LOMAS : A MICRO-COMPUTER-BASED LOCOMOTIVE MAINTENANCE MANAGEMENT INFORMATION SYSTEM

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ABSTRACT: *In 1982 Vicrail commissioned the design and construction of a management information system to monitor the performance of the locomotive maintenance activity and assist decision making at several levels of management. The paper describes the problems the system had to address, the performance indicators to be measured and the resulting design philosophy adopted. The reasons for selecting a microcomputer as a basis for the system are outlined together with the principles of operation in Vicrails maintenance environment. The paper finishes with a brief description of the project and some conclusions which may be applicable to other microcomputer-based information systems.*

CONIEXI OF IHE MAINIENANCE INFORMAIION SYSIEM

Vicrail's fleet of mainline diesel electric locomotives is older than that of most rail authorities. Some classes are 29 years old and the fleet average is 16 years. Keeping this fleet running has been a considerable achievement by Vicrail's maintenance facility, at the cost in recent years of increasing levels of maintenance and somewhat reduced locomotive availablity.

In 1981 Vicrail decided to introduce an improved standard and frequency of country passenger services. The inception of the service was expected to coincide with the seasonal peak of Vicrail's grain handling movements. As a result there was considerable pressure in the latter half of 1981 to ensure sufficient locomotives would be available to carry both traffics in addition to Vicrail's other normal commitments. A working party was assembled in August 1981 to study locomotive operations and maintenance requirements and then to formulate recommendations leading to improved locomotive availability and effectiveness of use. Where possible the study was to develop solutions which could be implemented rapidly, say within a year, leaving strategic considerations to a longer term locomotive requirement study already under way within Vicrail.

The Working Party included representatives from Workshops, Rolling Stock, Operations and Planning Branches. It identified a number of possible actions which could improve locomotive availability. The Working Party also recommended the creation of a system to inform the various levels of management concerned whether the improvement action had been successful initially, and the extent to which the improvements were maintained in the longer term. The new system would have to overcome the series of management information problems described in the following section.

THE MANAGEMENT INFORMATION PROBLEMS

The maintenance plan for each locomotive consists of a sequence of standard examinations performed when the locomotive has run for predetermined distances. The scope and frequency of examinations are related, ranging from minor examinations performed relatively frequently to major overhauls performed only after a million miles or so. A record of examinations due and performed is kept for each locomotive. Prior to commencement of the study it was known that a substantial number of major overhauls were overdue or likely to fall due within the next year. A quantitative exercise undertaken as part of the study showed that:

- the workload invloved in retrieving the backlog represented by the overdue examinations represented several months work for the entire maintenance workforce.

- substantial additional resources would be required to overcome the backlog, even over a five year period.

- existing information systems had failed to alert senior management to a major workload backlog which had built up over several years.

Thus a major goal for the new system would be to keep track of the forthcoming and outstanding examinations, to monitor the workload implications and to relate these to the capacity of the maintenance workforce.

Records were kept of maintenance work carried out on each locomotive, but not of the maintenance inputs in terms of manhours or materials. Thus there were no records showing which locomotives of a particular class and age were the most costly to maintain. Likewise there were no records of individual locomotives' downtimes and as a result there was no convenient basis for establishing which locomotives of a particular class and age yielded best availability. There was thus no routine way of discovering empirical relationships between locomotive downtime and exam frequency. If the system was to contribute to the optimisation of maintenance policies it would have to address both of these variables.

There was general agreement that one principal objective of a maintenance system was to a achieve a specified level of locomotive availability. Debate existed however between the various branches as to how this should be measured:

- one branch opted for the number of locomotives available each morning at a specified time.

- another inferred availability from a count of locomotives in the repair shops at midnight.

- some included all locomotives in the total, while others counted main-line locos and pilots separately.

If the system were to measure maintenance effectiveness then it would have to find a way of measuring availability which would be acceptable to all the parties involved.

The other major maintenance objective was agreed to be locomotive reliability - meaning an absence of breakdowns or failures in service. Vicrail's systems already captured information on service failures of all kinds, but did not segregate or summarise the locomotive failures in a convenient form for management.

