THE NETWORK INFORMATION SYSTEM

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1. BACKGROUND

1.1 Over the past 25 years many miles of Motorway (Freeway) and all-purpose Trunk (National) Road have been constructed, improved and maintained in the UK. A considerable amount of data has been collected to assist with the design of the works, to describe the construction as completed, its current condition, its use and performance. Yet access to this data is often difficult. Occasionally data cannot be easily retrieved, is in the wrong format and it is referenced in different ways that make sensible correlation impracticable. A number of computer based data storage and retrieval systems have been developed, but they have been generally limited in their scope and objectives and some have suffered through a lack of commitment and resources.

1.2 This problem was considered by a study undertaken within the Department of Transport (DTp) in 1982 and from this the proposal to develop a Network Information System (NIS) was born. At the same time the increasing power and availability of computing provides a means by which such a system could be effectively introduced and maintained.

1.3 During 1983 the concept of NIS was finalised and the cost effectiveness of the proposals investigated. As a result agreement was obtained to proceed with a further study (Phase 1) to produce a detailed framework for the development and implementation of the system whose objectives were defined as:

- the rationalisation of the existing disparate ways of collecting and storing trunk road data by the establishment of a compatible series of computer files

- the referencing of the data to a common base so that it can be correlated for analytical purposes

- through the development of a range of computer software, the analysis of the data to produce appropriate information as the basis for better decision making, obtaining better value for money in relation to Trunk Road expenditure, and facilitating a more positive approach to the management of the Trunk Road network.

1.4 After competitive tendering a team of consultants from PA Computers and Telecommunications (PACTEL) and MVA Systematica were appointed to advise the DTp on Phase 1. Their brief for the first phase was:

- to determine in detail the Department's present and future needs for information in relation to the Trunk Road and Motorway network following the guidelines established in the earlier internal study

- to identify application priorities

- to set out an outline system design and hardware/ software strategy to meet the requirements

- to set out development and implementation plans with resource estimates

- to propose methods by which the benefits of the systems components may be identified and measured as the project proceeds.

Work commenced in May 1984 and comprised the activities described below. The consultants have since reported, and the project is now proceeding.

2. INTERVIEWING

2.1 Interviewing took place over a period of 2 months, and 47 groups were covered in all. As the main thrust of NIS is to provide an effective management system to assist line managers within the Department, all of the nine Regional Offices together with potential HQ users were interviewed.

2.2 Other organisations interviewed included the Transport and Road Research Laboratory, the Scottish Development Department and the County Surveyor's Society.

2.3 The interviews were generally carried out by a joint DTp/Consultant team. For each Regional Office the sections to be interviewed (eg. maintenance, planning, legal, construction) were selectively sampled, to limit the impact on any particular Regional Office, while ensuring a thorough coverage of topics overall. The interviewing sought out functions and responsibilities that used data directly or indirectly related to the road network.

3. ANALYSIS OF REQUIREMENTS

3.1 The results of the interviewing were used to draw up a detailed picture of the Departmental road network related data sources, methods of storage and manipulation, and ways of access and use. This picture was recorded in three ways:

- entity diagrams and descriptions

- data flow diagrams and descriptions

- inventory of current systems.

3.2 The entity diagrams were used to show the relationships between items of data (eg. a length of road may have associated with it some accidents, some pavement history, some traffic counts, etc.). The data flow diagrams show how users employ items of data during the various stages of carrying out their functions (eg. the way various parties amend information on a TR121A form during the annual highway maintenance cycle).

3.3 From the analysis of the interview returns, the consultants, in conjunction with Departmental staff, drew up a list of NIS applications. These were designed to satisfy the requirements reported by the Regional Offices and the Headquarter Divisions during the interviews. Priorities were then assigned to these applications according to a number of criteria which included the current availability of data, the need to achieve benefits at the earliest opportunity, the scope for meeting requirements by relatively small enhancements to existing systems, the need to start collecting new data for use later, and the desirability of spreading development resources relatively evenly over the project period.

3.4 A Statement of Requirements (SOR) was then prepared detailing the items of data that would need to be held in NIS to satisfy these applications. The groups of data proposed are:

- Road Network. This is required in the form of a location definition and reference of links and nodes that will enable all types of data to be referenced and cross referenced. The main reference systems will be the higher (coarse) level of NIS links and junctions based on the Present Year Network File (PYNF) and lower (finer level) of the CHART system for recording highway maintenance data. They will be related to Ordnance Survey Grid References (OSGRs) and supplemented by the road number and chainage (if appropriate). Fundamental data, such as geometry, location and road markers, trunking history (ie. the period for which the road was a DTp responsibility) and statutory responsibilities (eg. police, Agent Authority) are also needed.

- Construction Data. This should include scheme history, design standards, as-built records and the records of tests carried out during new construction and major maintenance. These requirements apply to both the road pavement and any bridge works or other major structures. Information relating to construction progress should also be available.

