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Measurement of the Maintenance Process from a Demand-based Perspective

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SUMMARY

While various figures have been published on the workload distribution of maintenance activities, this information is at best indicative of management perceptions, most of it originating from surveys, and almost none based on actual data. The reason for such a lack of published data is very simple: the industry does not measure or collect maintenance-type data in a timely and accurate fashion. This article presents empirical data from a two-year measurement effort in the maintenance environment of a Canadian financial institution. The findings reported here are based on a daily data-collection process including 2152 *work requests*, which required 11 332 *days* to complete.

Based on the supply/demand paradigm, maintenance data have been collected and analysed to investigate the basis of productivity analyses through such concepts as the product group, the product mix and the product mix changes on the demand side, as well as resource allocation by product classification and quarterly and yearly distribution changes. This paper includes a discussion on the measurement program implemented, and illustrates how insights into the maintenance process are gained through various measurements. The paper also presents hard data on the demand side and on the supply side of the maintenance process, as well as an analysis of the data collected. The findings reported are part of a larger measurement program introduced to manage the maintenance area in the same way as any other business unit.

KEY WORDS Maintenance measurements Maintenance work products categories Measurement program Maintenance statistics Maintenance productivity ratios

Many organizations that started to implement computer applications 20 to 30 years ago now have a major portfolio of applications to support their business operations. Surveys indicate that 50% to 70% of an information systems (IS) budget is spent on maintenance activities (Lientz and Swanson, 1980; Harrison, 1987). However, these surveys of IS managers have not been supported by empirical data, and very little empirical software maintenance studies were carried out in the 1970s (Lientz and Swanson, 1980) and 1980s (Sharpe *et al.*, 1991).

Software maintenance is often defined as including all activities associated with changing, modifying or otherwise altering existing software applications (Sharpe *et al.*, 1991), or alternatively as work done on a software system after it becomes operational (Gill and Kemerer, 1990; Parik and Zvegintzov, 1983). Within that frame of reference, maintenance work is further divided into the following three categories of changes (Swanson, 1976; Martin and McClure, 1983; Arthur, (1988):

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(1) *Corrective*: changes to correct program failures, performance failures and implementation failures
(2) *Adaptive*: changes to adapt a program to changes in data requirements and processing environments
(3) *Perfective*: changes to enhance performance, improve cost-effectiveness, efficiency and maintainability.

Software maintenance productivity has been defined as a simple output/input ratio, most typically thousands of lines of code or thousands of function points maintained per work-month (Gill and Kemerer, 1990; IFPUG, 1990; Johnson, 1991). While interesting, such a ratio does not lead to causal relations in maintenance productivity studies, and our research motivation was to add to the body of knowledge in favour of a more appropriate measure of maintenance productivity.

The perspective selected for the analysis of the maintenance process is based on the supply and demand economic paradigm. The maintenance work product classification will be viewed from the maintenance customer perspective: the demand side will be analysed through an analysis of the maintenance work request distribution, and the supply in terms of work-days required to complete these work requests. This article also discusses the adjustments required to the above-mentioned maintenance category framework definition, and presents and analyses the data collected.

This research is a study of the measurement work carried out in software maintenance at a Canadian financial institution in 1989 and 1990. The work is empirical and can be classified as a field study wherein researchers collect data on several objects or groups of objects to identify significant differences, either at a single point in time or across time (Sharpe *et al.*, 1991). This research work includes an analysis of variations across applications. All of the data originated from one organization, therefore neither inter-organizational nor industry differences should introduce noise in the measurement process (Gill and Kemerer, 1990). The drawback is that this may limit the applicability of the results. However, owing to the lack of empirical data on software maintenance, these results will clearly be of interest to researchers in this field, and there is no *a priori* reason to believe that the maintenance measurements illustrated could not be applicable across organizations and industries.

The scope of this empirical research is, therefore, limited to a report on the maintenance measurement program as implemented, based on the supply/demand paradigm. The lessons learned and some of the difficulties involved in measuring software deliverables in a maintenance environment are described. This article also provides some insights into the decision-making process of software maintenance, as well as an illustration of the benefits derived from the measurement program implemented.

1. DEFINITIONS

In software factories, the classification scheme of the software process is based on a structure different from the one reported in the literature, and it is therefore imperative to clarify upfront the development-maintenance classification rationale used throughout this research (Abran and Nguyenkim 1991; Johnson, 1991).

1.1. Development

At the industry-research site under study, the definition of development work includes not only the development of new applications, but also major enhancements (additions and changes) to existing applications. There are three principle reasons for arriving at this definition of development.

(1) Development is characterized by the notion of project management. The addition of a major function to an existing application must be handled within a project structure: the issue, or problem to be solved, is complex and requires a team effort, involving both users and software staff. Usually, a business case must be prepared to identify the benefits, as well as the projected costs, of a project; specific funding must be approved, resources must be allocated and deadlines set up. This requires project planning, scheduling and reporting. Because of its scope, it must be managed in a project management style.
(2) The project must be planned ahead of time, usually on an annual basis at budget time. At this time, various project proposals are prepared and presented. The projects selected are funded either based on a target ROI (return on investment), or for strategic reasons, or on planned legislative changes. There are other projects approved in the course of a year, but these are few and far between and must go through a specific extra-budgetary approval process and have a strong business case in order to get the go-ahead.
(3) The project must be approved by senior executives, a project manager must be named, specific deadlines approved, and a steering committee set up to overview project's progress.

In the environment under study, all of the projects so-defined, are classified as development work and not maintenance work. The nature of the work carried out for major enhancements can be classified as a variation of the development life-cycle process. The

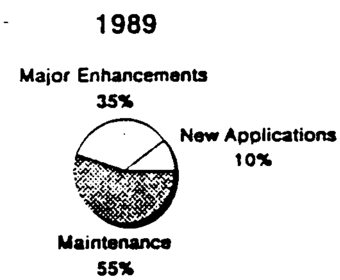


Figure 1. Research site total work effort (1989)

pie-chart (Figure 1) shows the distribution of the workload of this organization whose business units rely heavily on their computerized applications. Of the total budget, less than 10% is dedicated to building totally new applications from scratch, while 35% goes into the addition of new business functions within existing applications (classified as major enhancements in Figure 1).

1.2. Maintenance

At the empirical site under study, maintenance work is defined as that which is not related to project work, and, even with this restrictive definition, it still represents the greatest share (55%) of the total budget. Maintenance, as defined from now on, does not require a project management structure for its performance, and is handled very differently:

(1) The size and complexity of each work request are such that it can usually be handled by one or two resources.
(2) Work requests come in more or less randomly and cannot be accounted for individually in the annual budget-planning process.
(3) Work requests are reviewed by operations committees which are responsible for assigning priorities. These committees include both user representatives and application software support managers.
(4) The operations committees must work within preset annual budgets, and they must manage their queue of work requests (requests outstanding, completed, in progress, etc.)
(5) The maintenance workload is not managed using project management techniques with a single project focus. There are no project managers and there is no project reporting. There is, however, queue work status reporting: requests outstanding, completed, in progress etc.
(6) The maintenance workload is user-services-oriented and application-responsibility-oriented. Priorities can be shifted around at any time, and any work request on a production problem takes priority over work in progress.
(7) If additional funding is required during the year (for example, when there are too many requests in the queue or when the delays for initiating or completing work requests are too long), the executive steering committee is approached for funding approval to improve service levels, but not to fund specific requests.
(8) The work request will require fewer than 60 person-days to complete (this cut-off varies from 30 days to 80 days in various other organizations).

