A UK orientated decision support system for effective track maintenance and renewal

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Abstract

Modern data collection techniques produce a considerable amount of useful information [1], which, if made use of, can assist the engineer in the correct diagnosis of failure and to determine the most effective method of remedial action. However despite developments in data collection and subsequent research into the correct interpretation of this data, little has been done to draw the two together and produce a ‘vehicle’ to aid the engineer. The paper considers how this might be achieved through the use of a decision support system and discusses the development of such a system to assist the engineer in making effective maintenance and renewal decisions on the UK rail network.

1 Introduction

The effective planning of civil engineering maintenance and renewal work is a complex task when considering possession, resource and financial constraints and health and safety issues. Furthermore to adequately assess track condition and quality and to determine correct remedial action, it is essential that all factors be considered. Figure 1 shows a schematic representation for the analysis of data for maintenance and renewal decisions.

Within any industry the quality and timeliness of its decisions play an important part in ensuring its continued success, whether that is measured in terms of financial, safety or overall quality. Based on previous research carried out at the University of Birmingham into highway maintenance [2], it was expected that decisions about renewal and maintenance would be inconsistent and would depend more upon the subjective experience of the engineer and the information available to them, rather than an objective analysis.
Figure 1: Schematic representation of data analysis for maintenance and renewal decisions.

The research project undertaken, aimed to reduce the cost and increase the effectiveness of railway track maintenance and renewal by studying the current arrangements and identifying best practice. The project had four objectives:

1. To produce a code of practice that linked the condition of the track with recommended maintenance and renewal treatment.
2. To develop an expert system, based upon the code of practice to provide decision support.
3. To investigate the current decision making process and identify any constraints that may exist.
4. To comment on the maintenance management systems used.
2 Current maintenance management systems

Research into the use of maintenance management tools, available in the international industry has indicated a market gap for more supportive systems for track maintenance and renewal decision-making. The key factors being that many support tools do not use expert system type technology. More often they are actually quite complex data management systems, which provide a database of track data for a given section, and provide the user with some interface presenting a graphical image of the stored data. BINCO [3], BIS [4], LABOCS II+ [5], are examples of this type of system, supporting the engineer simply by displaying available data in a user-friendly format.

Other systems which provide more decision support, often based on expert system technology, rarely consider the whole picture. Examples of these include Trackmaster [6], which considers geometry maintenance only and REPOMAN [7], which considers rail replacement only.

Finally there are systems, which are principally concerned with the economic justifications of maintenance and renewal activity. Examples of these would be TRACS [8] and the TMS system [9].

In conclusion it may be seen that the development of decision support systems for the railway industry is a desirable approach to advancing already proven data management systems and there is certainly a market gap for more supportive systems for track maintenance and renewal decision-making.

3 Role of the decision support system

Decision support systems (DSS) are tools, which aid decision makers to gain a greater understanding of their business. They are the “front end” technology that is generally associated with a data warehouse and which provide modelling and analysing capabilities to help the decision maker see avenues, through which to gain a competitive advantage [10]. DSS also provide a level of standardisation, ensuring a consistent approach to the management of their business.

As the name suggests the tool is a supportive system, designed to aid the engineer by improving the choice process, between possible outcomes with uncertain consequences. This process can be improved yet further by integrating expert system (ES) technology into the modelling functions of a DSS. The ES technology assists the engineer to select the correct data for analysis and to determine the correct procedure for the analysis. Similarly by doing so the system can ensure that all aspects of a problem have been examined [11].

The proposed DSS can be used to support the engineer in the decision making process represented in figure 1, at the following key stages:

- Visualisation of available data
- Analysis of available data to make informed maintenance and renewal decisions based on current best practice and maintenance policies.
- Cost evaluation and optimisation to ensure a balanced engineering and financial solution.
- Support for network level decisions regarding future use.
Ultimately however the role of the DSS will be defined by the intended user of such a system and the users role within the management of the railway network. It is envisaged therefore that such a system could be used, both as an operational maintenance-planning tool for maintenance contractors and similarly as a strategic planning tool for asset managers. Thus allowing a continuum of data and model use throughout all levels of management.

4 Development of a prototype system

The principal reason for developing a support system would be to address the needs of the targeted user. During interviews with practising maintenance engineers and industry representatives in the UK a ‘users’ wish list’ has been established, demonstrating that current software was not meeting all the requirements of the technical user in today’s commercially competitive industry. Therefore supporting the notion that there is a definite need for a work-planning tool providing a reasonable assessment of future work requirements and a financial forecast for the proposed activities.

