3 – adequate	Able to approach speed limit for in excess of 90% of time
4 – poor	Frequent blocks and tailbacks
5 - awful	More than daily blocks and tailbacks

Other Asset Performance Grades
Consideration must now be given to the standards that the ancillary assets are required to perform. A few examples are given below.

Guard Rail Performance Grade
Obviously this must be assessed only where a guard rail is deemed to be necessary – usually bends, embankments, bridges and central reservations.

Grade	Description
1 – excellent	Will deflect a 40 ton HGV and prevent it from leaving its own carriageway; inherently safe
2 – good	Will deflect a 20 ton HGV and prevent it from leaving its own carriageway; inherently safe
3 – adequate	Will deflect 90% of the vehicles using the highway; inherently safe
4 – poor	Will only deflect 70% of the vehicles using the highway; not designed for HGVs; may have safety flaws
5 - awful	Will not deflect or retain average traffic; not designed for HGVs; may be dangerous in operation

Lighting Performance Grade
Obviously this must be assessed only where a guard rail is deemed to be necessary.

Grade	Description
1 – excellent	Exceeds standard by a comfortable margin with excellent reliability and low power consumption
2 – good	Exceeds standard marginally and inherently reliable with low power consumption
3 – adequate	Lighting meets standard for the highway/area and is basically reliable with adequate power consumption
4 – poor	Below standard lighting for the highway/area and with occasional malfunction; poor power consumption
5 - awful	No lighting in an area where there should be; excessive power consumption

It is possible to define the grades for all of the asset types based on the principles above. Should there a national or local standard this will form the basis of grade 3. Grade 1 is the best standard achieved locally with spare capacity and grade 5 is the worst standard achieved anywhere in the country. Grades 2 and 4 are interpolated.

Performance grades for traffic junctions are more difficult to define though safety and congestion will be the major factors in performance.

APPENDIX 3 - Asset Lives

Highways and footpaths

Asset type	Typical life	Range
Carriageway formation	100 years	50 – 150 years
Kerbs and channel	60 years	20 – 100 years
Asphalt surfacing	25 years	20 – 40 years
Bitumen surfacing	20 years	15 – 25 years
Tarspray surfacing	10 years	8 – 12 years
Flagged footpath	20 years	15 – 25 years
Bitumen footpath	15 years	10 – 20 years
Brick paved footpath	30 years	20 – 50 years
Gravel footpaths	12 years	10 – 15 years

Highway ancillaries

Asset type	Typical life	Range
Bridge structure	80 years	50 – 100 years
Bridge joints	15 years	10 – 25 years
Concrete footbridge	50 years	40 – 80 years
Steel footbridge	40 years	25 – 50 years
Retaining wall	100 years	50 – 100 years
Safety barriers	20 years	10 – 30 years
Bus shelters	20 years	10 – 30 years
Boundary fencing	20 years	10 – 50 years
Street lighting	25 years	20 – 50 years
Culverts	60 years	50 – 100 years

Surface Water Drainage

Asset type	Typical life	Range
Pump station structure	50 years	40 – 60 years
Pump station mechanicals	15 years	10 – 20 years
Steel pipelines	30 years	10 – 50 years
Plastic pipelines	60 years	50 – 100 years
Cast/ductile iron pipelines	80 years	60 – 100 years
Concrete/clay pipelines	80 years	60 – 100 years