Furthermore, in the industrial environment under study here, development projects and maintenance work are handled not just by two different managers, but by two different types of managers, one an expert in project management techniques, and the other a skilled service manager responsible for the applications under his care. What is expected of each of the two types of managers is quite different. A project manager must be within budget and on time, and the project sponsor must be satisfied with project performance. A maintenance manager, on the other hand, must keep his applications running smoothly, he must react quickly to restore order when there are production problems, he must provide the agreed-upon level of service and keep user-community confidence that they have a dedicated and competent support team at their disposal, which is acting within the agreed-upon budget.

2. INDUSTRY-RESEARCH SITE

2.1. Research motivation

The maintenance process at this industry-research site is recognized as a vital function of the corporation, and the maintenance area is run like an internal service bureau for the user community. The budget is approved annually by each of the business units, with a specific number of annual billable work-days for the maintenance of each application. These costs are then charged back, on a monthly basis, to each profit centre. Maintenance work request queues are managed by joint user/information systems (IS) operations committees.

In 1987, additional metrics (function points) were introduced within the *development* environment, and these metrics provided senior IS executives with management information which gave them both productivity measures and insights into the deliverables of the development work. With these metrics based on the user's perspective of the development work product, they provided other corporation executives with credible measurements of the development process, and this measurement process in turn considerably enhanced their credibility as good managers with adequate tools to manage the resources under their control (Abran and Robillard, 1990).

Senior IS management was therefore interested in looking at improving the measurement process within the *maintenance* areas. They were interested in obtaining productivity-oriented metrics, similarly based on the user's perspective of the maintenance work product, that would provide them with appropriate and credible information which would allow them not only to manage the process as it was, but also to influence the process and bring in changes that would foster the interests both of the user community and of IS maintenance staff. They were looking not for specific answers from the maintenance metrics, but rather for tools to manage and improve the maintenance process. They also needed metrics to measure the progress and benefits brought in by the introduction of new productivity tools, both in the maintenance area and on the downstream side of major investments in development productivity tools, such as the very expensive CASE technology. In summary, they wanted to monitor, to analyse and to manage the demand and supply sides of the maintenance workload. From this perspective, the research questions were the following:

Demand — How can the maintenance work requests be classified, from the demand perspective?
— What is the distribution of the work requests?
— What is the evolution of this distribution?

Supply — What is the workload distribution, based on the demand classification?
— How does a shift in demand affect the workload distribution?
— Do the various applications have different supply characteristics?

Answers to the above questions would initially provide an understanding of the cost-accounting structure of the maintenance work product. Insights into these demand and supply dimensions of the maintenance work products and processes could then eventually lead to the management of the maintenance workload through some kind of pricing mechanisms.

2.2. Measurement programme history

The maintenance management processes have been formalized and improved over the past few years. A work request can only be initiated by means of a signed form, called an RFS (request for service). As soon as the form is received by a maintenance manager, a number is assigned and it is registered in the internal computerized time reporting system (TRS). Additional information is also logged on, such as the request originator's name, the name of the application, the date of receipt and time estimates (if they are known at the time).

All work carried out that pertains to this request for service (RFS) is logged on against the RFS number in the time reporting system (TRS), which includes the effort required to conduct the impact analysis and prepare the estimate, and to analyse, program, test and implement the solution. Actual effort is entered daily by all staff into the computerized TRS system, and all time spent over half-an-hour must be reported. Overtime in this organization is recorded and fully compensated, either through an overtime fee or a time-off equivalent. Daily, weekly and monthly controls ensure that all of the effort is recorded. There is also a variety of reports produced from this time reporting system, including monthly billing to the user community with details of all time spent for every RFS for which there was activity during the current month.

Up until the end of 1988, the measurement process was based on what could be called the metrics for the management of queues. such as:

— the number of outstanding requests;
— the average waiting time before being serviced;
— the estimated number of days in the queue;
— the number of requests completed;
— the number of requests in progress;
— comparison of estimates versus actual costs, etc.

While these standard maintenance metrics provide information on queue servicing performance levels, they do not provide enough information on the maintenance work product and they are not conducive to productivity analysis and comparisons. The objective in improving the measurement program in the maintenance area was fairly simple: to gain insight into the biggest chunk of the IS budget (55%) in order to manage maintenance in the same way as other business units. This required, as the first step, proper classification of the maintenance work. Lientz and Swanson's 1980 classification system was selected with its *Corrective, Adaptive* and *Perfective* maintenance categories. By definition, these work categories focus on changes made to the software applications. However, a significant number of work orders do not request changes but only information on the software components. To these three categories a fourth was therefore added, called *Other*, to take these into account.

It must be noted that this classification is not standard, either in academia or in industry

(GUIDE International, 1985; QAI, 1988; IFPUG, 1990: Madhav and Sankar 1990). Readers should, therefore, be careful when comparing this set of data originating in their organization or with survey data published in the literature. Furthermore, data pertaining to general administration and overhead activities are not included in this presentation, which is strictly limited to a consideration of maintenance work that can be attributed directly to a specific work request, and that can be billed to the user community as work carried out on their applications.

2.3. Pilot project

When the measurement program for the maintenance environments was proposed, there was initially a great deal of pessimism among the maintenance managers with respect to the feasibility of the proposal and the amount of effort required to collect the required data. A pilot project was set up to fine-tune the procedures and to demonstrate the feasibility of this endeavour to measure the maintenance process. This pilot project was initiated in March 1989: all maintenance work requests for a period of three months (Janary–March 1989) for the biggest application were analysed and classified according to the initial definitions of the work categories.

One objective of the pilot project was to verify in the field the appropriateness of the classification scheme of four categories: *corrective, adaptive, perfective* and *other*. It was found that while the first three categories were well defined and did not need changes in their definitions, the fourth category needed clarification. In light of the majority of types of services carried out in this category, it was re-labelled *User support*, and included the following types of activities:

- user requests for information on the particulars of the application's rules and behaviour:
- preliminary analysis requests;
- requests for ad hoc (one-time) reports that would not be reused or implemented in the production environment.

All the required information was available for the retroactive collection of data:

- Work request descriptions were available from the RFS forms filled out and signed by the users (including written confirmation by the maintenance managers on the nature of the work and confirmation that the work had been carried out and signed off), and the technical information on each RFS was still available, as were the staff who had worked on these RFS, should some information be found to be missing.
- Work effort by work request was available from the time reporting system.

The pilot project was successful: it demonstrated that the classification could be done comparatively easily, that the information required was available, and that the administrative systems were either in place or could be modified without any great difficulty. The results of the pilot project were presented in June 1989 to middle and senior IS management, and they approved the following recommendations:

(1) Implementation of the measurement program throughout the whole maintenance area.
(2) Identification and classification of all work requests retroactively to 1 January 1989, in order to collect a full year's worth of data rapidly.
(3) Implementation of a quarterly reporting mechanism for the maintenance managers. It was felt that monthly reporting would be too frequent in the light of the workload of the maintenance teams, and that on a monthly basis there might be not enough work requests by category for the analysis of trends.
(4) The results of the data collection process are then passed on to the productivity measurement coordinator, who prepares a consolidated quarterly departmental report.
(5) The productivity measurement coordinator is also available on a consulting basis, at no charge, to the application support managers.

