

## Selecting road management systems

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### 1 System choice

Senior managers in road administrations may be required to make decisions about the choice of computerised road management systems that are to be implemented within their organisations. The consequences of such decisions can be very costly, not only in terms of the cost of initial system procurement, but also because of the on-going costs of system management and data collection. The implementation of systems can have far-reaching effects on all aspects of the operation of the road administration. Hence, it is important that managers are aware of the need for an effective approach to system implementation, and of the pitfalls of making inappropriate decisions in this area.

The need to process data and provide meaningful information through management reports for the direction and control of highway operations can be greatly facilitated by using computers. However, simple processes and procedures should not be overlooked as effective means of controlling or enhancing performance. The installation of operational management systems can, therefore, make an essential contribution to the effective operation of highway organisations. The systems need to be structured to support the primary management functions of: planning (including budgeting), organising (including staffing), directing, and controlling.

Unfortunately, experience with the implementation of systems in many countries has been disappointing. Reasons for this include:

- (i) user attitudes;
  - lack of genuine commitment to the implementation;
  - expectation of high-tech solutions when, in fact, simple common sense solutions are appropriate;
  - resistance to change;
- (ii) cultural issues;
  - problems of introducing modern management practices, including incentives, into cultures with no management tradition;
- (iii) economic and financial problems;
  - weak local economies and foreign exchange shortages preventing the purchase of even basic commodities needed to support the system;
  - local budgets dominated by the payment of staff salaries, with residual funds being insufficient to pay for maintenance works to be carried out;
- (iv) key staff positions not filled, or filled with staff of insufficient experience;
- (v) training;
  - operational requirements preventing local staff being released for training;
  - over-ambitious training programmes with instructors being inadequately prepared;
  - insufficient follow-up training and revision;
- (vi) deficient computer facilities and inadequate availability of hardware;
- (vii) poor availability of existing data; and
- (viii) systems being too complicated and demanding to be sustainable with local resources.

Based on this past experience, the following steps can now be recommended to specifying and selecting systems in order to avoid these pit-falls:

- (i) obtain genuine commitment - proceed no further without this;
- (ii) identify the policy framework, and the highway authority's capability and limitations through an institutional appraisal; if the appraisal indicates that the institutional capacity is insufficient to support a highway management system, then proceed no further;
- (iii) if the appraisal indicates that a system is required and can be supported, then agree the objectives for the system, determine what components the system needs to contain, based on an analysis of costs and benefits of each of those components, and prepare a procurement plan to meet identified objectives;
- (iv) identify users of the system and the outputs that they will require to support them in their management function;
- (v) identify data and models required to produce these outputs; and
- (vi) identify appropriate software, and hardware and operating system requirements necessary to support this.

These steps are now considered in more detail.

## **2 Commitment**

The introduction of highway management systems will have a significant impact on the existing highway organisation. If changes are to be made, this can only be achieved if there is strong political leadership and government commitment to the need for change and support for those implementing change. Without this, there is little point in proceeding further.

## **3 Policy framework**

These issues have already been discussed in an earlier module.

## **4 System objectives and procurement**

### **4.1 Types of management system**

It is convenient to differentiate between *information systems* and *decision-support systems*:

- (i) an *information system* collects, organises and stores data; and
- (ii) *decision-support systems* comprise applications modules to process the data and provide the information on which decisions can be based and, ultimately, implemented.

Use of the terms like *maintenance management system* and *pavement management system* can cause confusion, because systems produced by different vendors can often have quite different characteristics, even though they may be referred to by the same type. The following definitions will be used here:

- (i) *information system*;
  - network information;
- (ii) *decision-support systems*;
  - planning;
  - programming;
  - preparation; and
  - operations.

The general objectives of these can be described as follows.

*Network information*

An information system, as defined above, containing data about the highway network.

*Planning*

Decision-support system for strategic planning undertaken to develop long term plans for the highway network as a whole; planning time horizons typically of five years or more; undertaken to determine what are the implications resulting from meeting objectives in terms of future budget needs, consequential pavement conditions, user costs, *etc.*

*Programming*

Decision-support system for tactical planning or programming concerned with determining need in the budget year; planning time horizons of one to three years; including identification of links or sections from the network which require treatment and the timing of treatments, possibly in conjunction with a rolling programme; cost estimating, prioritisation, budgeting, monitoring.