THE SYSIEM'S CUSTOMERS

From the outset it was clear that the system would have to provide regular summary reports on the success of locomotive maintenance for top-level management, including at Vicrail the General Manager and a number of AGM's. The objective was to produce for this audience a periodic one-page report summarising for the entire locomotive fleet:

locomotive availability
locomotive reliability
maintenance workload
maintenance backlog

For each variable the report would indicate the current level and also some comparisons with previous or target levels.

The next level of management, branch heads and their senior assistants concerned with locomotives, were interested in the same variables, but in more detail and with varying emphasis. Operations people were interested in availability and reliability by class of locomotive. Maintenance and Workshops staff needed to know about locomotive workload and downtime in each shop. Thus the second level of reports consisted of about 20 pages of reports broken down by locomotive grouping and shop.

A third level of management was concerned with the technical conduct and improvement of maintenance. Their need was for a conveniently accessible database of locomotive information on which they could draw:-

- to answer specific questions from higher management levels

- to carry out investigations leading to improved maintenance procedures and policies

THE BASIC DESIGN

The range of needs described above dictated much of the system's design. For instance, the need for information about individual locos led directly to the decisions to:

- base the system on information about individual locomotives.

- retain as much information as possible about maintenance work on locomotives in the original "as-entered" form.

- retain information about individual locomotive failures in service

- keep the jobs and failures records conveniently accessible by loco.

Thus the basic information would be retained disaggregated and management reporting would be based on periodic summations of this data.

This design provided a total record of each locomotives downtime for maintenance or failures including start and finish times of each occurrence. It thus offered the possibility of measuring fleet availability in a number of ways:-

- the number of locomotives available at a particular time

- the number of locomotives which were available at some specified time in the past.

- the aggregate hours of downtime as a proportion of the total hours available during a specified period.

The system thus offered the possibility of reconciling conflicting views on availability.

Early in the project it was necessary to agree reporting formats with representative members of the customer groups described above. In principle, report layouts should not affect the underlying data structures. In practice the discussions led to the design of a reporting framework which for reasons of efficient processing within limited resources became linked to the structure of the stored information itself, and of the operating procedures. The reporting framework could not therefore be easily changed once the system was in operation. The key decisions were:

- Weekly reporting, based on a week ending on midnight Sunday

- The existing eleven locomotive classes were collected into the following more significant groupings:

  - Large Mainline Diesel Electric
  - Small Mainline Diesel Electric
  - Mainline Electric
  - Large Pilot
  - Small Pilot

- Reporting comparisons showed:

  - This week
  - Weekly average year to date
  - Weekly average last year

More ideal reporting comparisons would be "this week" against target and/or "this year to date" against target. However, at the time of commencement of the project insufficient information existed to enable realistic setting of targets. Vicrail intends to incorporate target comparisons at a later stage in the system's life when better target setting information is available.

Additional Requirements

As initially conceived the system's sole aim was to produce various levels of management information. However, during the design process it became clear that in order to be successful the system would have to meet certain additional requirements.

- Input methods would have to be suited to the locomotive maintenance environment.
- The system should, where possible, produce outputs helpful to locomotive maintenance foremen.
- The system should, where possible, reduce clerical effort within the locomotive maintenance function.
- The system should in time become the principal source of data concerning locomotive maintenance and fault histories.

The system was called IOMAS - Locomotive Maintenance System.

PRINCIPLES OF OPERATION

Continuous Input

The system was designed to receive maintenance and fault data daily, virtually on a continuous basis. New data and modifications to previous entries are recorded by foremen or clerical assistants on a series of input sheets. From time to time, at present daily and we hope more frequently in future, these are keyed into the machine by a clerical assistant. As each piece of data is keyed it is checked against that already in the system and where there is inconsistency, rejected. For instance, the system will object to a loco's being booked into a workshop unless the loco has been previously known to be available; conversely a loco cannot be booked out of a shop unless it has already been booked in there, maintenance jobs must finish after they start; and so on. It is up to the clerical assistant entering the data to correct and retry rejected items either from his own knowledge or by direct reference to the foreman originating the data.

Reporting Cycle

Once a week (preferably early on Monday) the system performs its weekly reporting cycle.

- Maintenance information is brought up to date as at the close of the Sunday night shift. Fault information is also updated to the same time.
- Speedometer information for every main line loco in the fleet is collected over the weekend and early on Monday is entered into the system.
- A weekly reporting run occurs resulting in production of a complete set of the Management Information Reports providing the weekly outputs and making the system ready for resumption of daily inputs for the following week.
- The weekly reports are distributed as quickly as possible to all recipients on the distribution list.