There is a positive argument to suggest that the use of ‘shells’ in the building of expert systems prevent the developer from ‘re-inventing the wheel’. Consequently they also attempt to solve many of the programming problems associated with the development of such systems [12]. Thus allowing the developer to concentrate on the production of the knowledge base or rule-base, which is the more critical and complex section of the system. This has been the case for the project’s prototype system. Ecotrack, a commercially available DSS designed for railway maintenance and renewal has been adopted for UK use. Using Ecotrack as a shell system and developing a rule-base orientated towards the UK industry, has enabled the project to be taken further than originally anticipated and the system is currently undergoing full-scale tests.

4.1 Ecotrack

The Ecotrack system has been developed through support by the European Rail Research Institute (ERRI), and through a working group involving 10 European Rail networks. It is designed to optimise the management of track maintenance and renewal productivity and provides an environment for organising and storing track data and decision tools for producing maintenance and renewal plans [13,14].

The system has been developed under an expert system model (see figure 2) in that it makes use of a rule-base and a fact-base. The rule or knowledge base provides the knowledge required for the system to make expert decisions. The fact-base has been developed using Microsoft Access, which is a relational database system. The system’s inference engine supports forward chaining, that is, reasoning from facts to the conclusions resulting from those facts. For example if you see that it is raining before leaving home (fact), then you should take an umbrella (the conclusion) [15].
The Shell System.

Being a rule-based Expert system, Ecotrack provides a simple, concise and relatively easy environment for the development of a compatible UK-orientated rule base. Furthermore rule-based systems tend to be incremental in their construction. This assists the development of such software by providing an environment in which a basic system can be quickly implemented into industry, with further modules being developed and added as they become available. It also provides an easier testing and evaluation environment, allowing the user to test rules independent of each other.

There are many benefits in both the development and the end-use of using the Ecotrack system as a shell for this project. The most important points to bear in mind are that the Ecotrack system provides the UK with a fully designed interface and inference engine with the only requirement being the need for a nationally orientated rule-base. This assists the development stage, by reducing the programming skill-level required to develop a system of a similar standard, and allowing a more concise development of the rule-base. Furthermore the developed UK-orientated rule-base could be used in systems other than Ecotrack, if need be.

4.2 Development of compatible database

To develop an Ecotrack compatible database, extensive data mapping exercises were necessary to establish what data was available in the UK, how it was stored and what data would be needed by the system. Routines have now been developed to transfer the data from the current systems into an Ecotrack compatible database. These have been tested and verified using trial sites.

The transfer of data has not been without its problems. The most significant being the difference in measuring units. The UK network uses the imperial
system to record track lengths, whereas the Ecotrack system, designed for use on European railway networks, uses the metric measuring system. This has caused some difficulties, which have been resolved by adopting a decimalised imperial system. The system used, converts miles and yards, miles and chains and miles and eighths into miles and 1000th of a mile during the import process. To compliment this the segmentation lengths has been adjusted to correspond to an eighth mile (i.e. 125 units), as this is the traditional measurement in the UK.

Finally to ensure the system was still user-friendly it was necessary to develop a new language module for Ecotrack. "Railtrack-English" enabled the system to display distances in mls (miles) and not km (kilometres). The new language also allowed text to be displayed in a more user friendly way. An example being that “Variant” was changed to “Work plan”. Furthermore by having the capability of the language module, this meant that more use could be made of the database, allowing the storage of UK data in fields designed for other parameters. An example being that “Weld” now reads “Alloy” to reflect the contents of the database.

4.3 Development of compatible UK orientated rule-base

The development of an UK orientated rule base was necessary because the original rule-base was deemed not suitable for UK use. This was predominantly due to differences between the rules implemented and the criterion set out in UK industry documentation. Furthermore differences in data stored within the UK-database meant that some rules required re-writing. Finally the lack of background information for some rules meant that they could not be adopted, until a complete understanding of the nature of the rule was understood.

Development of the rule base has been predominantly data driven and undertaken under a three stage systematic approach to rule design. Initially a working party was set up to, define the direction of rule development. The first phase of the development of the rule base considered each component in turn and through the working group developed a number of rule tree diagrams based on the reason for intervention.