During the first phase of the implementation within all maintenance teams, additional adjustments were required to ensure that consistency of the measurement process across the various maintenance teams, such as walkthroughs of the measurement process with the staff in the field and identification of fuzzy issues, a work request, for example, that could have been classified simultaneously into two categories. To address these issues, a detailed procedural classification guide was prepared, complete with real-life and complex case studies. Similarly, an ordering process for the classification scheme, based on the priority to be given to the most important category from a user's viewpoint: *adaptive*, *corrective*, *perfective* and *user support*. This introduces, therefore, a bias within the classification, but this bias is believed to be minimal, such situations being rare exceptions.

3. DEMAND ANALYSIS: Work Request Distribution

Two year's worth of data have been collected and examined: 1013 work requests in 1989 and 1139 in 1990 were classified and analysed, for a total of 2152 work requests (Table 1). The information provided for this analysis originates from the maintenance managers' quarterly reports on *work requests completed during the respective quarters*. Information on work in progress would not be included in these reports until completion time, and included in the following reporting period.

The distribution of the maintenance demand for both years is illustrated in Table 2. A comparison of data of 1989 and 1990 shows a significant increase in work requests in the adaptive category (from 20% to 33%), a decrease in the perfective category (from 9% to 6%), and in the user support category (from 44% to 35%).

It must be understood that, except for corrective maintenance, the number of work requests is strictly user-driven, and reflects, up to a point, their priorities. For example,

Table 1. Quantity of data analysed

Measurement units	1989	1990	Total
Demand: work requests	1013	1139	2152
Supply: work effort (days)	5209	6123	11 332

Table 2. Work request distribution

Work category	1989	1990
Corrective	28%	26%
Adaptive	20%	33%
Perfective	9%	6%
User support	44%	35%
Non-corrective	72%	74%

in 1990 the emphasis was shifted towards adaptive maintenance through a significant increase in requests (from 20% to 33%) to add new (but small) functionalities to existing applications, and a corresponding decrease in requests for information in the user support category (from 44% down to 35%). No information was found in the literature to compare this set of information on the demand side of the maintenance process.

Maintenance managers have indicated that the data collection process based on individual work requests is yet to be normalized for two subsets of maintenance work: emergency fixes and very small call-in user requests. In both cases, the formal authorization process is perceived by both clients and maintenance managers as an irritant and as red-tape: in order to provide a high level of responsiveness to user needs, the administrative procedures are partially bypassed in these situations by billing the effort involved to two general-purpose work requests that stay open throughout the year and against which effort is recorded daily, charge-back billing is processed monthly, and management reporting is done on a quarterly basis. On the demand side, the number of work requests is most probably understated in these two categories (corrective and user support). On the supply side, no bias is introduced in terms of work effort by work category. In cost-accounting analysis by work request, these open-ended work requests will have to be set aside when computing statistics by work request: while individual managers have kept detailed information on such requests for both control and planning purposes, the recording process is not yet standardized across teams, and the exact bias could not be determined. It was therefore decided that these data be taken into account for the analyses at the aggregate level, while taking specified normalized data subsets for detailed analyses.

4. SUPPLY ANALYSIS

4.1. Work effort distribution

On the supply side of the maintenance process,a total of 11 332 days of work effort were categorized and analysed (Table 1). This represents 57 work-years for this organization, whose yearly average of billable days per person is 200 days, a day representing 7 hours of actual billable work. This in turn represents, on average, 5.2 days of work effort per work request.

The maintenance work effort distribution is presented in Table 3. From this table it can be seen that maintenance teams in 1989 did far more than correct defects and errors (36%). In fact, they spent 64% of their time in 1989 doing other types of maintenance

Table 3. Maintenance work effort distribution

Work category	1989	1990
Corrective	36%	35%
Adaptive	29%	34%
Perfective	11%	5%
User support	24%	25%
Non-corrective	64%	65%

work: they spent 29% adding new functionalities to the applications, 11% optimizing application performance and a quarter of their time (24%) answering user requests for information.

The distribution of work is fairly stable over the two-year period, specifically for the corrective and user-support types of maintenance work, while the shift in effort between the adaptive work (from 29% to 34%) and the perfective work (from 11% to 5%) reflects the increased amount of resources required for the adaptive requests to add functional enhancements to facilitate business operations, offset by a decrease in the amount of resources required for perfective maintenance.

4.2. Industry comparisons

No other hard data sets were found for comparison purposes. However, analysis of industry survey results can provide a basis for comparison (Zvegintzov, 1991). These data were obtained from three surveys: Lientz and Swanson surveyed 487 organizations in 1980, R. K. Ball (1987) surveyed participants at the 1987 Annual Meeting and Conference of the Software Maintenance Association and S. Dekleva (1990) surveyed participants at the 1990 Annual Meeting of the same professional association (Table 4). In order to compare the above survey figures with this set of empirical data, the following equivalences

Table 4. Zvegintzov's comparison table of maintenance effort

Work category	Lientz and Swanson (1980)	Ball (1987)	Dekleva (1990)
Corrections	22%	17%	16%
Enhancements	59%	39%	43%
Adaptations	6%	9%	8%
Tuning	4%	5%	5%
Documentation	6%	5%	6%
Re-engineering	N/A	10%	9%
User support	N/A	12%	12%
Other	3%	3%	1%
Non-correction	78%	83%	84%

Table 5. GUIDE maintenance work effort distribution

GUIDE categories	1985	GUIDE categories restated	1985 restated
Repairs	8%	Corrective	10%
Enhancements	54%	Adaptive	69%
Conversion and perfective	5%	Perfective	7%
User support	11%	User support	14%
Non-project	22%	N/A	—
Total	100%	Total	100%

are established: 'enhancements' become adaptive, 'adaptation', 'tuning', 'documentation' and 're-engineering' are classified as perfective maintenance, and 'user support' and 'other' become user support activities.

Another set of data (Table 5, left-hand side) was published based on a survey of 12 organizations (GUIDE International, 1985). In order to compare the GUIDE's survey figures with this set of empirical data, the following equivalences were established: 'repairs' for corrective, 'enhancements' for adaptive, 'conversion' and 'perfective' for perfective, and a one-to-one relationship for user support. The overhead activities (22%) have been taken out and the ratios restated on a 100% basis (Table 5, right-hand side).

For comparison purposes, the Abran data sets must also be restated to take into account the 35% for all IS effort for major enhancements and the 55% for maintenance in Figure 1. This 90% of the total workload, restated as 100% of maintenance gives the following ratios: 39% for major enhancements and 61% for all other maintenance activities. Table 3, restated on this 61% basis, gives the distribution illustrated in Table 6.

