

INFORMATION INTEGRITY - THE LIMITATION TO FUTURE INTEGRATION OF ISLANDS OF AUTOMATION

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Introduction

There is at present much discussion on the subject of joining up the 'islands of automation' currently implemented in the manufacturing area (e.g. ref. 1), for example CAD, CAM and MRP-based CAPM systems. These discussions tend to concentrate on the more obvious benefits of such integration, and the technical hurdles to be overcome in order to achieve these benefits. With the current rate of progress, the implication is that this integration will soon begin to take place in earnest, and installations reflecting this trend will appear in the near future. The utilisation of production control database information by other functions, for example accounts, purchasing and design, does not imply integration in the context of this article.

In its simplest form, integration could be regarded as the replacement of the current manual interfaces between these islands with computer-based interfaces. In a more developed form, the interfaces may be removed altogether and fully integrated systems developed; however, the implications of this in terms of complex interactions and software validation difficulties may prove unacceptable in some cases.

One area that is seldom discussed in detail is the range of functions actually carried out by the manual interfaces, both between the islands of automation and within each one where appropriate. Further examination and definition of functions actually carried out, levels of performance achieved and problems which occur, would assist in specifying requirements for computer-based replacements for these interfaces. A major, usually informal, function of the manual interface is that of 'information filter' or validator. This function involves more than the mechanistic validation of individual items of data (e.g. checking that a part number exists when raising an order for it) and typically utilises experience and intuition.

The main aim of this article is to examine in more detail the 'information filter' function in the context of MRP-based CAPM systems, and the ramifications of this when considering the future integration of the various computer-based systems in the manufacturing area. Figure 1

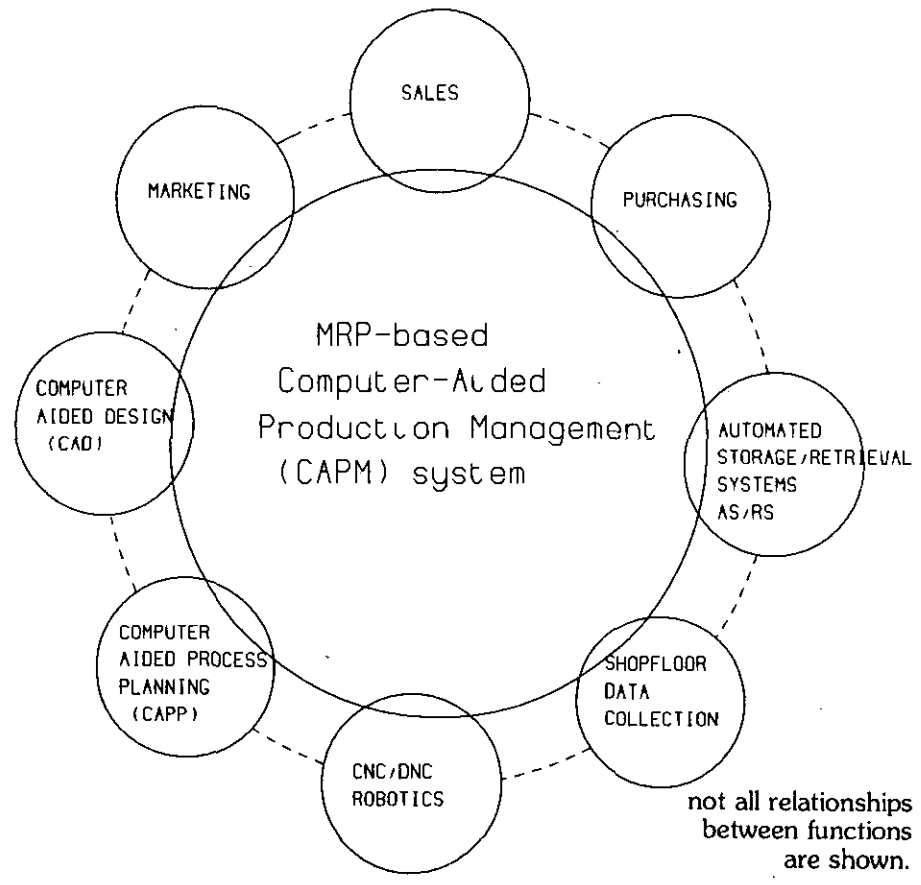


fig. 1: The position of the MRP-based CAPM System within a computer integrated manufacturing organisation.

illustrates the position of the MRP-based CAPM system within a fully integrated manufacturing organisation.

A Historical Perspective

The initial introduction of computer systems into the production/inventory control area was in the form of batch processing systems, which attempted directly to mechanise some of the functions of the manual systems which they replaced. There were major problems of reliability and hardware limitations; batch processing introduced significant delays into the system, causing further problems.