Phase two of the development considered current UK industry practice as prescribed in the Railtrack documentation [17], or as described in the civil engineers conference code of practice [18]. Here a more detailed description of the rule has been developed covering the rule source, the data source (measured) and the prescribed limits (thresholds). Through discussion with the working group the contents of this stage are established as correct and best practice. Subsequent research has identified a number of extra rules, which have also been included. The final stage of rule development (phase 3) was to develop the rule description into a function of the form:

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\text{IF Premiss THEN Conclusion.}
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Ecotrack makes use of twelve reference models, of the above form, allowing for the easy programming of codified rules. The system is structured into five
levels of detail (see figure 3). The first level allows decisions to be made using the most basic of data. The system also suggests where component condition inspections are required. Asset condition is input using the asset states as laid-out in Railtrack’s Asset Management Manual [19]. Level two produces a more detailed work plan and in level three the system carries out coherence checks to ensure that the planned activities are integrated correctly. The fourth level allows the work plan to be adjusted for budget restrictions and the fifth level provides statistical analysis for overall network management. Through all levels the system provides flexibility to allow the engineer to adjust the plans based on personal experience and local knowledge. Some 100 level 1 and level 2 rules have now been developed and coherence checks have been adjusted to suit UK policy. Many systems give the user a feeling that it has plucked the answer from a ‘black box’ and to overcome this a full explanation has been attached to every rule. The explanation describes why the rule has been activated, the source of the rule and its attached threshold limit.

The core rule-base has been implemented into the system, and is currently undergoing full-scale tests within both a maintenance contractor and Railtrack.

Figure 3: Processing structure of the Ecotrack system. Modified version of the system architecture by ERRI [11], to include UK input data.
5 Testing and evaluation

The new system has been installed within the Crewe contract area of GTRM Ltd., a maintenance contractor and the York regional office of Railtrack plc. Initial feedback from the staff in both sections is very positive. Users have welcomed the ability to view all available data for a given section of track. It was expected that users would start by using level 1 analyses and then progressing to other levels. But in practice both GTRM and Railtrack users have also made immediate use of the strategic planning tools within level 5, to analyse work done and to determine quantities of work planned.

Testing of the system is now underway and initial results have proved that even with the minimum required data, the maintenance plans produced are comparable to current renewal proposals. The details of the rules activated can be displayed if requested by the engineer and alternative actions can be taken if justified. The basis for a more consistent approach to decision making has been established.

The system has also enabled engineers to take a critical view of the quality of data, which in many cases is not as good as expected. The availability of a complete system, even with incomplete or inaccurate data, is encouraging users to initiate improved data collection and consider additional data requirements.

It is envisaged that in the long term the system will be used by Railtrack as a strategic management tool, for identifying and prioritising track renewals, based on engineering need and optimised for budget restrictions. Similarly GTRM will use the systems as an operational maintenance management tool, to identify renewal proposals, manage maintenance activity and forecast future costs for contract bidding.

6 Future requirements

The future of Ecotrack within the UK will depend on the results of the testing and evaluation currently being carried out. Results are looking positive, however the future needs of the engineer should now be addressed. Consideration should be given to how data is collected in the future, how better use can be made of it, including better and more accurate collection, in improved formats, that can be easily integrated into systems such as Ecotrack. Support issues need to be established to ensure that the system receives the updates and improvements necessary to keep it state of the art.

Within the UK the next steps will be to improve rule-base performance, by refining existing rules to include economic modelling and justification. The training of staff needs to be addressed, not only to use the system correctly, but also to ensure they make better use of available data, to improve the effectiveness of the maintenance and renewal decisions. Also there is a need to develop a greater understanding of what Ecotrack does during rule processing and to develop improved deterioration models, which consider more components and condition parameters. Furthermore the integration of Ecotrack with current
maintenance systems needs to be addressed to ensure long-term use of Ecotrack, and to remove the double handling of data.

Finally the project has only dealt with plain-line track, which is only one area of expenditure within the rail industry. Similar systems for switches and crossings, bridge and structure maintenance and the inclusion of electrical components need to be considered to provide an integrated decision support system working from one common data source.

7 Conclusions

The work presented in this paper can be considered as a systematic approach to the development of a decision support tool using expert system technology. The paper has established how a decision support system may be used as a vehicle to bring together data and knowledge and to assist the engineer to make effective maintenance and renewal decisions. Ecotrack, a European DSS was used as a shell expert system and this allowed the project to be taken further than originally anticipated. The developed rule-base is novel in that it will automate current industry practices. It is also intended to codify the “tacit” knowledge of individual Permanent Way Maintenance Engineers, to provide some commentary on the key factors, which influence or constrain technical decisions. The developed DSS has been summarised by industry representatives as “A good start, which shows potential for asset management systems,” and how that “the extended use of the system will depend upon results of trial and resolution of outstanding issues.”

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9 References