The final distribution in Table 7 is derived from the addition of the 39% for major enhancements to the adaptive category of Table 6. The Abran data set, based on real data but from a single organization, illustrates one instance of real measurement of the maintenance workload distribution. This data set is remarkably close (Table 8) to the Lientz and Swanson (1980), specifically for the corrective and adaptive categories, while the ratios are reversed in the perfective and user support categories. It must be noted that the user support category had not been identified as such in the Lientz and Swanson survey.

The Ball and Dekleva survey results concur with those of the user support category,

Table 6. Abran—restated on a 61% basis

	1989	1989 restated	1990	1990 restated
Corrective	36%	22%	35%	21%
Adaptive	29%	18%	34%	21%
Perfective	11%	7%	5%	3%
User support	24%	14%	25%	15%
Total	100%	61%	100%	61%

Table 7. Abran—including major enhancements

Category	1989 restated	1990 restated
Corrective	22%	21%
Adaptive	57%	60%
Perfective	7%	3%
User support	14%	15%
Total	100%	100%

Table 8. Maintenance work effort—data sets restated

Work category	Lientz and Swanson (1980)	GUIDE International (1985)	Ball (1987)	Dekleva (1990)	Abran[a] (1989)	Abran[a] (1990)
Corrective	22%	10%	17%	16%	22%	21%
Adaptive	59%	69%	39%	43%	57%	60%
Perfective	16%	7%	29%	28%	7%	3%
User support	3%	14%	15%	13%	14%	15%
Non-corrective	78%	90%	83%	84%	78%	79%

[a]See Table 7

but differ significantly from those in the adaptive and perfective categories, which could be caused by definitional discrepancies and the reclassification schema selected. Overall, this set of hard data is closer to the GUIDE survey results.

5. COST ACCOUNTING ANALYSIS

5.1. Maintenance/project cut-off validity

In the 'definitions' section (section 1), it is reported that the cut-off between a maintenance request and a development project had been set up empirically at 60 work-days for this industry research site with 100 budgeted staff positions in both maintenance and development projects. This cut-off varies according to the size of the organization, with larger organizations having larger triggers. For example, this cut-off is set at 75 days for an organization with 309 budgeted staff positions (Johnson, 1991). To analyse the true impact of this arbitrary cut-off, specific extracts from the computerized time reporting system were analysed with the 1990 data set, excluding open-ended work requests for emergency fixes and very small user requests (Table 9). The analysis of the number of days by work request is therefore based on a subset of the full 1990 data set, with corresponding figures on both the demand and supply sides, thereby removing any biases that would otherwise have been introduced.

For this subset of 1990 data, the mean is 4.3 days by work request 'Total' column. The

Table 9. Work-days (mean) by work request—1990 subset

	Corrective	Adaptive	Perfective	User support	Total
Work requests	170	324	73	272	839
Total days	615.0	1831.0	350.0	806.0	3602.0
Mean (days)	3.6	5.7	4.8	3.0	4.3
Median (days)	2.0	3.0	2.5	1.0	2.0
75% (days)	3.9	6.9	5.0	2.4	4.4
90% (days)	7.3	14.1	13.4	7.3	10.7
95% (days)	15.0	20.9	18.1	14.1	16.4
99% (days)	33.1	33.4	38.3	33.4	33.4

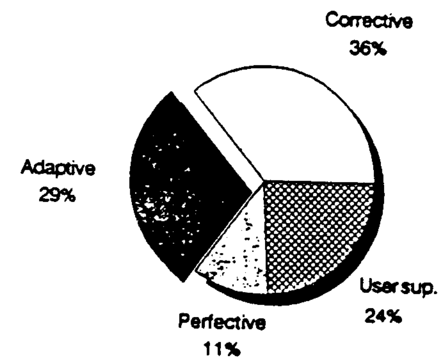
significant difference between the median (2.0 days) and the mean (4.3 days) indicates that the distribution is not normal and that it is highly skewed towards the low end. The percentile distribution is also very interesting: 75% of all work requests took fewer than 4.4 days to complete and 99% took fewer than 33.4 days. This represents only 21 work requests out of 839. This confirms that the 60-day cut-off selected at this research site does not have a significant impact on any of the analyses presented in this paper. The analysis for each of the four maintenance work categories concurs with this conclusion at the 99 percentile level (Table 9, last row). It can be noted that the user support category has by far the lowest median, at 1.0 day, while the adaptive category has the highest, at 3.0 days.

5.2. Quarterly analysis

Analysis of the quarterly figures for 1989 (Figure 2) indicates that the work effort distributions for corrective and adaptive maintenance are fairly constant throughout the year, especially for the first, second and fourth quarters. If the perfective and user support categories are grouped together, they represent approximately 35% for the three quarters. Only in the third quarter is there a decrease of a few percentage points in the corrective maintenance category, offset by a corresponding increase in adaptive maintenance work.

Figure 3 provides a tentative explanation for this variation in work distribution. In this figure, we can see that the workload for three of the four 1989 quarters is around the 1400-day mark, while there are fewer than 1000 days of workload for the third quarter (July, August and September). In fact, this corresponds to peak summer holidays for both the IS staff and the user community. From the same figure, it can also be seen that two work categories (corrective and user support) have been cut almost in half, while the other two (adaptive and perfective) have remained almost the same in terms of the number of days spent on each. The various maintenance managers have provided the following reasons for this phenomenon:

- During the summer months, there is less user data input (decreased workload) in the applications, leading to a decrease in user-induced errors.
- During the summer months, there is almost no project implementation in the



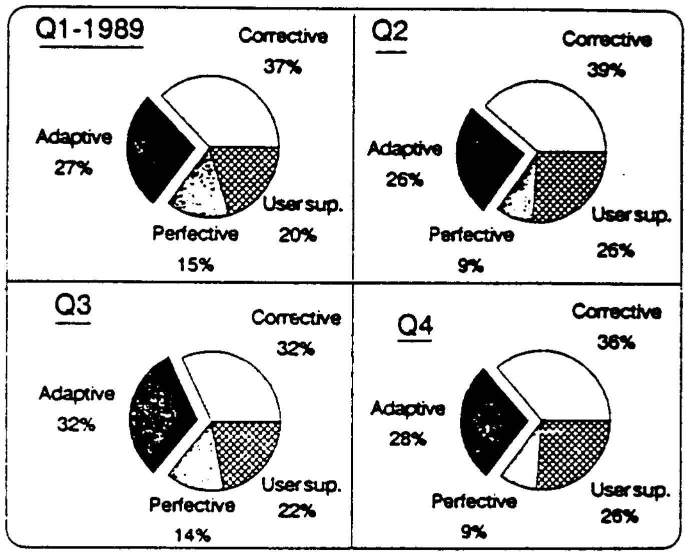


Figure 2. 1989 quarterly work effort distribution

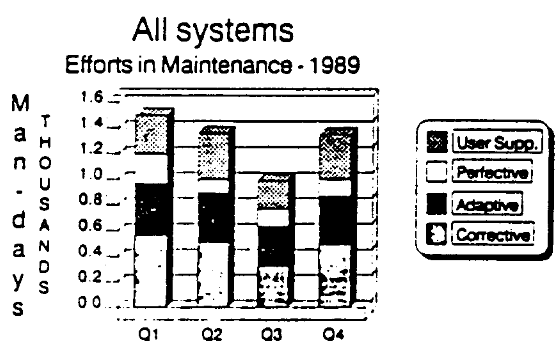


Figure 3. 1989 quarterly effort volume (days)

production environment, and therefore fewer sources of application destabilizing factors.

