# A framework for benchmarking appropriate productive maintenance

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**Keywords**
Manufacturing,
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Modelling

**Abstract**
Addresses problems with the practical implementation of total productive maintenance (TPM), and presents a rather appropriate approach to TPM implementation. This approach is termed by the author as appropriate productive maintenance (APM). The APM concept offers a rigorous methodology that utilises several tools to achieve a world-class manufacturing (WCM) status. A modelling tool, called IDEFO, is used to map the whole process. Presents a nine-step framework for formulating the APM programme. Concludes that the integration of operational tools can contribute towards developing a strategic world class maintenance programme. Describes a computerised maintenance system, developed at a company in the automotive sector in the UK, as a practical example of the issues presented.

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## Introduction

The purpose of this paper is to first assess total productive maintenance (TPM), then to suggest an upgraded framework – appropriate productive maintenance (APM), and finally to propose a decision model for benchmarking implementation of the APM framework in a systematic process.

When coping with disturbances in manufacturing environments, practitioners and academics in "many research publications list machine breakdowns as the most important factor that can influence shop floor performance" (Gindy and Saad, 1997). The manufacturing maintenance problem, compared to other areas in operations, has always been considered to be of a fuzzy (grey) nature. This has been due to the fact that maintenance activities were not repetitive in the same manner as operations tasks. Consequently, maintenance did not lend itself to systemisation. This characteristic has been observed at all of its organisational levels starting from the maintenance engineer who faces new problems that require various skills, and up to the maintenance manager who faces conflicting multiple objectives in setting adequate maintenance strategy depending on corporate strategy and both production and quality requirements.

The view of the present paper is that there is a need for a revised approach to maintenance that treats maintenance as an integral part of business strategy and which incorporates key factors at the operational level which should be considered to identify the most appropriate maintenance policy to meet strategic goals and to achieve a world class status. With the increasing demand on productivity, quality, and availability, machines become more complex and capital intensive. Developing and implementing a maintenance programme is a difficult process that suffers from many problems. It often suffers from lack of a systematic and consistent methodology. In addition, since the process of developing the programme relates to different parties interested in maintenance, it becomes difficult to attempt to satisfy all these parties simultaneously, and at the same time achieve the objectives of the company. It is apparent that developing a maintenance programme is an iterative process that involves different decision makers with usually conflicting objectives. In deriving these objectives maintenance managers usually try to achieve multiple, and sometimes conflicting, objectives such as productivity, availability, and quality subject to constraints on production plan, available spares, manpower, and skills.

## TPM versus APM

### The main idea of TPM

The main idea of TPM is to bring maintenance and production together, through small groups, to exchange skills, and take specific actions. Hence, identifying the major problems and the means to overcome them by the involvement of the parties concerned, i.e. blending maintenance and production, is the core philosophy of TPM. There are three main concepts of TPM, which have been promoted by Seichii Nakajima (1989) and the Japan Institute for Plant Maintenance. These concepts are related to improving equipment to its highest performance level (by achieving no losses), maintaining equipment at its highest level (by applying autonomous maintenance), and procuring new equipment with a defined level of high performance and low lifecycle cost (through small groups). TPM uses a measure of effectiveness called overall equipment effectiveness (OEE), which is the product of three efficiency measures: availability, productivity, and quality (Labib, 1996). It then decomposes



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those efficiency measures to six losses related to maintenance, which are:

1 breakdowns;
2 set-up;
3 minor stoppages;
4 reduced speed;
5 scrap rate; and
6 start-up losses.

The intention of this paper is to develop a working model that extends these key points by taking into consideration the skill levels analysis and the information system that supports decision making in a systematic process.

## Shortcomings of TPM

The TPM concept is simple and obvious, but there are some reported shortcomings. Managers tend to focus on early results rather than activities aimed at reducing losses in the long run (Al-Najar, 1996). Improving personnel and changing the corporate culture is more easily said than achieved. The traditional cultural division between operator and maintenance, "you bend it, we mend it", must be altered by mutual consent. Continuous improvement means data analysis. Often data are collected but not analysed. There is a need to find a less time-consuming method that is also precise.

