1. **Study some Case Studies for software maintenance and maintenance costs and write summaries of these case studies?**

OVERVIEW OF CASE STUDY

Aims and objectives the major aim of the case study was to promote the maintenance function. Control and visibility of maintenance would be enhanced through the collection of data and the production of reports. Detailed objectives were to:

- Improve the monitoring and control of the maintenance function; - establish a reporting system to promote effective communication with senior management,

Record the problems in supplier materials (hardware and software) in order to report

- Determine the actual level of resources that the maintenance function consumes, - investigate the characteristics of maintenance incidents in order to classify them, - apply statistical methods to the maintenance data for prediction purposes, problems and complaints,

It was recognized that if current maintenance resource consumption could be quantified then future projections would be more accurate than those based on subjective estimates.

Maintenance records and projections would be valuable to senior management and customers. Use of the MDCS and Reporting was found to be a significant improvement on the existing personal diaries for maintenance activity management.

Maintenance procedures:

When the personal diaries were substituted by the MDCS and reporting procedures, maintenance activity became more structured and the steps within maintenance more visible. The overview in Figure 1 shows the steps which were followed as part of the MDCS and reporting procedures.

Steps are displayed as boxes and the sequence of step execution shown as directed lines. A maintenance incident, planned or unplanned, enters the MDCS when the software maintainer opens an Incident Form. The incident is then investigated and the solution planned and implemented.

A high proportion of incidents are successfully resolved and this leads to the closure of the incident and the Incident Form, by the maintenance manager. During all of these MDCS steps pertinent details on incident category, severity and technical background are recorded for future analysis.

The Reporting section of Figure 1 illustrates the steps followed as part of the Reporting procedure. Each Closed Incident is entered to a data repository. Incidents are then extracted from the repository using Query routines to form the necessary input data for statistical analysis.

The results from this analysis then form the major part of the Maintenance Report.

Steps in using the MDCS Users found that the MDCS proved more involved than originally expected. The use of the Incident Form followed standard steps, as in Figure 1, but the sequence of execution of each step varied from incident to incident.

Figure 2 gives an expanded view of the MDCS part of Figure 1.

Step 1 involves the allocation of identifiers to the Incident Form for the incident and its context. The incident is now open and is investigated. After investigation the incident remains open, is closed or is closed to await further information. An incident is closed to await further information if circumstances dictate that investigation, planning or resolution cannot proceed.

The incident remains open if a solution is planned and it is closed if no actual fault is found or if a user error caused the incident. The resolution of the incident often required planning. At the planning step more information on the expected effort required for solution and technical detail is recorded on the Incident Form. The incident is now ready to be resolved, that is the fault is fixed or the planned enhancement made.

During resolution it was sometimes found that the incident required substantial resources. In this case the incident was linked to other Incident Forms. Thus for major incidents more than one Incident Form is associated with the original incident. On complete resolution of an incident the incident and the Incident Form are closed. When an incident is closed the Incident Form is added to the central repository.