— There are fewer requests for information from the user community.
— Finally, there are fewer programmers working on both development and application support, and, therefore, fewer sources of programmer-induced destabilizing factors.

Analysis of the quarterly distribution for 1990 (Figure 4) indicates less stability throughout the year and larger quarterly variations. It also points out that a time series over a longer period is required for a comprehensive analysis and that a single year of data, while informative, is not enough to derive causal relationships.

5.3. Work effort distribution shift 1989–90

From 1989 data in Table 2 and Table 3, it can be seen that while 44% of the work requests fall within the user support category, they account for only 24% of the workload, or, on average, only 2.8 days (Table 10). This is almost half of the overall average of 5.14 days; this can be easily explained since for most of these requests there is no programming or testing involved—it is purely analytical work. It could also be an indicator of the analytical work required before initiating any work in the other categories where programming changes are required (to functions, data or controls). It might also be an indicator of the fixed costs in a particular maintenance work request.

The 1989–90 shift in the maintenance work product mix (demand side) is illustrated in Table 2, while the shift in the work effort mix (supply side) is illustrated in Table 3. An analysis of mix changes in both tables reveals that there is not a one-to-one relationship between the number of work requests and the effort required. This is illustrated through the variation in the average number of days by work request by category of maintenance work, as illustrated in Table 10: even though the combined average has not varied much over the 2-year period (from 5.14 days to 5.38), there are significant differences in the average number of days by work category, as well as over this period within the same category (for example, the adaptive maintenance average dropped from 7.51 days to 5.58,

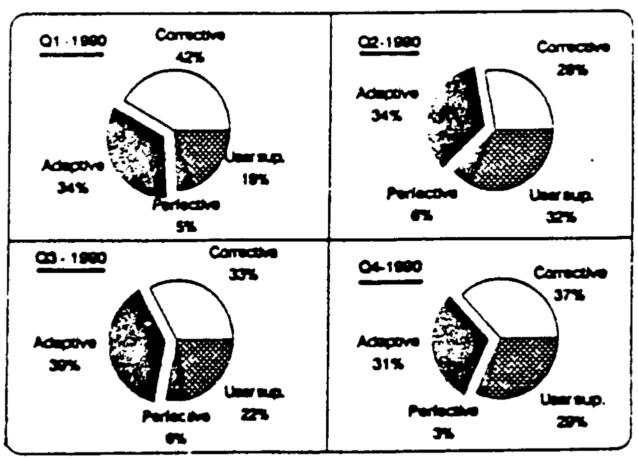


Figure 4. 1990 quarterly work effort distribution

Table 10. Average number of days by work request

Work category	1989	1990
Corrective	6.73	7.36
Adaptive	7.51	5.58
Perfective	6.63	4.33
User support	2.80	3.80
All categories	5.14	5.38

while the user support average went up from 2.80 days to 3.80). When both factors (number of work requests and average number of days per type of work request) are taken into consideration, the shift in total work effort within the work categories can be explained through the variation in the structural mix of the productivity factors.

5.4. Trend analysis

The two years of historical data, by quarter, are represented graphically in the following two figures. Figure 5 illustrates the relative work effort distribution (percentage) by

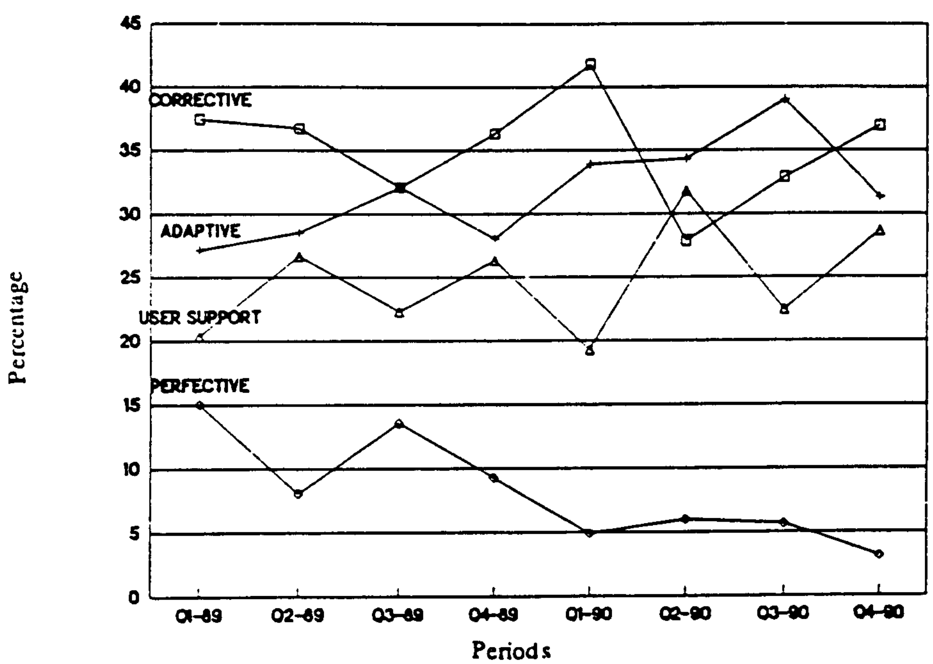


Figure 5. Relative distribution (percentage) over eight quarters (Qi)

maintenance category over the 24-month period, while Figure 6 illustrates the actual effort in terms of work-days over the same period. Over this two-year period, the largest proportion of maintenance work fell into the corrective category to keep the computerized applications operational. For the corrective category, the annual peak in the first quarter corresponds to peak processing volumes, in addition to special year-end procedures. The effort required for adaptive action and user support grew steadily.

The next figure (Figure 7) was prepared with the cumulative historical data to smooth out the various abrupt and seasonal changes noted previously in Figures 5 and 6. These cumulative data provide a better indication of the trends at the industry-research site under study. Two maintenance categories show downward trends (corrective and perfective), which represents positive improvement in terms of a slight decrease in the relative number of resources required to support applications that keep increasing in size and complexity.

The other two categories (adaptive and user support) show upward trends. The increase in the adaptive category is encouraging and illustrates the ability of this organization to dedicate a greater share of its maintenance staff to work on functional enhancements to these applications in response to changing business requirements. The upward trend in the last category, user support, is more difficult to interpret and will need further analysis: on one hand, there are fewer requests on a relative basis, but on the other it took more effort, on average, to complete each one. Preliminary information indicates that a significant turnover in the user areas has had to be offset by additional support from the software maintenance teams in terms of additional training, coaching and analytical support in systems analysis.