While its philosophy is sound, its implementation lacks focus, and a systems approach that is compatible with different environments. Hence, an appropriate approach is presented. This approach is aimed at extending TPM in an effective and efficient model, rather than contradicting it. In addition, this approach addresses maintenance practice in both the strategic and operational domains. The trend in recent maintenance literature seems to emphasise the cultural difference between the Japanese culture and the Western. Hartmann (1992) pointed out the cultural differences between the Japanese and the West, stressing the Japanese affinity for small groups and consensus decisions. Willmott (1994) confirms this and emphasises that the work ethic is very strong in Japan, coming before self and family. Also, in an article by Kelly and Harris (1993) about uses and limits of TPM, the authors of the article conclude that TPM succeeds not because of its systems or engineering techniques but because of its attention to the management of human factors.

Any TPM programme is supposed to go through four stages: self-development, improvement activities, problem solving and autonomous maintenance. However, it seems that most groups do not transit from stage two to stage three. They die before they are really grown up (Al-Najar, 1996). An analogy of adopting TQM and TPM is of having a good brain and strong muscles. It seems, however, that a nerve system (data and decision analysis), is missing in this analogy.

Through personal experience, industrial collaboration, and research, the author has formulated the opinion that while TPM is obviously a step in the right direction, it is clear that there is a need for a revised, "appropriate", approach regarding TPM. There is also need for a more appropriate approach that is dynamic, practical, focused, adaptable, and integrated with other functions of the organisation.

## Need for a revised, appropriate, approach

The above literature survey shows that TPM in its pure form is not totally applicable to Western industry. TPM appears to be in danger of being just an activity-centred management theory rather that a result-driven approach. Therefore, there is a need for a revised approach to TPM, an appropriate one. The revised approach is intended to be keyed to specific results, rather than to too large scale and diffused objectives: an approach that is a management thought process rather than a thing unto itself. It is not intended to contradict TPM philosophy, but to complement it. The proposed approach is a further step that puts a concept into practice. This revised approach is intended to account for differences from the ideal case, which embodies "best" practices yet which can be "tailored" to yield an appropriate system.

## APM as a strategic and operational model

The word "appropriate" here is used to reflect a structured and systematic, yet flexible and human- entred approach that can deal with multi-level problems that may be expandable to different scenarios and alternatives. Also, "appropriate" means a cohesive system, with standard methods that encompass different ways of doing things within a unified framework, and a system with an inherent feedback property. An inappropriate system might be a system that is appropriate at present, but due to lack of continuity, and feedback, may lead to inappropriateness. For example, a firm with skilful tradesmen, but which does not have an adequate system of transferring or retaining those skills and knowledge, will lose competitiveness in the long run. Also, a fully automated condition monitoring system that monitors most of the faults, and presents data in the form of reports and graphs, may not be appropriate if this information is not used adequately for decision making and analysis.

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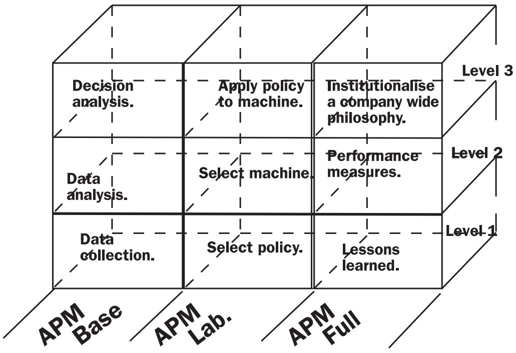
**Figure 1**
The APM model