*Preparation*

Decision-support system for project preparation, including project formation and design, costing, works order or contract preparation and issue.

*Operations*

Decision-support system for the management of operations on a daily or weekly basis, including defining work to be carried out, developing appropriate costs for this in terms of labour, equipment and materials, and making arrangements for carrying out the work by force account or by contract, the recording of work accomplishment, and the use of this information for monitoring and control.

The above four types of decision-support system can also be seen in terms of a sequence of planning and management operations. As these move from *planning* through to *operations*, the following changes in procedure normally occur:

- (i) the highway sections considered change from all those contained in the network to only those where works are likely to be carried out;
- (ii) the time horizon being considered changes from multi-year, to budget year, and then to the current week or day;
- (iii) the data used change from being summary or sampled, to detailed with full coverage over the part of the highway covered by the project; and
- (iv) processes undertaken by the computer change from being automatic, to being undertaken by the user working interactively with the computer.

#### **4.2** *Priorities for system implementation*

In general, subject to detailed policies of individual highway authorities, the following order of system implementation has some merit:

- (i) ensuring adequate identification and control of costs through the use of *operations* systems;
- (ii) budgeting and setting priorities under budget constraint by the use of *programming* systems;
- (iii) introduction of *planning* systems provides forecasting tools for assisting with policy formulation and identifying longer term budget needs; and
- (iv) implementation of *preparation* systems can be considered as lowest priority because most highway organisations already have reasonably effective manual systems for this.

However, note that *operations* systems are mainly appropriate in highway authorities carrying out works by force account, although they can be used to assist with the letting and management of contracts.

## 5 Users and outputs

### 5.1 System users

The generic system type needs to be determined by identifying the required objectives. But system *specification* is a function undertaken by, or in close consultation with, the potential users of the proposed system. There is, therefore, a need to identify who the potential users of the system will be. In general, potential users of systems might be characterised by the following.

**Table 1 Characteristic system users**

{PRIVATE }System type	Potential users
Planning	<ul style="list-style-type: none"> <li>• Top management of the highway authority</li> <li>• Planning or economics unit within the authority</li> <li>• Funding agencies</li> </ul>
Programming	<ul style="list-style-type: none"> <li>• Professional staff in the highway management/maintenance department</li> </ul>
Preparation	<ul style="list-style-type: none"> <li>• Highway management/maintenance department</li> <li>• Contracts/procurement department</li> </ul>
Operations	<ul style="list-style-type: none"> <li>• Works supervisors</li> </ul>

### 5.2 System outputs

The key element of any system will be the outputs that it can produce. These provide the basis of reports that assist users in undertaking their work and, as such, contribute to meeting the highway authority's policy and the system objectives. The first step in system *specification*, therefore, is to define the outputs that are required from the system. From this can be determined the data and models that are required to produce these outputs.

Clearly, outputs required will depend on the particular policy of the authority, on its institutional arrangements, and on the detailed objectives and use to which systems will be put. *Examples* of the type of outputs that might be required from network information systems and the four types of highway management systems are given below.

#### *Network information systems:*

- (i) gazetteer of highway sections, in user-defined order, giving attributes of sections; and
- (ii) lists of sections based on user-defined selections of section attributes.

#### *Planning systems:*

- (i) projected annual capital and recurrent budget requirements to meet given standards for a user-defined future period;

- (ii) projected pavement conditions resulting from the application of pre-defined annual budgets for a user-defined future period;
- (iii) projected highway authority costs and user costs for pre-defined standards, or annual budgets, for a user-defined future period; and
- (iv) incremental NPV of adopting one set of standards compared with another, or of adopting one particular stream of annual budgets compared with another.

*Programming systems:*

- (i) list of sections, showing recommended treatments and costs that can be funded in the budget year under pre-defined capital and recurrent budget constraint, in both priority and section order;
- (ii) list of user-selected sections showing conditions and recommended treatments, in section order;
- (iii) list of user-selected sections showing traffic, axle loading and user costs, in section order; and
- (iv) Projected rolling programme of work over a multi-year period.

*Preparation systems:*

- (i) project formulation (produced interactively); and
- (ii) works order for project, including bill of quantities.