Hardware and software developments in the 1960's and early 1970's led to three major innovations:

1. On-line real-time systems
2. Database software systems
3. MRP application software systems

These three developments have allowed computer-based production control systems to step beyond the

direct emulation of previous manual systems. For practical reasons, the MRP calculations are still effectively batch processed, but most commercial production control systems allow on-line updates and interrogation of the database for the majority of functions. The use of databases not only allows rapid access to each item of data, but also eliminates duplication of data and the corresponding risk of data inconsistency within the system. The use of on-line systems can also reduce the risk of simple errors when updating the database, for example due to incorrect keying or misreading input documents.

A Brief Examination of MRP and some of its Implications

The introduction of MRP systems removed the manual interface from many intermediate stages in the production control (information) system. Consider earlier systems such as reorder point control or reorder

cycle control (ROPC, ROCC) - orders for each stage of the product structures down from the top level (master production schedule, MPS) would effectively be manually checked and authorised in turn; the process is quite different in MRP systems.

The MRP process is effectively a 'what-if' simulation in that it ascertains what must be ordered if demand is to be satisfied. The system models the decisions, stepping back in time, which would have to be taken in order to supply the products listed on the MPS at the appropriate times. This process takes account of current physical stock of components, planned receipts, order methods, scrap factors, lead times, etc. After this 'simulation modelling' of a 'pull' system, sets of recommendations or planned orders are produced. These are available to users in the form of printed reports or enquiry facilities; as a large amount of information is available, only recommendations for a short timespan ahead are usually examined and acted upon.

From the above description, it can be seen that the process is the reverse of that in ROPC and similar systems; demand caused by any MPS order will usually first appear for low level items, as these items will be required earliest for that MPS order. Low level demand represents the highest level of aggregation of demand, therefore the validation of planned order levels in a typical MRP system is seldom practicable. Some MRP systems allow sources of demand to be traced through the product structures by 'pegging' the requirements; this does not give the full picture and is costly in terms of processing and storage. Pegging is also to some extent contrary to the aim of MRP to aggregate demand for each component, a comment to this effect is made by Orlicky (2). Figure 2 illustrates these major differences between ROPC and MRP-based systems.

Some indirect acknowledgement of the problems of lack of validation is apparent in articles considering the implementation of MRP-based systems; typical statements of the higher data accuracy pre-requisites for successful implementation include:

- physical stock accuracies for A, B and C class items 97-99%, bill of material accuracy 100% (3).
- physical stock accuracy 95%, bill of material accuracy 98-99%, routing accuracy 95-98% (4).

For clarification of the meanings of the above statements, the reader should refer to the actual texts in which they occur. Assuming that the above accuracies could initially be obtained

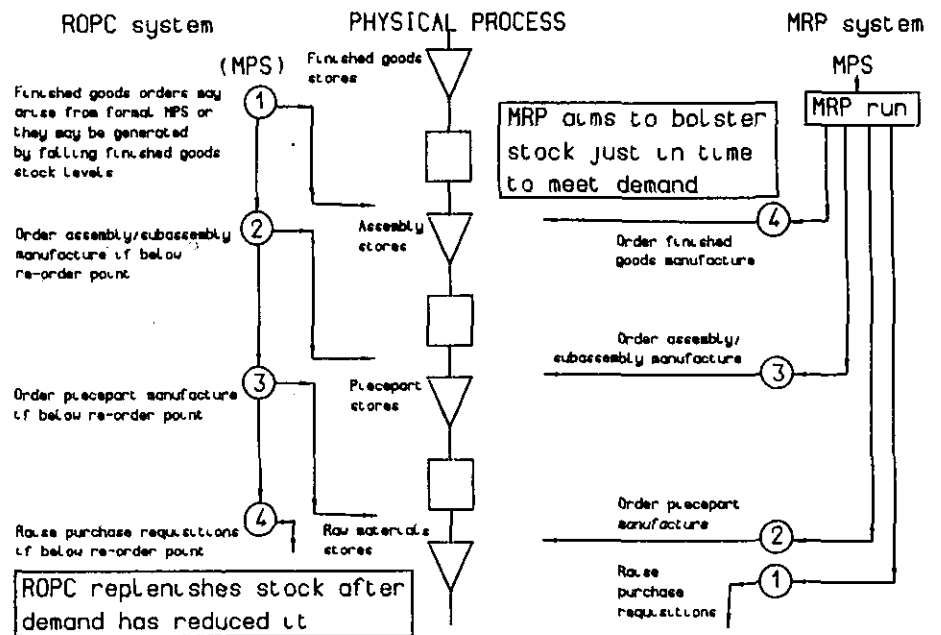


fig 2: Simplified representation of ROPC and MRP ordering processes.

by a considerable investment in manhours, the problem of maintaining that level of accuracy remains. Many organisations attempt to tackle this problem by appointing file controllers, each of whom has responsibility for the accuracy of specific files or areas of data in the system. A major drawback of this approach is that errors are only likely to be uncovered when gross problems occur, or occasionally by chance if random checks are made.