The daily cycle resumes for the following week followed in turn by another weekly cycle producing the next generation of weekly reports.

Once a year it is necessary to reset annual totals and move the system's base date with an annual reset run carried out after the weekly reporting run.

The most convenient existing source of data on maintenance work completed within Vicrail was a list of locomotives unavailable prepared daily by the maintenance shops and showing when locomotives were expected to be completed. The existing source of Failures in Services Information was the daily "Items of Information" dealing with failures of all kinds including those due to Rolling Stock and other causes as well as locomotives. Distances run were obtained from weekly speedometer readings collected by the Rolling Stock Department. It was decided to collect data for LOMAS from these three sources using the following principles:

- Io use the computer to produce data collection sheets in a similar format to existing documents.
- Io minimise the changes in peoples' habits by making the computer input sheet look as similar as possible to existing forms.
- Io help in the collection process by printing on the input sheets up to date information on the status of all partially completed work.

The result of these decisions was introduction of the new procedures without disruption to existing patterns of work in the Maintenance Shops. There was also considerable improvement in the accuracy of the data collected.

Convenience of Inputs

The usefulness of the data in the system depends in large measure on the speed and convenience with which it can be gathered and entered. All inputs of data to the system are via the input sheets described in this section which were designed to:

- Be easy to understand. Where possible, layouts resemble existing manual forms.

- Minimise work. Abbreviations are used wherever possible. Users simply handwrite new information in spaces provided (or write corrections over existing items).

- Save effort. Input sheets show all relevant information from previous day's inputs, thus eliminating transcription.

- Minimise error. Data from input sheets is checked for consistency with previously entered data before being accepted by the system. Problems can be resolved while the facts are still in people's minds.

The input sheets were initially designed to gather data on daily (Maintenance Sheet, Fault Sheet) and weekly (Distance Run Sheet) cycles but could be used more frequently if desired.

Loco Maintenance Sheet

The Loco Maintenance Sheet is the medium for inputting to the system all progress on maintenance work. Its layout follows a similar format to existing manual "locomotives unavailable" sheets, which (once working) it is intended to replace.

Each morning the system produces a maintenance sheet for each shop showing all outstanding jobs as known to the system the previous night, and providing space to enter additional jobs as they arise throughout the day. Spaces are provided on the maintenance sheet for entry of the expected updating information (manhours worked and so on) but in addition, there is provision to amend most of existing information in handwriting. Thus the Maintenance Sheet provides two-way communication between the system and the maintainers, feeding back yesterday's progress at the same time as capturing today's. It also eliminates the need to transcribe loco and job information from one day's sheet to the next.

Fault Input Sheet

The Fault Input Sheet is the system's way of capturing information about Failures in Service. The initial story of a failure in service is entered directly from the "Items of Information". A fuller description and the true cause of the failure comes from the report of technical people in Rolling Stock Branch responsible for fixing the fault.

The Fault Input Sheet provides for both cases: previous failures awaiting entry of cause; and new failures.

Distance Run sheet

The Distance Run Sheet is the means of inputting weekly to the system the distance run by each locomotive.

The sheet provides for 3 types of input:

- Normal weekly input consisting of a speedo reading and date
- Change of speedo resetting the base value and units of measurement if required
- Correction of an input speedo reading subsequently discovered to be in error.

CHOICE OF HARDWARE

The new information system was wanted urgently and therefore had to be developed in as short a time as possible. This meant that there would be little time available for the selection and purchase of additional equipment: if the system were to be computer based it would have to run on equipment already existing within Vicrail.

The options available were therefore:

- A manual system
- A system based on Vicrail's FACOM mainframe
- A system based on IRS-80 micro-computers in the Rolling Stock Branch.

The requirements described above, plus a need to reduce clerical workload made selection of a computer-based system inevitable. The convenience, proximity and availability of the rolling stock IRS-80 computers meant that they were ideally situated to support LOMAS. The problem, therefore, become one of designing LOMAS to fit within the limitations of a TRS-80 model 3 with 64 kilobytes of memory and 4 x 8" floppy disc drives each with a capacity of about 480 kilobytes.