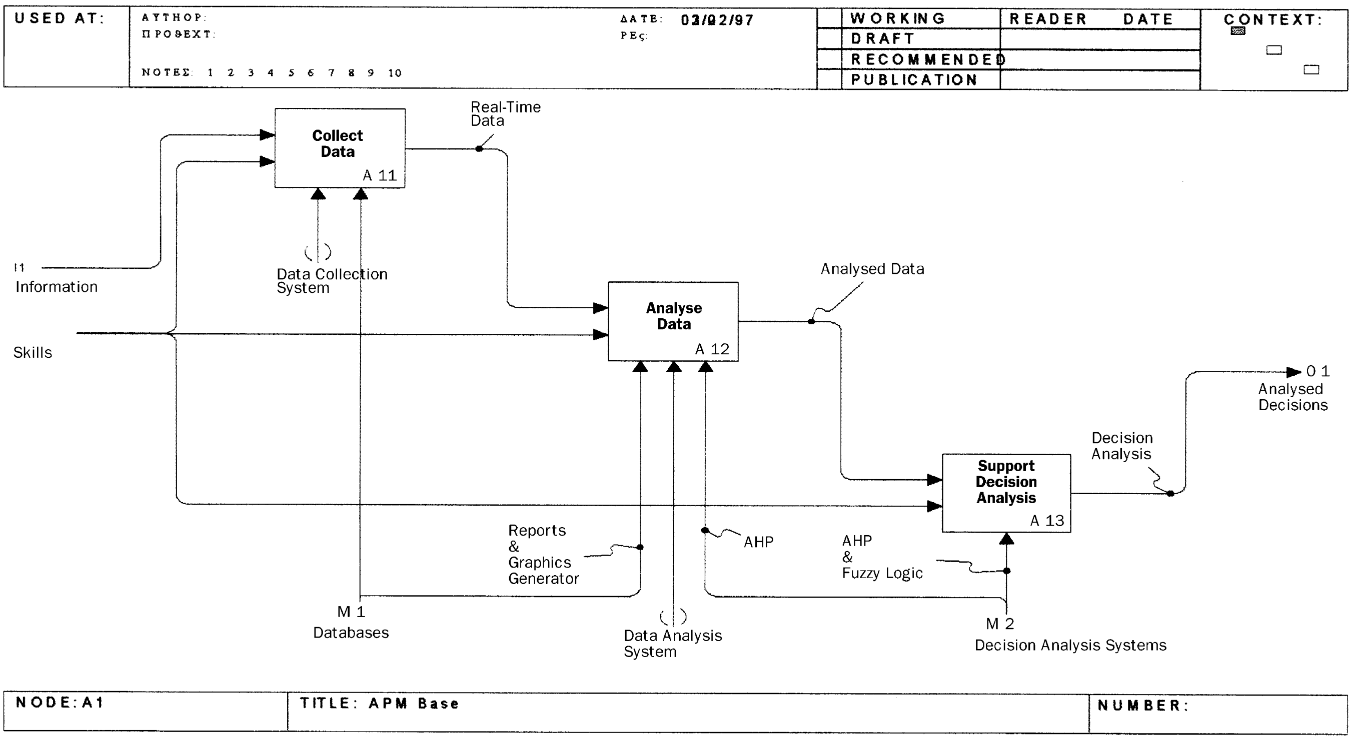

Hence, the importance of continuous improvement, feedback, integration, and interaction are essential elements of appropriateness. In addition, analysis of skills, and decisions are vital components of an appropriate approach. It is believed that there is no one prescription for achieving best maintenance practice. Maintenance should be looked at as being composed of different components (dimensions), and every dimension consists of different levels. This approach explains why it is called appropriate rather than total. It is appropriate because the model is decomposed into a hierarchical structure that resembles a specific environment, then evaluation is performed taking into consideration different criteria and parameters that may affect the decision process. Figure 1 illustrates a conceptual view of the APM model. The nine grids represent the elements of APM, and will be further discussed in the subsequent sections of this paper. The grid is structured into three phases:

1 a base of collected and analysed data and decision models;
2 a laboratory to examine a selected policy applied to a pilot equipment; and
3 a company-wide full implementation of policies based on lessons compiled. Each of these phases consists of three levels as illustrated in Figure 1.

## World class manufacturing (WCM)

It is useful to use the plant as the level of analysis because, although world class manufacturing (WCM) is a strategic approach, many of its measurable improvement initiatives have occurred at the plant level (Flynn *et al.*, 1989). Strategic considerations and operational decisions are influenced by other corporate functions such as production, finance, quality, and human resources. It is true that the information gathered by these systems at the operational level and actions taken are in fact strategic – improved asset availability, productivity, and quality, as well as resource management, inventory

**Figure 2**
The APM base



control, planning, and so on. It is also true that the adoption of advanced and appropriate practices such as the ones presented in the APM model using decision tools such as analytic hierarchy process and fuzzy logic controllers can show such remarkable benefits that they too could be regarded as strategic.