- Maintenance History. This heading covers the descriptions of any resurfacing or other maintenance works carried out on the road since the last major reconstruction.

- Pavement Condition Data. All records of pavement condition will be covered here, including CHART, Deflectograph, SCRIM (skid-resistance) and the High Speed Road Monitor results.

- Accidents and Traffic. This heading covers all accident and traffic count data collected by the Department, plus any other counts obtained from the Regional Offices or Agent Authorities, eg. ad-hoc junction counts.

- Inventories. The details of items such as traffic signs and signals, gullys, drains, culverts, road markings, verges, kerbs, pedestrian crossings, height and weight restrictions, safety barriers, etc. will be included.

- Development Control Applications. Regional Offices require a history of development control applications, so that consideration of planning applications can be made on a consistent basis.

- Video Recordings of the Network. These will be used for quick reference and for building up inventories of the network.

A number of other data sets to meet lower priority applications were recommended for review after the main 3 year development stage of NIS was complete.

3.5 The number of ways in which the NIS data might be used and the benefits of the system obtained are considerable, many being the results of being able to link data sets together through the adoption of the standard referencing system. Early uses are likely to include:

- identifying and setting priorities for construction and maintenance

- monitoring schemes in relation to operational requirements (eg. traffic, accidents, etc.) and to design standards (eg. pavement construction, component design, etc.)

- selection of cases with particular features for further investigation (eg. HAC concrete, sub-base construction, etc.)

- ad-hoc enquiries (eg. for parliamentary questions, ministerial correspondence, planning applications, etc.)

- research purposes (eg. relating traffic to accidents to road layout, maintenance history, road lighting, etc.).

Thus it can be seen that a wide range of uses of the system is envisaged which will put a heavy demand on the retrieval software and require substantial flexibility in the system.

4. SYSTEM STRATEGY AND OUTLINE DESIGN

4.1 The NIS system strategy defines those aspects of the system design which cannot be easily changed during the life of the project. It therefore has a major influence on the facilities available and how they are developed. The elements of the strategy are:

- the operating system, programming language and data management facilities to be used

- the types and locations of computer equipment to be used

- the types of data communication facilities used.

4.2 The main criteria used in evaluating the various options for each element were:

- the ability to meet the user requirements set out in the Statement of Requirements (SOR), and the design features derived from the SOR

- cost (present value of all costs, taken over a 10 year period)

- compatibility with the current DTp hardware and software policies.

4.3 There are a number of important design issues which contributed to the selection of the system strategy. These included:

- Network Locational Referencing. The referencing system must provide an accurate and unambiguous method of relating together different types of information which relate to the same point on, or same length of, the road network. It was proposed that NIS link and node and CHART section number and chainage be used as the basic reference definition, associated with OSGRs for presentation and exchange between systems.

- Representation of Past and Current Network. For many purposes, users will only be interested in the current state of the Trunk Road network. For some activities (eg. comparison of accident rates before and after the construction of a bypass and the de-trunking of the old road) users will need access to both current and past network configurations and data.

- Network Definition in the Database. There is an extensive list of items making up the complete definition of the road network. These include Road Numbers, NIS links, NIS nodes, CHART sections, CHART nodes and 100 metre subsections.

- Division of Data between HQ and Regional Offices. It was considered that each Regional Office should in general hold a complete record of all the data related to that Region, and that a copy of this data should be held for all Regional Offices on the central machine for central use.

- Entering Data into NIS. For the foreseeable future, tape transfer is expected to be the major source of data for NIS. This is currently the practice for traffic and accident data, and will be the case for pavement construction and performance records. A certain amount of data input may come directly from terminals in the Regional Offices and the Agent Authorities.

- Retrieval Methods. Users will need to make retrieval requests in numeric, textual or graphical ways. These include zooming in on maps, selecting particular links on the network, choosing the attributes of links to be retrieved, and selection of exception (ie. the best n% or the worst y%).

- Handling Highly Variable Search Criteria. Many interrogations of the NIS database will need to search for the required lengths of road using a highly variable set of search criteria. Any data management software used for NIS would need to be capable of dealing at run time with variable selections of files to search, and with variable lists of conditions to be satisfied.

4.4 The software elements of the NIS system strategy were the choice of operating system, programming language and data management software. The operating system recommended is DEC's VMS, which runs on the DEC range of minicomputers which are the current standard in DTp. This operating system is already used widely within Highways Computing Signs and Lighting (HCSL) and other DTp divisions. The main programming language recommended is FORTRAN 77. It is widely used by HCSL, other DTp divisions and HCSL contractors, and is well suited to handle the technical requirements of the NIS system.

4.5 The recommendation for database management software (DBMS) was less easy to make. A hierarchical DBMS would superficially have appeared attractive, but could not (without difficulties) cope with components of the NIS data. In addition, such DBMS are not suited to catering for the majority of cases in NIS where arbitrary and variable requests are likely to be made of the data. The recommendation is therefore to use a relational DBMS, which have been designed to answer these types of requests efficiently. However, further work is needed to determine the most suitable DBMS available on the proposed hardware and operating system that meets ad-hoc requests efficiently but also can cater for the standard enquiries (eg. accident statistics, highway maintenance monitoring) where the scope and structure of the request is well known in advance.