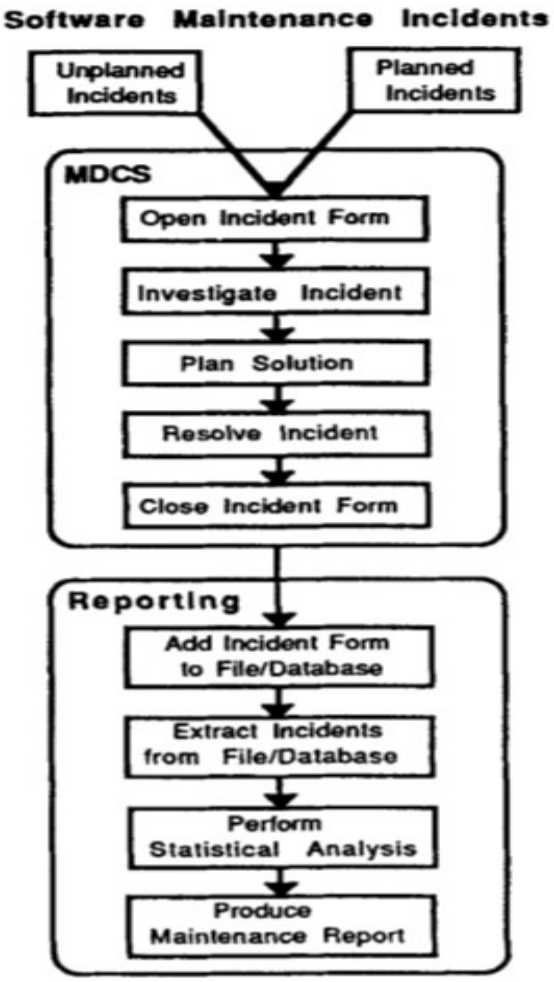

Figure 1. Overview of software maintenance data collection and reporting steps

Steps in using the reporting procedures:

The Incident Forms from the MDCS were aggregated regularly to the central repository and the data extracted. The next step involved statistical analysis. Graphical and tabular items produced were interpreted by management and other staff, and those items which proved most informative were included in the Maintenance Report. Maintenance Reports followed a standardized format (Pressman, 1988) and were produced on a quarterly basis and contained:

Introduction, definitions and background information,

- Analysis of incident effort, category, severity and resolution time,

- Analysis of incident frequency over time with trend interpretation,

- Study of maintenance effort expended at user installations,

- Summary statistics for total time period,

- Reporting of complex and troublesome incidents, - catalogue of software products and versions maintained by group.

The reports produced were circulated to maintenance staff as well as to higher management. This feedback meant that maintainers could see clearly how well the maintenance activity was being performed.

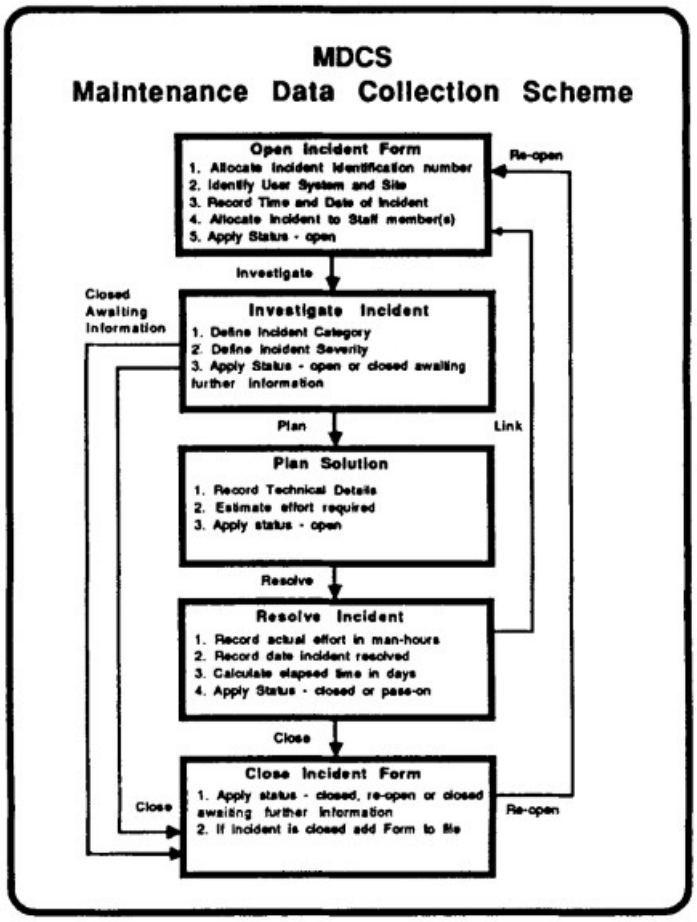

Figure 2. Steps in software maintenance data collection scheme

MAINTENANCE DATA COLLECTION SCHEME (MDCS):

It needs to be stressed that data collection is a non-trivial activity (Comer et al., 1987; Mellor, 1989; SCOPE Consortium, 1989; Ross, 1989) and must be taken seriously by management and the data collectors if it is to succeed. In particular:

- Management must be supportive of data collection; - data collection should be seen as an investment both in the short and the long term.