The use of database systems (with only a single computer source for most items of data) increases problems of validation. A further difficulty is that, because validation is now separated from the individual transactions that change the database values, all that can directly be validated is the state of the system. Inconsistencies or inaccuracies can be caused by one of a large number of errors or error combinations, often in other areas of the system. Tracing the primary cause or error is therefore difficult.

From the above, it can be seen that increased computer integration within MRP-based production control systems, in conjunction with a corresponding reduction of the numbers of manual interfaces (or 'information filters') has led to a requirement for increased data accuracy. The organisational commitment required to achieve this has not always been forthcoming; this has contributed to the low success rate achieved in the implementation and running of MRP-based production control systems. A minority of companies have committed the appropriate management, financial and other resources and achieved

successful MRP2 systems.

Further 'mechanistic' integration of the islands of automation would increase the distance between intelligent checks (i.e. between information filters). The sensitivity to errors, already a problem in MRP, would be increased further.

Functions and Problems of the Manual Interface

There appear to be three main functions of the manual interface:

1. To transfer information from one system or sub-system to another.
2. To supply additional information as necessary; this may be in the form of decisions or judgements.
3. To validate the data which is input, output or modified at this stage to act as an 'information filter'.

The first function, that of transferring information, can be replaced directly in integrated systems whose sub-systems can communicate with each other. The second function can in some cases be eliminated by providing additional information within the database, and by providing decision-making logic where decisions are based on simple quantitative criteria. The third function is seldom formally incorporated into integrated systems (other than at a trivial level); however, the effects of errors may subsequently be detected in the form of production problems or via exception reports. Examples of such reports include shortage lists, excess stock, overdue receipt and late delivery reports.

There are two main problems with manual interfaces:

1. Introduction of errors
2. Introduction of delays

Every manual interface introduces the risk of incorrect information transfer or input (whether or not the original information is correct), and integrated computer-based systems would almost eliminate this problem. The second problem, that of delay, is of equal importance in leading to a reduction in system performance; a typical area suffering from this problem is manual shopfloor feedback of operation status for made-in-works orders.

The Need for Information Filters

Is it possible to ensure that all data entering a system is correct? If this can be achieved, would the normal system software error-checking facilities maintain accuracy? The answer to both questions is no, for the following reasons:

1. It is possible to define and apply a tight specification for physical items (e.g. components, plant); however, the 'correctness' of an item of data entering the system is determined in relation to other items of data and their representational meanings. Some of these items of data may not be available at the time of entry, and also their inter-relationships are in many cases too complex to guarantee correctness at each stage.
2. An item of data which is initially correct may become incorrect (or inaccurate) due to a change which has subsequently occurred in the physical production system or products, which has not in turn been reflected in the production control (information) system; i.e. errors of omission or delay are very difficult to eliminate.

In MRP systems, shortage, late delivery and other exception reports are indications of the existence of information inaccuracies in the production control database, or faults in the software logic. As an error typically occurs a number of steps 'upstream' (earlier) from the detected deterioration in performance resulting from that error, tracing effect back to cause is extremely difficult; various error combinations may lead to the same 'symptom'.

The information validation function of the manual interface, removed from MRP systems, could be replaced by filters built into the computer software. The imposition of software filters at regular intervals, preferably at every transaction stage (whether internal or external), could much reduce the number of upstream error possibilities. The manual filter problems of delay and error introduction would largely be avoided.

The Japanese Approach

Japanese manufacturing organisations tend to tackle physical manufacturing problems directly, utilising large amounts of resources, if necessary, to eliminate them. By eliminating or reducing the physical problems, the information system requirements are also simplified. The success of this approach can be seen in the Japanese achievements with set-up times, scrappage rates and inventory levels. Typical approaches in Europe and America are that such problems are accommodated partly by the use of information systems and partly by the provision of additional physical items, for example inventory itself provides a way of accommodating scrappage.

The simplicity which can be achieved in information and control systems is clearly demonstrated by the manual Kanban systems. The physical proximity of information carriers (Kansans) to corresponding physical items also encourages the manual detection of errors and inaccuracies. The kanban systems are 'pull' systems, items are only produced at any level in direct response to usage for the next level in the manufacturing process. The feedback and control paths are therefore very short, providing fast response and stability; the clerical effort and cost required to maintain such information systems is small.

It should be recognised that the Kanban systems are generally applied to flowline-type situations with steady high demand rates. Such systems would produce disastrous results in typical batch manufacturing situations in Europe and the US unless other changes were also made in the areas of purchasing, manufacturing, sales and personnel. Due to this limitation of Kanban systems, a number of Japanese firms are now installing MRP systems in order to cope with more complex manufacturing control situations (5).