*Operations systems:*

- (i) performance standards for works, based on defined activities, plant and equipment costings, materials cost rates, and labour schedule and rates;
- (ii) work instruction/accomplishment;
- (iii) weekly labour time summary by person and budget head;
- (iv) weekly cost summary by activity and budget head, with totals; and
- (v) annual cost summary by section of highway, activity and budget head, with totals.

## **6 Data and models**

### **6.1 Approach to data design**

The outputs from a system are produced from a combination of data and models. Thus, definition of the outputs required will determine the data items that need to be collected and stored within the system. The choice of models will also influence data requirements, since models combine data items and parameters, using pre-defined algorithms and relationships, to produce further data items. Note that the cost of data acquisition is likely to be the most expensive aspect of implementing and operating a highway management system. Annual data collection costs are typically five to ten times the cost of purchasing the computer hardware on which to run the system. As such, it is essential that appropriate data design is undertaken if a cost-effective result is to be obtained.

The following criteria should, therefore, be considered when selecting data items:

- (i) *Relevance*  
having a direct influence on the required output;
- (ii) *Appropriateness*  
both to the stage of planning and management process, and to the authority's capability to undertake the required data collection;
- (iii) *Reliability*  
in terms of accuracy, coverage, completeness and correctness; and
- (iv) *Affordability*  
in both financial, and staff requirement, terms.

## 6.2 Information quality levels

As the management process moves from *planning*, through *programming* and *preparation* to *operations*, the amount of data detail required can be seen to increase progressively in intensity, but to reduce in the extent of its network coverage. This feature can be used to assist the data design process by combining the functional levels of highway management with *information quality levels* (IQL), as discussed earlier. These provide a standardised definition of the level of detail of different data items, such that they are of a consistent accuracy for different functions.

## 6.3 Models

A key difference between *decision-support* systems and *information* systems is that they have the ability to process data and to produce information on which decisions can be made by users. Models contain relationships and algorithms which are normally enshrined in the design of the system.

Depending on the specific model considered, data requirements will differ. Thus, the appropriate combination of model and data in a particular situation must be determined using the same criteria and considerations as listed earlier:

- (i) relevance;
- (ii) appropriateness;
- (iii) reliability; and
- (iv) affordability.

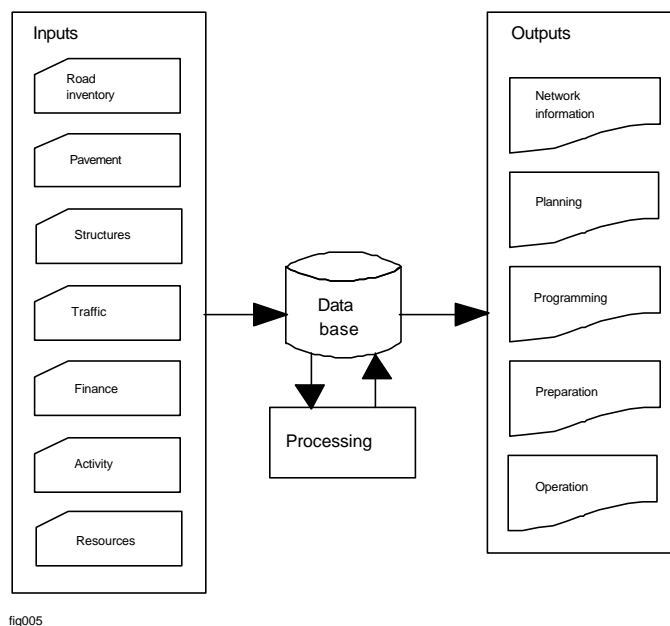
The models incorporated in the World Bank's HDM-III system are incorporated into several highway management systems since they address many appropriate issues. These models are very comprehensive and many of them represent the current state of knowledge in the areas considered. However, these models are not universally applicable, and care should be taken to ensure that they are only used in appropriate situations, and with local calibration - which can be time-consuming. A disadvantage of these models is that they demand significant data requirements, typically at IQL-I and IQL-II, as defined earlier. Careful consideration needs to be given to the ability of highway authorities to meet these data requirements on an on-going basis before using these models in the design of systems. HDM-III is described later, as are on-going developments in this area.

## 7 Computer requirements

### 7.1 Software

Normally, the most efficient and flexible structure for highway management system software is one which is modularised, with integration achieved through a common data bank. This modular structure must reflect the manual operation of the highway management process when broken down into functions and tasks. Many proprietary systems lack this modularity and are only available as complete system, with a resulting loss in flexibility and ability to match the physical management structure.