## IDEF as a modelling representation tool

IDEF (Integration DEFinition) was developed by the US Air Force's Computer Aided Manufacturing (ICAM) project in the late 1980s (see Appendix for more information). There are many different IDEF methods. Each method is useful for describing a particular perspective of an enterprise. The major IDEF methods in use are functional or activity modelling (IDEF0), information modelling (IDEF1), data modelling (IDEF1x), process description capture (IDEF3), object-oriented design (IDEF4), and ontology capture (IDEF5) (Leach *et al.*, 1999).

The IDEF0 modelling technique is a tool for representing processes or systems in a graphical, and a hierarchical form, concentrating on functional relationships. See the Appendix for more details on IDEF. It is based on the idea of grouping a system to a hierarchy of activities (boxes), where every activity can have a set of Inputs, Controls, Outputs, and Mechanisms. The main advantage of presenting the APM model using IDEF0 is to facilitate analysis of the interaction among the different boxes in Figure 1.

### The APM in detail (A1, A2, A3)

*The APM base (A1):*
Step 1: Data collection system (A11).
Step 2: Data analysis system (A12).
Step 3: Decision analysis system (A13).

*The APM laboratory (A2):*
Step 4: Select a policy (A21).
Step 5: Select machine (A22).
Step 6: Apply policy to machine (A23).

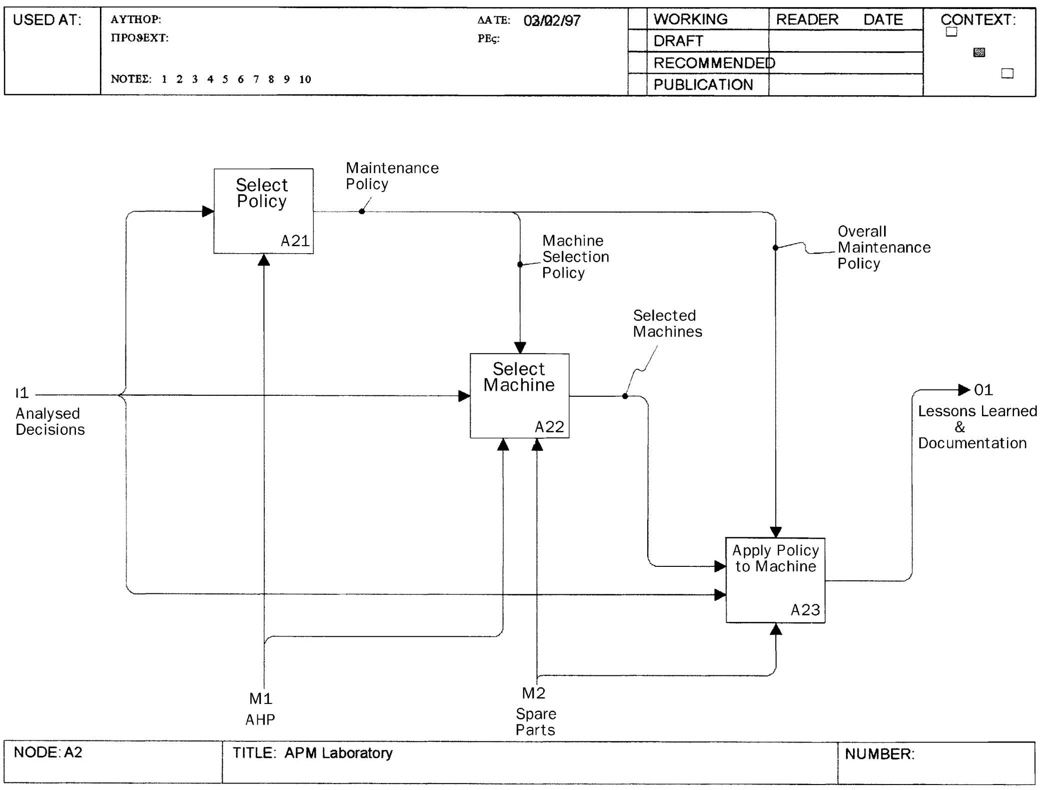
*APM company wide (A3):*
Step 7: Lessons learned (A31).
Step 8: Measure performance (A32).
Step 9: Institutionalise a plant wide programme (A33).