5.5 Analysis by application

While the previous figures demonstrate some stability in the maintenance workload distribution at the overall level (for all applications combined), the next research question was to verify whether or not this stability was also present at the application level. The

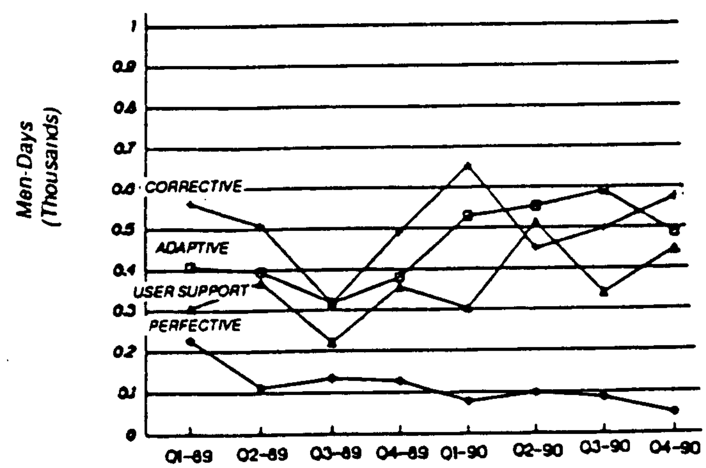


Figure 6. Distribution of actual effort (work-days) over eight quarters

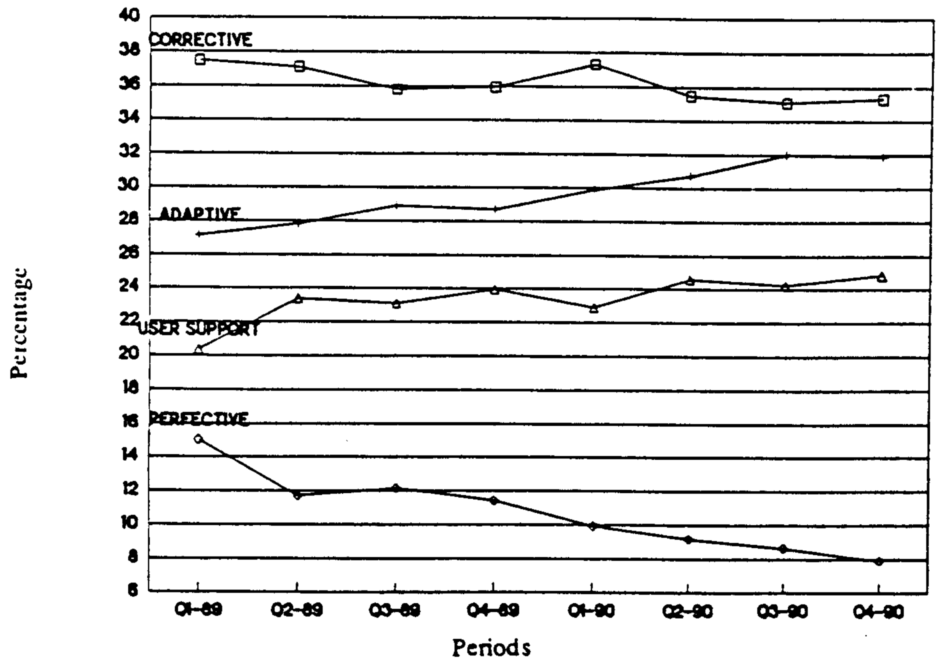


Figure 7. Cumulative distribution (percentage) over eight quarters

results are presented in Table 11, broken down by major applications (over 1 million lines of code), packages, and small applications bundled together.

From Table 11, it can be seen that there is considerable variation from one application to another. Each major application has a different effort distribution, with application C showing a greater variation from the other three and from their combined average. Owing

Table 11. Maintenance work distribution by application

Application	Total days	1989	1989	1989	1989	Total days	1990	1990	1990	1990
		Corr	Adap	Perf	User		Corr	Adap	Perf	User
Major A	1205	34%	32%	12%	22%	1740	26%	49%	4%	21%
Major B	991	43%	29%	14%	27%	772	30%	33%	7%	31%
Major C	1571	50%	14%	14%	22%	1882	46%	25%	1%	28%
Major D	454	17%	51%	6%	26%	552	22%	46%	7%	25%
Subtotal	4221	40%	27%	9%	24%	4946	34%	37%	3%	26%
Packages	614	20%	30%	31%	19%	753	59%	12%	11%	18%
Small applications	407	15%	51%	2%	32%	424	9%	46%	13%	32%
Subtotal	1021	18%	38%	20%	24%	1177	41%	12%	23%	23%
Total	5209	36%	29%	11%	24%	6123	35%	34%	5%	25%

to their importance relative to the overall work effort (4946 days out of 6123 days = 81%), the major applications have considerable influence on the overall average. Their combined work effort hides the much greater variations in work effort spent on maintaining either packages or small applications.

This leads us to believe that the type and size of software applications might have a significant impact on the work effort distribution (large applications, small applications, packages, and their relative effort distributions). It should also be noted that the set of data analysed does not contain any information on non-mainframe-based applications.

The MIS applications analysed in Table 11 are briefly described in the following paragraphs.

Major application A: This application has over one million lines of code and was developed in the early 1980s using structured methodologies and a database management system (Network Database). Maintenance activities are performed in a structured way and the system documentation is kept up-to-date. There is a considerable amount of development work being carried out by different development teams concurrently.

Major application B: This application is mostly batch, with a few on-line processes. It closely matches (within 5%) the subtotal averages for each work category for both 1989 and 1990 data.

Major application C: This was initially a non-package-based application, which was acquired in the early 1970s and which has been completely overhauled since then. No structured methodology has been used in this application, and the maintenance team has considerable experience in maintaining it. The 1989 workload distribution is not entirely accurate due to an under-representation of work requests in the adaptive category: there were some problems in this work category in counting the function points, and, in the opinion of the researchers, this generated an over-representation in other categories. However, the data collection process was improved in 1990, and reflects a more accurate work distribution for the second year for this major application.

Major application D: This is a business application package designed in the 1970s and implemented in the mid 1980s, with a significant amount of modification having been carried out using structured methodology. The data collected is considered very accurate, even though it differs substantially from the averages. This application is considered bug-free compared to other applications, and it performs extremely well, leading to an under-representation of work effort in the corrective maintenance category.

Standard packages: These are essentially package-based applications with smaller workloads and less data individually. Their work distribution varies considerably, depending on the specifics of the package implementation, scope of modifications and frequency of releases install.

Other small applications: Some of these applications are run in a service bureau outside the corporate data centre. The information collected is incomplete and not necessarily accurate.

Another analysis was conducted to determine, by application, the average number of days spent per work request (Table 12), and again major variances were found from one application to another, while there was significant stability within each application over the two-year period.

It must be noted that at this industry-research site, this information, by application, is

Table 12. Average days per work request by application

Applications	1989 Corr	1989 Adap	1989 Perf	1989 User	1989 Average	1990 Corr	1990 Adap	1990 Perf	1990 User	1990 Average
Major A	4.1	6.8	6.1	2.5	4.2	2.9[a]	5.1	4.9	3.2[a]	4.3[a]
Major B	10.6	6.9	1.8	4.8	6.8	6.2	6.8	2.6	3.0	4.4
Major C	12.3	18.3	11.9	2.0	5.9	11.2[a]	9.7	2.0	2.4	5.0
Major D	4.5	6.3	5.2	2.6	4.3	10.0	2.8	10.0	11.3	4.7
Subtotal	7.7	7.7	7.3	2.6	5.2	6.82	5.33	3.95	3.51	4.98
Packages	3.6	8.0	5.8	3.8	5.1	14.9	10.2	3.4	12.0	10.2
Small applications	2.2	6.2	3.3	4.0	4.2	2.1	7.3	14.0	6.1	6.0
Subtotal	3.0	7.0	5.6	3.9	4.7	10.01	8.03	4.93	8.06	8.12
Total	6.73	7.51	6.63	2.80	5.14	7.36	5.58	4.33	3.80	5.38

[a]Some data in 1990 have been normalized to ensure consistency over 1989; the subtotal and total have not been normalized (see Appendix).

distributed to all application maintenance managers in order to allow them to compare the performance of each application versus the specific average. Whenever there are significant variations, they have to provide additional information to explain them and, most of the time, confirm that the information at the detail level is in fact significantly different from the average (and not due to a faulty data collection process).