Initial checks on the numbers of records that would be required, the volume of input and the amount of information to be stored showed that the existing machine would be suitable for development but that a machine with a larger storage capacity might be required once the system went into full operation. In the event the larger storage capacity was required and the production machine was equipped with a hard disc drive with a capacity of 2 x 10 megabytes.

PROGRESS OF THE PROJECT

Initial design started around Christmas 1981 and preparation of a specification started in earnest in January 1982. The specification was complete by end January and following discussions and acceptance by VicRail Executives programming occupied February resulting in a demonstration version being available early in March 1982. An initial exercise was mounted to collect a week's real data and enter it on the system to provide a realistic demonstration set of reports. This initial demonstration was so successful that it was decided to continue collecting and entering data with the result that a file of increasingly accurate production information started to accumulate almost immediately.

Demonstration copies of the various reports were circulated to VicRail Managers and suggestions for minor modifications received. These resulted in preparation of a number of additional reports and provision of one or two extra functions not anticipated in the original design. By April the complete design was approved and a production machine had been ordered. By the time it arrived in June around 35 programs were in routine operation and the pressure to transfer them to the production environment was quite intense. However, the machine delivered was not available for service until August as various equipment faults took considerable time to remedy.

The system has become fully operational in its final form late in 1982 and by this time it has accumulated six months operational history. The information is of a high standard of accuracy and is beginning to build a usable picture of trends in maintenance performance. Thus the system has taken eight months to build from start to finish but in effect the last four of these months have been spent in improving, testing and validating what was already a production system achieved by April.

CONCLUSIONS

The project is a good example of how a modern microcomputer costing less than $20,000 can support a significant information system. A decade ago the task would almost automatically have been assigned to a mainframe machine costing hundreds of thousands of dollars. However, microcomputer capacity is limited and considerable effort was expended early in the project in designing files and links to make best use of the computing and disk capacity available. We believe that for some time to come resource usage considerations will play an important part in the design of any production system attempting to use a micro computer. They became particularly important to the current project when, once production was under way, greater precision of recording of locomotive jobs revealed that many more were in fact undertaken than had been recorded under the previous manual system. Once in full production the computer had to deal with between two and three times the through-put that had originally been envisaged and as a result efficient use of resources became extremely important.

Effort was devoted at the beginning of the project to developing a set of central program modules for accessing files, comparing dates, converting record numbers to locomotive numbers and other standard functions. This meant that while initial programming development was rather slow, once the central modules were complete all subsequent programs could be written very rapidly. As 12 programs were originally envisaged but upwards of 30 were actually written, this approach permitted substantial savings in the programming and testing time required for the whole project.

Hardware problems were unanticipated as the TRS-80 is a well-proven and most reliable machine. However, the production machine relied on a hard disk and line printer from a separate supplier: the reliability problems were associated with these items. Another time it might be preferable to accept lower overall performance and higher purchase cost in return for the additional support offered by a supplier who provides the peripherals as well as the machine.

The were significant problems in persuading the various branches interested in maintenance performance to accept the figures produced by LOMAS as correct. In order to do so it was necessary to write a number of additional output reports that would provide doubters not only with the LOMAS measure of average downtime but also with records of the number of locos out of service at particular times chosen by them. The lesson here was that in order to convince users of the accuracy of the results as reported by LOMAS, it was necessary to provide results in a format similar to that which users were accustomed, at least for an interim period.

The central modules will facilitate creation of further programs which can use LOMAS data to analyse:

- Mean time between failures
- Distributions of repair times
- Optimal preventative maintenance scheduling
- Locomotive scrapping and replacement decisions
- Identification of recurring faults

LOMAS is now tracking locomotive availability consistently and confirms that there has been some improvement since the 1981 study. Vicrail has taken action to overcome the maintenance backlog and an accelerated workshop overhaul programme is under way. LOMAS is recognised as the prime information source within the locomotive maintenance function; there is still room for improved acceptance in other branches.

In conclusion, it was clear to the team that the major factor in the success of the project was that the micro computer belonged to the Rolling Stock Branch which was the major user concerned. As a result they regarded it as "our" computer, provided assistance with design and programming and automatically took over responsibility for operation of the system right from the outset. The result has been a truly user-owner system.