## Implementation of an APM programme

### The APM base (A1)

This section is concerned with the collection, and analysis of data, as well as the identification of candidate decision models. It is believed that an available computerised maintenance management system is not an aim by itself, but rather a platform for decision analysis that can lead to the

**Figure 3**
The APM laboratory



development of the APM model. This coincides with the view presented by Olafsson (1990) regarding TPM implementation, where it is emphasised that "... an early prerequisite for TPM implementation in a company, is the development of a Computerised Maintenance Management System for collecting and recording the data for TPM implementation". However, experience gained by the author in developing computerised maintenance management systems in several automotive industries has shown that managers rely on such systems for data collection and data analysis, but seldom for decision analysis. Furthermore, it is argued that in order to transform data to decisions, tools such as the AHP and fuzzy logic rule based techniques are adequate as effective and efficient methods (Labib and Williams, 1998; Labib *et al.*, 1998).

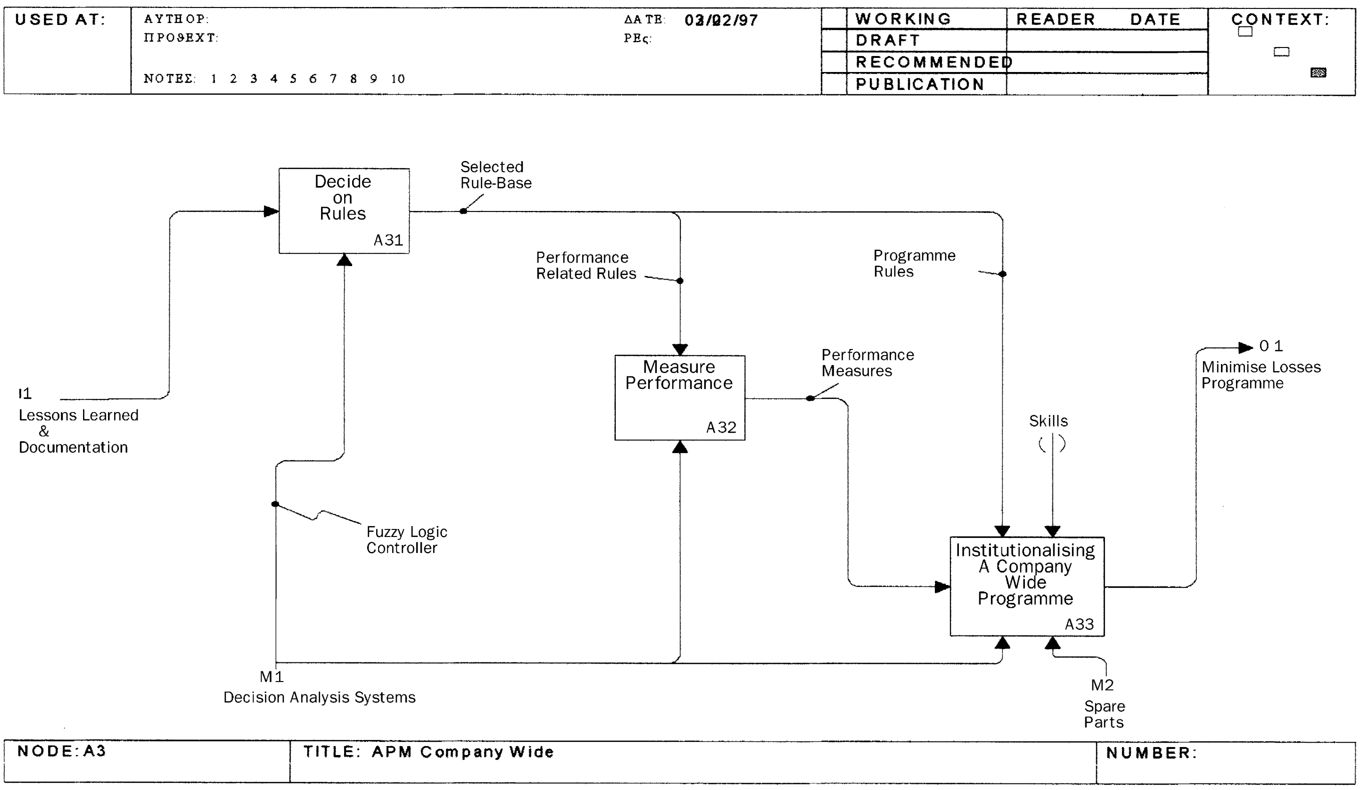
A data collection system that can gather relevant data is a prerequisite for APM. It is advantageous to have a data collection system that is real time, and it should handle data related to frequency and duration of maintenance breakdowns as well as spare parts costs. A practical example of such a system is the breakdown recording system developed, by the author, at a company in the automotive sector in UK, where data are collected systematically in a real-time basis, and analysed accordingly (Labib, 1998) (see Figure 2).