This feedback information has provided the researchers, as well as the maintenance managers, with a much better understanding of their work effort distribution and of the specific characteristics of the applications they have to maintain and their impact. It has also provided additional insight into the quality of the data collected.

6. MEASUREMENT CONTROLS

Most of the previous analyses on maintenance work categories are based on data collected from the time reporting system (TRS), but analysed and summarized by each maintenance manager and then transmitted to the productivity measurement coordinator. There could be questions, however, on the completeness and reliability of this data set. How much of the maintenance process has not been measured and has gone unnoticed? Is there an impact on the analysis of the results? How can the data collection process be improved?

In order to find out what could have been missed, an analysis of the data collected in the TRS system was conducted. Although the information is not stored exactly as needed for the productivity analyses, there are still enough ways to access the data to identify and quantify how much has slipped through the measurement reporting process.

Let us remind readers that in this organization the TRS system is compulsory for all of the software staff, that they must record their time daily, and that their time must be allocated at a detail level, either to specific work requests (both in Development and in Maintenance) or to specific overhead activities (such as training, conferences, holidays, administration activities). The system is accurate to the half-hour, and there are strict daily, weekly and monthly controls.

An analysis was conducted on all work requests by application. These work requests were sorted and labelled as either Development or Maintenance (based on the 60-day trigger), and the total effort in days was added, by application. This information was then compared with the information collected through the maintenance measurement reporting process (Table 13). The differences between columns 2 and 3 are mainly explained by the fact that there were two different sources of information:

(1) TRS report (column 2): This monthly automated report includes all time reported within the period, whether the work request was completed or not within that period. It does not include time from previous quarters but it includes time spent on work requests in progress (not completed) at the end of the quarter.
(2) Maintenance work categories (column 3): The information is collected on a quarterly basis based solely on the work requests completed within that time period. It therefore excludes, on one hand, the time spent on work requests that have not yet been completed within that quarter, while, on the other hand, for work requests initiated from the previous quarter and completed within the current quarter, it includes the total time on these work requests.

Taking into account the above comments and the overall 94% measurement ratio for all applications, there is a great degree of confidence on the part of the researchers that the information has a very high degree of accuracy. Measures have been taken in 1991, the third year of this measurement program, to align both sources of reporting and to automate the process in order to decrease the amount of manual work previously required of all maintenance managers. From then on, all data will originate directly in the TRS system. However, managers will still be held accountable for the quality and the integrity of the data.

7. BENEFITS

Major benefits were derived from the introduction of these additional metrics in the maintenance area. Some of the benefits from a research perspective have already been

Table 13. 1990 measurement ratio

Applications	Total no. of days	Days categorized	Measurement ratio
Major A	1890	1740	0.92
Major B	868	772	0.89
Major C	1745	1882	1.08
Major D	604	552	0.91
Packages	810	753	0.93
Small applications	582	424	0.73
Total	6499	6123	0.94

Note: The information in column 2 is based on report TRS920.

mentioned. The emphasis in this section is on the benefits observed at this industry-research site, derived as direct benefits of this maintenance measurement program.

7.1. Management credibility

A major benefit is the added credibility of the senior IS executives in that they have successfully put in place a measurement program in an area where there was a critical lack of management information (involving substantial corporate costs), and the numbers coming out of the process are now credible to the user community.

This measurement program provides insights into the maintenance process and a much better understanding of the maintenance function and of the costs attached to each type of maintenance. At budget time, for example, the maintenance managers can come to the user community with a lot more information on the services provided and the goods delivered. Discussion can then focus on sets, or subsets, of information, which can be verified at the lowest level of primitives (the work requests), and not on a single global number for the whole maintenance process.

7.2. Corrective maintenance

Where the quality, or lack of quality, of an application had previously been to some extent a matter of hearsay, the corrective maintenance ratio of the application can now be used to compare it to other applications. Questions are raised on applications with very high ratios in this category. The time spent in this category is considered 'untouchable' at budget time, a fixed expense of the application, and the bare minimum to keep an application running. The information collected in this category has been an essential component in developing quality indices for each application. These quality indices will be monitored over the next few years. The numbers are used to build business cases to justify preventive maintenance programs, and later to monitor the realized benefits. This information is considered critical for future quality improvement programs, and will be used to promote and justify preventive maintenance concepts. It will also help to quantify the cost-avoidance factor in quality improvement programs.

7.3. Adaptive maintenance

The ratio of adaptive maintenance by application is an indication of the amount users are willing to invest in each application in order to obtain *additional information* (business information) or *additional functions*. This is not, in our opinion, a reflection of the weaknesses of an application, but rather an indication of the user's willingness to invest money to enhance their own operations through the leverage of additional computerized functions within their existing applications. In addition, it became evident that this was the most expendable category of maintenance work, and one which was strictly under the control of the user community. This category of maintenance work could then represent the discretionary share of the maintenance workload to be taken into consideration when planning the maintenance workload and expenses per application.

7.4. Perfective maintenance

This maintenance category accounts for only 11% of the workload, on average. However, there are major differences from one application to another and these could be monitored. It has been observed that applications based on software packages have a much higher ratio of perfective maintenance (from 50% to 75%, as compared with the 11% average). This could be explained by the very low ratio of corrective and adaptive maintenance. These packages have a proven track record, and must be almost foolproof (e.g. general ledger, payroll, accounts payable packages). However, they do not seem to use computer resources efficiently and the transaction cost is relatively high resource consumption as compared with that of internal applications, thereby requiring a high level of system tuning throughout the maintenance life-cycle.

7.5. User support

The 24% of the time spent on non-programming-related work requests came as a surprise, both in terms of the amount of effort expended and in terms of the number of requests (44%). Measurements in this category of maintenance activities has helped define this type of work as a specific business function provided to the user community, at their request and under their total control. It also indicates that the user community both needs this information to manage their businesses and is willing to pay IS specialists' rates to get this information.

For example, a request for information on the details of a computational algorithm, based either on the system documentation or on the program code, will provide them with appropriate and accurate business information that they could not otherwise obtain through their own channels. It is now recognized in this organization that maintenance teams not only correct bugs, but also provide the user community with 'business information' that is both timely and accurate. Similarly, a user request for a time estimate for a modification or an addition to an application that they would like to initiate will provide them with business information. These are the IS costs that they have to take into consideration and weigh against the projected benefits before initiating adaptive or perfective work requests. Similarly, the user support function has even been incorporated in the IS mission statement as a 'provider of business information' to the user community.