- Maintainers must be aware of the reasons for collecting data. Data collection is not

- Bias in the data is easily introduced. Incident Forms should be screened by management

Better control of the maintenance process will mean savings in effort and time, for assessing the productivity of individuals, and signed-off before acceptance.

Case study results:

The case study results given here are the graphs, tables and fitting results found during analysis of the nine months' data.

Incident effort From Table I:

The average effort necessary to investigate and resolve incidents is approximately 5 man-hours of effort. The variance at 85 man-hours, with the median and mode being respectively 1.5 and 0.5 hours, is considerable. This variation is easily understood by examining the minimum and maximum figures. Incident effort is highly variable and this variation would lead to difficulties in prediction. The box plot of effort in Figure 4 shows the frequency distribution of incident effort over its range.

Table 1. Maintenance incident effort statistics (man-hours)

Sample size	217
Average	5.10806
Median	1.5
Mode	0.5
Variance	85.8239
Standard deviation	9.26412
Minimum	0.5
Maximum	91.5

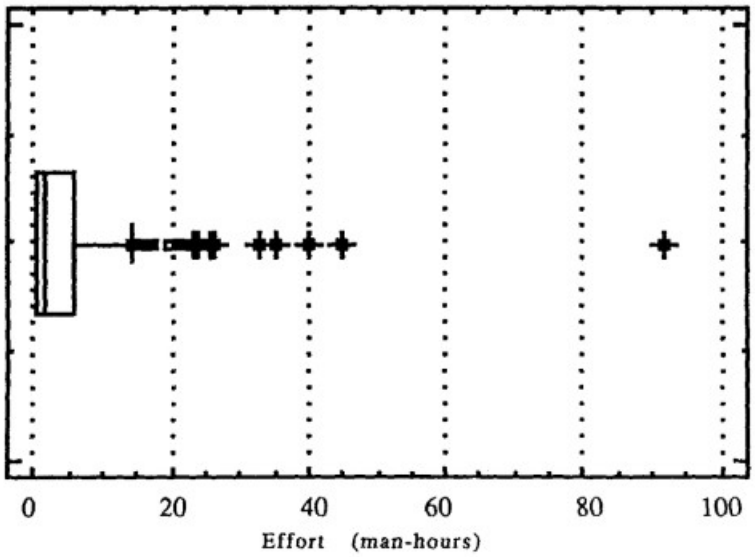

Figure 4. Box-plot of incident effort

The distribution of incidents concentrated at the lower effort end of the box-plot shows that most incidents require relatively low amounts of effort and only a relative few are outliers. These outliers were legitimate and were reported to management.

The box-plot of incident effort shows a skewing to the left. This indicates that any theoretical distribution fitted to the effort distribution should also be skewed to the left, which rules out the normal distribution.

CASE STUDY CONCLUSIONS:

The case study was deemed a success by management and maintenance staff and the collection of data was continued by the group. Two sets of conclusions were drawn from the case study, those which concern data collection and statistical analysis and those which are of practical importance to management. Conclusions which could be drawn on data collection and statistical analysis are that:

- simple descriptive statistics, using pie-charts and histograms were found to be useful to management for the purpose of supervision and control of the maintenance process; - a data collection scheme is a necessary prerequisite for the systematic recording of faults; - an appropriate statistical model did give a good fit to the distribution of the weekly number of incidents.

However, there was not sufficient data to conclude that the model was a good predictor of the future weekly number of maintenance incidents; - it was not possible to make an accurate prediction of weekly maintenance effort, owing to the high variability in the effort required to resolve maintenance incidents; - the incident rate per week is no indication of the total effort necessary to resolve them all; - careful thought must be given to the basic aims of data collection and the analysis methods which are to be used.

Conclusions which were of more practical value to software maintenance manager's incited:

The collection and analysis of data resulted in maintenance being made visible to management; user enquiries and systems upgrades formed 71% of the total effort, in man-hours, of the maintenance activity. Maintenance was therefore much more than 'fixing faults'; only 7% of maintenance incidents were severe enough to cause 'loss of service' at a user's site; around 80% of incidents were resolved on the same day they were reported by the user to the maintenance group.