With modular software, the highway *information system*, or data bank, provides the back-bone of the management system. This comprises the network referencing system around which is built an inventory of the network. This provides the framework within which all information about, or associated with, the network is stored and retrieved. The software for this must be flexible enough to accommodate future changes and growth. The modular framework is illustrated in Figure 1, which includes the five types of *information* and *decision-support* systems identified earlier. Although such an integrated approach to software development should be a long-term target, in the medium-term most highway management systems may only contain part of that shown in the figure. In the short-term, only a very small part of the total should be considered for implementation.



**Figure 1 Modular system framework**

This approach represents an ideal situation and does have long-term benefits. Different parts of the system can be developed independently, at different times depending on the resources available, using different software products. The disadvantages are that considerations of the long-term will be dictating short-term actions, with the result that the initial solution may be more expensive and complicated than a dedicated application.

Remembering that the most expensive component of the highway management system is the *data*, the key issue is to have the potential for upgrading the system in the future and still to be able to utilise data collected in the past. There will be many benefits when introducing systems for the first time to adopt a very *simple* approach in keeping with the institutional capacity of the highway authority. As operation and use of the simple system becomes institutionalised, and as technology advances, the system can be replaced. Providing that the original system utilises a database or a spreadsheet to store data, it is a relatively straightforward exercise to down-load the data from the original system and to load it up into the new one, although computer system skills are needed to do this. Such an approach may be more in keeping with institutional development requirements whilst, at the same time, protecting the authority's investment in data.

## 7.2 *Hardware and operating systems*

The last decision that should be made when planning the implementation of a highway management system is the choice of hardware on which the system will run: this is contrary to the approach taken by almost all projects to develop and implement systems in the past. In most cases, once the requirements of the management system software have been defined, and the choice of operating system have been made, the choice of hardware will be self evident. A system based on microcomputers should be considered as a starting point in many cases because of the availability of hardware maintenance. But the use of work-stations should not be overlooked, particularly where large data volumes are anticipated. At a cost of little more than a micro, large gains in efficiency of data storage and operation can be obtained.

## 8 **HDM-III**

The Highway Design and Maintenance Standards Model (HDM-III) has been developed by the World Bank to meet the needs of the highway community for evaluating policies, standards, and programmes of highway construction and maintenance. The model simulates total life cycle conditions and costs, and provides economic decision criteria for multiple design and maintenance alternatives for one link, a group of links with similar characteristics, or an entire network of paved and unpaved roads. The primary cost set for the life cycle analysis includes the costs of construction, maintenance and vehicle operating costs, to which travel time costs can be added as an option. The cost of works-related traffic delays, congestion, accidents, and environmental pollution are not included, but can be entered to the model exogenously based on separate estimates. The broad concept of HDM-III is illustrated in Figure 2.

HDM-III is designed to make comparative cost estimates and economic evaluations of different construction and maintenance options, including different time-staged strategies, either for a given highway project on a specific alignment or for groups of links on an entire network. It estimates the costs for a large number of alternatives year-by-year for up to 30 years, discounting the future costs, if desired, at different specified discount rates, to search for the alternative with the lowest discounted total cost. Rates of return, net present values or first year benefits can also be determined by the model. In addition to comparing alternatives, the model can analyse the sensitivity of the results to changes in the assumptions about key parameters such as unit costs, traffic composition, traffic growth rates, the discount rate, the value of passenger time, and accident costs.

In order to make a comparison of alternative construction and maintenance strategies, detailed specifications of construction programmes, design standards, and maintenance alternatives are needed, together with unit costs, projected traffic volumes, and environmental conditions. The model simulates, for each highway link, year-by-year, the pavement condition and resources used for maintenance under each strategy, as well as the vehicle speeds and physical resources consumed by vehicle operation. The physical resources for highway construction for each design option may be estimated from relationships within the model, or may be specified directly if more specific or local information are available. After physical quantities involved in construction, maintenance and vehicle operation are estimated, user-specified prices and unit costs are applied to determine financial and economic costs. Relative benefits are then calculated for different alternatives, followed by present value and rate of return computations.