7.6. Estimates

It is not an immediate objective of the measurement program to improve the estimating process within the maintenance environment. While it is believed that such a step would facilitate the estimating process, it is felt that additional insight will be required before doing so, based strictly on the measurements collected.

For the time being, the averages will be monitored but will not be used for specific estimates: this is still the domain of expertise of the senior maintenance staff. The maintenance work still depends too much on the individual staff assigned to the various work requests. While this may be valuable at an individual cost level, the intention is to move away from this and to develop an estimating process and a pricing mechanism that do not take into account the individuals assigned to the task. Flexibility is needed to keep management free to assign either a junior or a senior individual to a work request.

depending on priorities and time constraints, and maintain the leverage of moving staff across applications and technologies, rather than putting them into a dead-end situation within the confines of a specific application.

In 1989, these additional metrics were introduced within the maintenance environment, providing senior IS executives with management information that gives them both productivity measures and insight into the deliverables of the maintenance work. With these metrics, they can provide other business executives of the corporation with credible measurement of the maintenance process, measurement that has enhanced considerably their credibility as good managers, providing them with adequate tools to manage the resources under their control. These metrics also allow them to move progressively from a *cost-centred* concept to a *profit-centred* concept, like any other business unit. IS will eventually be in a position to prepare fixed-price estimates for maintenance work requests, based on the historical unit cost per category of maintenance work. This means, for example, that a maintenance work request could be priced based on the average cost by work request category, and not on the exact number of person-days spent on the work request. This also means that they would be in a position to keep the profits if work requests are completed under budget.

This also makes it easier to invest in productivity tools. In the past there was no incentive to do so, since the process was a cost-recoverable one based strictly on the number of days spent and on the fact that there was no mechanism in place to charge back to the users the cost of the productivity tools. Now, with a cost algorithm based on the units of the deliverables, it is easier to prepare business cases on software productivity tools, and to recover these costs through the added productivity of more function points delivered per unit cost, while maintaining the user price per function point. The difference between the cost and the price would then go into paying for the productivity tools and productivity improvement programs, without getting the users involved in technical issues.

8. CONCLUDING REMARKS

This set of data confirms some of the findings of the opinion surveys in terms of the stability of the overall workload distribution in the maintenance area, while providing some interesting insights into the maintenance process itself. Based on the supply/demand paradigm the following issues have also been identified, and data collected and analysed to investigate such issues as:

Demand side

- Maintenance products groups (work request classification)
- Maintenance products mix (work requests distribution)
- Maintenance products mix changes (yearly distribution changes)

Supply side

- Maintenance resources allocation by product classification
- Maintenance resources allocation by application groups
- Maintenance resources distribution changes (quarterly and yearly)

From this perspective, the feasibility of collecting the required information and using it for productivity analysis of the maintenance process has been illustrated through actual measurements at an industry-research site.

Based on the preliminary findings of this research effort, additional research will be carried out to improve the understanding of the maintenance process through cost accounting and econometric productivity models initially developed for the manufacturing environments. For example, additional work is being carried out to introduce function point metric within the maintenance category. This should then support further work to investigate the feasibility of establishing various pricing mechanisms for the different types of maintenance products and services.

Acknowledgements

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APPENDIX: VALIDATION AND NORMALIZATION OF DATA SETS

The information provided for this analysis originated from the maintenance managers' quarterly reports. To prepare these reports, the maintenance managers used the information recorded in the Time Reporting Systems (TRS) software application as initial input and then made the required adjustments for their quarterly report. When an analysis was conducted at the end of 1990 to determine the number of days by work request by maintenance categories, it revealed a discrepancy between the figures reported in the quarterly reports and the computer-based TRS data sets. This discrepancy was explained by some weaknesses in the updating of the computer-based data sets: when RFSs are opened up and registered in the TRS system, the classification was done on a minimal set of information. However, when they are closed up, they are revisited to verify the classification and correct it based on more accurate information. This reclassification was included in the managers' quarterly reports, but the changes were not recorded in the computer-based system which previously had been used strictly for user billing. To complete the analysis on the average number of days by work category, the complete list of RFS were extracted from the TRS system and passed back to the maintenance managers for quality control and reclassification, whenever required. This research analysis has been conducted with the validated set of data. The maintenance staff has also committed to keep this information up-to-date on the TRS system.

1. Major application A

The significant increase in work effort in maintenance for this application (from 1205 days in 1989 to 1740 days in 1990) is explained mostly by differences in reporting mechanisms. In 1989 the information collected, and analysed, included strictly the information related to individual work requests (RFS) that had been opened and authorized specifically. However, a review of the 1989 data with the maintenance manager indicated that the data-collection mechanisms based strictly on RFSs was bypassing two subsets of maintenance work for which the administrative procedures were deliberately bypassed in order to provide a high level of responsiveness to the user's needs: emergency fixes and very small user requests. In both cases the formal authorization process was perceived by both the clients as an irritant and red tape. They, however, still agreed to pay for these services on a monthly basis based on monthly billing. In 1990, the impact of this additional information on maintenance work is the following for this application:

- corrective: + 170 days (overnight production support (31 days) + daytime production support (139 days))
- user support: + 221 days

This additional information was taken into account in the analysis of workload distribution by maintenance category, but could not be taken into account in the analysis of average days by work request (the number of different requests being not available for the information classified within these general RFSs year-long. Work effort data for emergency fixes and very small user requests were included within all other applications data sets for both 1989 and 1990.

2. Major application B

No specific information available owing to a change in maintenance manager.

3. Major application C

For this application, all corrective maintenance work was recorded within a single RFS on the TRS system. To complete the analysis of the 1990 data of average days by work request by category, the maintenance manager for this application was interviewed. He referred to his own historical set of monthly (manual) reports to provide the following information:

Month	RFS	Days	Ratio (Days ÷ RFS)
January	6	77	12.83
February	4	82	20.50
March	6	60	10.00
April	2	57	28.50
May	7	59	8.43
June	11	86	7.82
July	10	80	8.00
August	4	71	17.75
September	8	92	11.50
October	8	49	6.13
November and December	12	162	13.50
Total	78	875	11.22

4. Normalized data

The original set of 1990 data, as extracted from the TRS computerized application was the following (after validation):

Application	RFS Corr	RFS Adapt	RFS Perf	RFS User	RFS Total	Days Corr	Days Adapt	Days Perf	Days User	Total
A	99	167	14	47	327	459	846	69	366	1740
B	37	37	20	80	174	229	253	51	239	772
C	98	48	5	224	375	872	457	10	533	1882
D	12	90	4	12	118	120	256	40	136	552
Total	246	342	43	363	994	1680	1812	170	1274	4946

The modified set of 1990 data, taking into account the above information to validate and normalize this set of 1990 data, gives the following:

Application	RFS Corr	RFS Adapt	RFS Perf	RFS User	RFS Total	Days Corr	Days Adapt	Days Perf	Days User	Total
A	97	167	14	45	323	289	846	69	145	1349
B	37	37	20	80	174	229	253	51	239	772
C	78	48	5	224	355	875	457	10	533	1875
D	12	90	4	12	118	120	256	40	136	552
Total	224	342	43	361	970	1513	1812	170	1053	4548