### *The APM laboratory (A2)*

Once data and decision models are available, it is appropriate to select a pilot machine based on suitable criteria such as its criticality, complexity, or age, and a pilot decision model. The rational behind this is that it focuses attention to specific aspects of the problem rather than being too general. It is trying to avoid a similar situation where ten patients are given ten different drugs and hopefully one of them would work.

This section aims at proposing practical methods that translate boardroom strategy to the shop floor. According to Mackenzie (1997), without the translation of major goals into many individual objectives, it is unlikely that progress will ever be made. A proposed model for translating corporate objectives to maintenance operational policies was recently reported (Labib *et al.*, 1997). In this work the selection of appropriate maintenance policies, as alternatives, are derived taking into consideration corporate objectives, as criteria, through using a multiple criteria decision-making tool known as the analytic hierarchy process (AHP) (see Figure 3).

**Figure 4**
The APM company wide



*APM company wide (A3)*

In order to implement a company-wide APM (see Figure 4), there is a need for a systematic mechanism for collecting knowledge in the form of lessons learned and producing rules that can be fed into a system which intelligently applies them when needed. Labib (1996) has investigated an example of such a mechanism. There is also a need for a feedback mechanism that measures performance against benchmarks and monitor deviations. Finally, the aim is to institutionalise a company-wide approach. This activity means establishing a methodology that becomes part of running the business, not just a supporting tool. In order to achieve this status, there is a need to consider availability of spare parts, skills, and rules for every activity.

## Discussion and conclusion

Research and experience have demonstrated that there are three areas of controversy in the maintenance and reliability of manufacturing processes and systems that require analysis and understanding. The first area is data and decision analysis, where there is evidence that available computerised maintenance management systems (CMMS) deal with data collection and data analysis of the decision process, but seldom with decision analysis (Labib, 1996). The second area is corrective and preventive maintenance. One of the major problems in maintenance practice is the lack of a systematic, focused and adaptable, re-configurable approach in setting preventive maintenance instructions (Labib *et al.*, 1997; Labib and O'Connor, 1998). Hence, preventive maintenance instructions tend to be static, and not adaptable to changes in the shop floor; they are unable to react to on-line monitoring signals and to trigger corrective actions. The third area is the gap between techniques used in CMMSs implemented in industry, and models used in reliability studies, which are based on mathematical algorithms. Results of research conducted by Cho and Parlar (1991); Briggs (1994); Kobbacy *et al.* (1995); Vanneste *et al.* (1995); Dekker (1995); Srikrishma and Yadava (1996) and Pujudas and Chen (1996), have shown that the vast majority of maintenance models are aimed at answering efficiency questions, e.g. "how can this particular machine be operated more efficiently?" and not at effectiveness questions, such as "which machine should we improve and how?". The latter question is often the one in which practitioners are interested. Hence, there is a need for a re-configurable, adaptable and responsive maintenance model, based on multiple criteria, which is capable of addressing the above industry-driven challenges.

This paper offers an attempt to determine a practical framework of necessary steps needed to achieve a world class maintenance status. Details of sub activities have been cited to work previously published in the areas concerned. As shown in Figure 1, computerising the maintenance function is just the first phase of a three-phase framework to achieve world class maintenance.