A major international research project is under way to update the HDM-III model. The project is centred on the University of Birmingham in the United Kingdom, and is funded by the British and Swedish governments, and the Asian Development and World Banks. The project objectives are to provide software that is more user-friendly than HDM-III, and to enable the model to address a wider range of investment decisions in a wider range of environmental areas. In particular, the new model will be less demanding of data detail in appropriate situations, and will address such issues as traffic congestion, safety and pollution implications, a wider range of pavement types and their performance, and the extension of models to different environments, including cold climates.

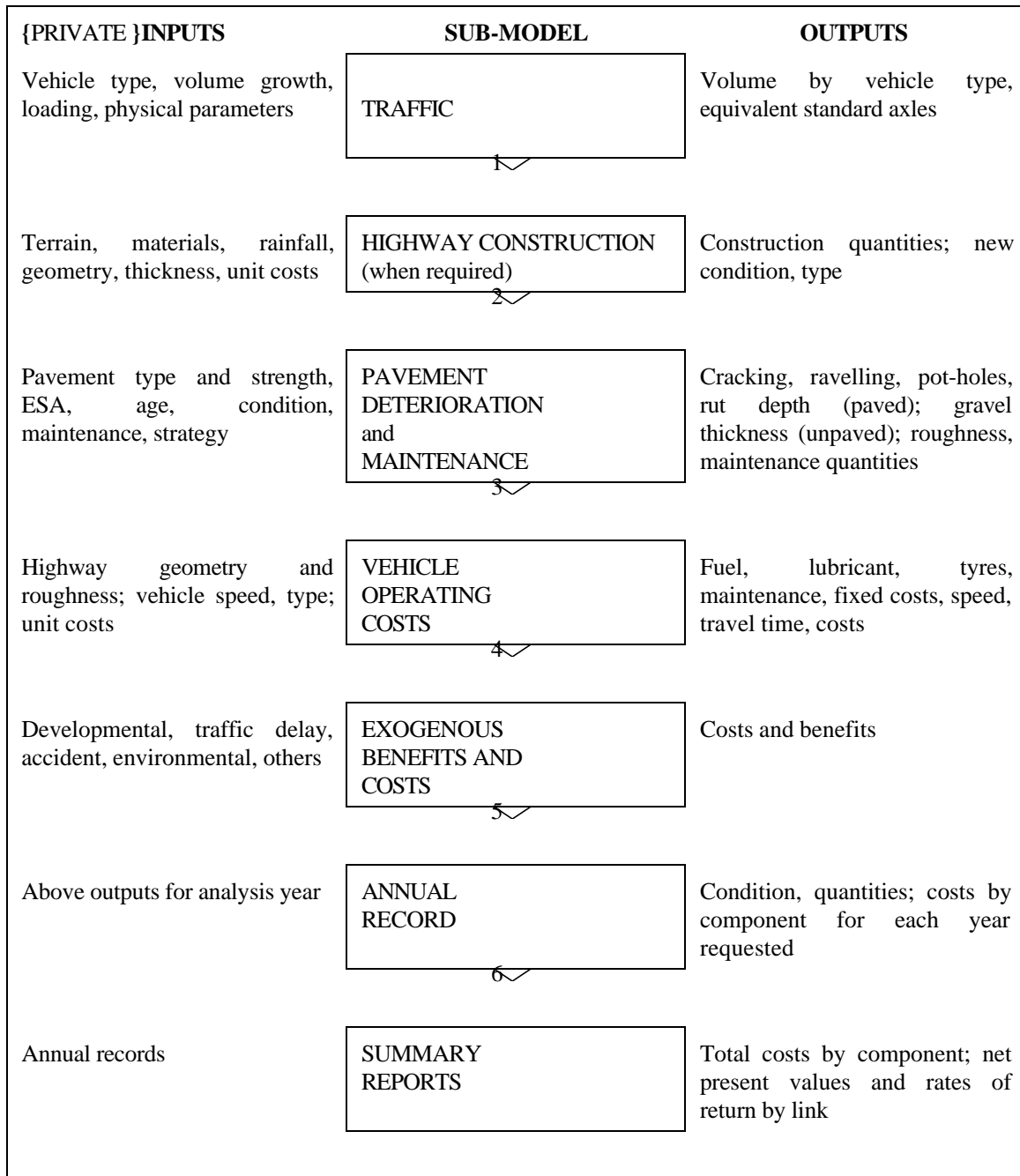


Figure 2 Structure of HDM-III model