4.6 The goal of the hardware strategy is to create a flexible system, since the final level of demand for NIS services is difficult to forecast. With systems used to extract and present information, transfer to computer typically generates many new and unforeseen uses. A step-by-step approach has therefore been recommended, with equipment purchase initially being made in two stages, so that the result of the first stage can be used to decide what level of equipment is needed for the second stage.

4.7 A particular feature of NIS is the proposed use of medium resolution colour graphics for presentation of retrieval requests. This makes heavy demands on the hardware, both in terms of the demand on the central processor and the level of data transfer between the computer and the terminal.

4.8 The hardware strategy recommended is to adopt a phased distributed system, where each Regional Office has its own computer holding the data local to that region. All the RO machines would be connected by the DTp's telecommunication network to a central HCSL machine, which will be used for HQ work, database maintenance and software development. The hardware acquisition plan proposed is as follows:

- upgrade the current HCSL bureau hardware to allow for initial software development and pilot use of NIS to ROs

- during 1986-7 review the mix of hardware and telecommunications, and identify computer equipment for the ROs.

The trade-off in costs between computer equipment and telecommunications means that for a heavily used system (such as NIS is expected to be) it is cheaper for the foreseeable future to put sophisticated computing equipment in the Regional Offices with comparatively low demands on data transfer, rather than centralise the system and incur constantly high costs of using an extensive telecommunication network.

5. THE WAY AHEAD

5.1 The Phase 1 report recommendations have been accepted by the Government, and NIS will be developed over the next three years. It will be designed to hold and analyse data about the Trunk Road network for use by those concerned with its planning, construction, maintenance and management. This implies that whilst it will need to hold a wide range of data, it will not duplicate large quantities of data held by other systems both within and outside the Department. Instead, interfaces will need to be established with other systems, for example the Routine Maintenance Management System currently being developed by TRRL. NIS will often therefore hold a subset or aggregation of the data held in other systems. According to the type of use then either NIS or the other system could be accessed, the former particularly where an analysis across a range of data (and systems) is required. For systems maintained within the Department it is anticipated that a common entry module will be provided with users being automatically branched to a particular system if appropriate. The systems may, or may not be, held on the same physical computer. Representatives of the Department's agents (County Councils and Consulting Engineers) will be given suitable access, to enable them to carry out their responsibilities as the Department's Agents.

5.2 An essential feature of NIS will be its user-friendliness and the presentation of information in graphical format rather than as pages of plain, indigestible computer printout - though some of the latter may still be necessary for some applications. It is intended that all accesses, searches and analyses will be able to be initiated through menus with simple yes/no answers rather than through the use of long and tortuous command sequences. The use of maps and networks displayed on the terminals will enable the user to rapidly identify the length of road or location of interest. Selected data will then be able to be displayed in a variety of forms - by addition to the network display, as histograms, pie-charts, etc, all in colour - according to the requirement. A screen dump will be available so that the user can then obtain a copy for accompanying other papers, a report, etc. Whilst this approach may appear expensive in terms of the extra resources needed for hardware and software, it will be far more cost-effective than training all staff in the use of computers. For NIS to be a success it is felt to be essential that the system is available to all staff rather than become a province of a specialised few. If this happened then the remainder of staff would soon become less interested, be less conscientious in checking data and entering new data and the system could fall into disrepute.

5.3 It is also planned to make a video recording of the whole of the Trunk Road network so that pictures of the road scene superimposed with appropriate data for that location stored in NIS can be displayed on terminals.

5.4 The adoption of this style of presentation for NIS will require the use of particular types of computer hardware, printers and terminals, and graphical software packages. This means that the development of a portable system in the traditional sense that can be mounted on a wide range of computer configurations will only be possible at an extremely high cost that could not be justified and, almost certainly, with a loss

of functionality. Wherever possible, applications software will be written in the well accepted HCSL standard subset of FORTRAN that will at least allow other possible users of the NIS system to mount the programs on their own computers.

5.5 During the consultations on the Phase 1 report, work has begun on several fronts that are independent of the consultation and which represent valuable aids to staff. The video recording of the whole of the Motorway and all purpose Trunk Road network was undertaken in the summer of 1985 and the computer/video interface to enable data and pictures to be superimposed is being developed. Development of the graphics facilities has been stated and will be available soon for use with the limited sets of data already held by the Department. The need for a Data Directory in which the existence and storage location of existing data can be entered has been identified and a system developed as a preliminary to locating and entering data into NIS itself. A more detailed study than was possible in Phase 1 of the alternative DBMS's has been undertaken and incorporated a study of the Data Directory that will be required to control the specific data components within the complete NIS system. The precise definition and usage of each data component is vital to the successful longer term development of NIS.