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## Further reading

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## Appendix

IDEF (Integration DEFinition) was developed by the US Air Force's Integrated Computer Aided Manufacturing (ICAM) project in the late 1980s. There are many different IDEF methods. Each method is useful for describing a particular perspective of an enterprise. The major IDEF methods in use are functional or activity modelling (IDEF0), information modelling (IDEF1), data modelling (IDEF1x), process description capture (IDEF3), object-oriented design (IDEF4), and ontology capture (IDEF5) (Leach *et al.*, 1999).

IDEF is a rigorous methodology. The reason for the rigour is to ensure a robust and complete representation. As part of this rigour, a thorough review process is used. The review cycle is enhanced by the rigid IDEF syntax. The syntax for IDEF is very explicit. This research used one of the IDEF methodologies, IDEF0. There are five elements in the IDEF0 functional model as shown in Figure A1. The boxes represent functions such as activities, actions, processes or operations. Boxes are denoted by an active verb phrase inside the box, such as "Make Part" or "Perform Activity". Arrows indicate data. In IDEF, data can be information (like "current status") or physical objects (like "raw materials"). They are named by noun phrases such as "Raw Materials" or "Tools". The position of the arrow indicates the type of information being conveyed. Inputs are represented by the arrows flowing into the left hand side of an activity box; outputs are represented by arrows flowing out the right hand side of an activity box; the arrows flowing into the top portion of the box represent constraints or controls on the activities; and the final element represented by arrows flowing into the bottom of the activity box are the mechanisms that carry out the activity (Mayer, 1992). The IDEF0 method utilizes a subordinate principle of abstraction called decomposition, which is the breaking down of each box (activity) into more detail in a continuous manner until the greatest level of detail is achieved. An example of this is shown in Figure A2 (Leach *et al.*, 1999).

**Figure A1**
IDEF0 nomenclature

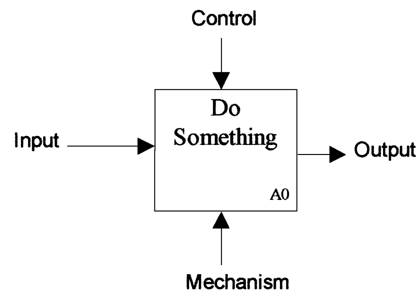

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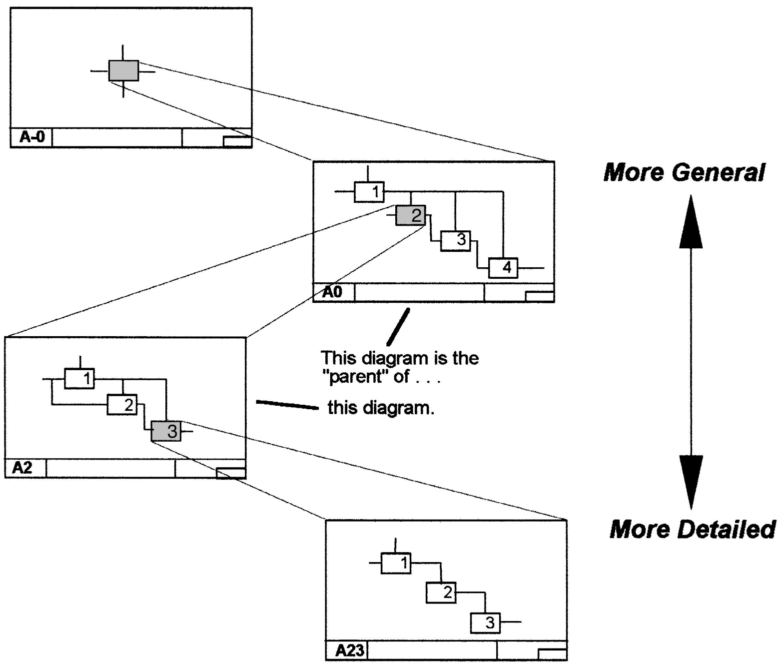
**Figure A2**
Functional decomposition




## Application questions

1 How does your organization deal with maintenance issues?

2 In this field, how important is it to benchmark the work of others?