The apparent recognition by Japanese manufacturers of the difficulties introduced by complex information systems does little to encourage the view that 100% verification of information input accuracy is feasible. As has already been stated, subsequent changes to physical systems could in any case lead to inaccuracy.

The Basic Problem - Deducing Cause from Effect

In considering errors and inaccuracies, three stages can be identified:

1. The basic cause which allows an error to be input or to occur, for example sloppy change note procedures.

2. The initial error or inaccuracy, for example incorrect used-on-quality.
3. The resulting effects or detected inconsistencies, for example stockouts/shortages of low-level components affecting several products.

Research has been carried out to investigate the 'forward' relationships between cause and effect, amplification, stability, etc, in various types of production control systems. Very little, if any, serious research has been carried out to investigate the 'backwards' relationships between perceived effects and possible causes. These relationships are unlikely to yield to algorithmic approaches except in grossly simplified representations of reality. Figure 3 illustrates this relationship.

The Development of Software-Based Information Filters

The long-term major objective in developing software filters are to highlight the major causes of errors in the system and (of course) to eliminate information errors. A more realistic medium-term objective is that of detecting data errors in the database system; to achieve this, some or all of the following approaches may be considered:

1. To detect gross errors - those which, though syntactically correct, are unreasonable in practical terms. Examples of this might include projected capacity loadings well in excess of available capacity, made-in-works orders of more than a certain value or weight, or large disparities between orders for left- and right-handed items where these are used mainly in matched pairs. The actual checks or limits applied will depend on the particular manufacturing organisation, and will need to be updated regularly. This approach is tedious if applied mechanically and only a limited number of checks could be applied in a practical situation.
2. To note and report occurrences which are unusual, or which represent large changes in the values of certain parameters; this implies some memory of previous states of the database over a period of time. Examples might include large changes in the standard costs of previously costed items following a recosting run.
3. To detect failures in the performance of the system (e.g. stockouts, excess stock, late despatches) and to attempt to relate these to possible previous errors, in particular those unusual

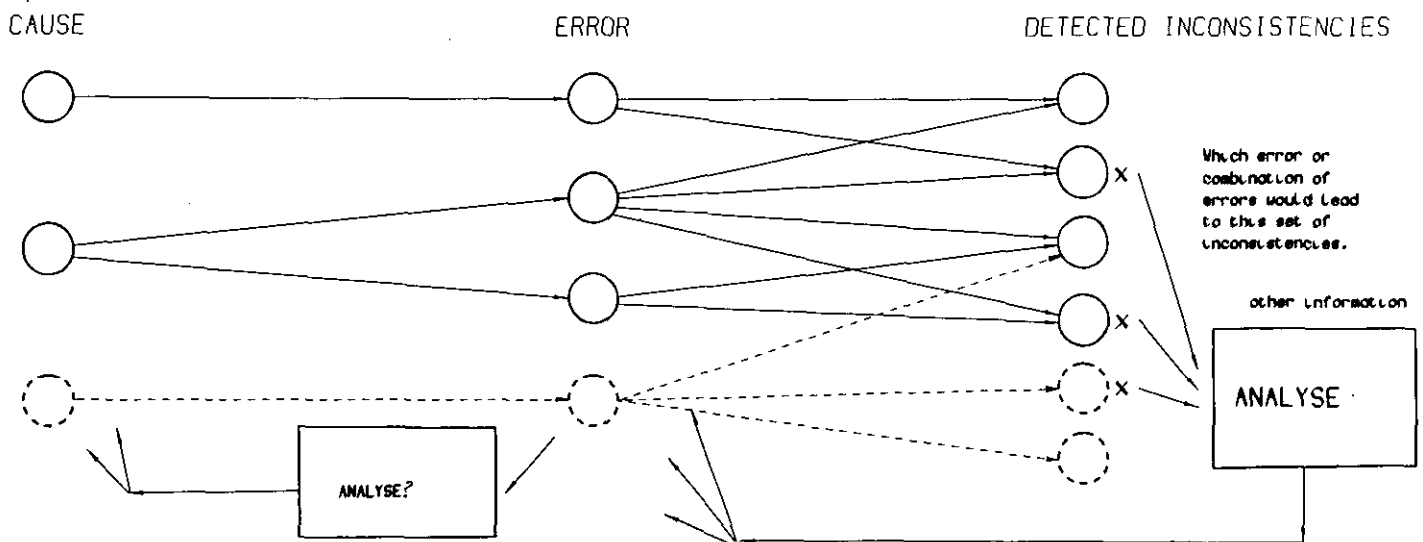


fig 3: The Problem - attempting to ascertain error and cause from effects.

occurrences noted in (2) above. To assist in this task, simplified forward relationships between errors (or inaccuracies) and inconsistencies could be made available in the form of sets of rules (e.g. if a database used-on-quantity value is too low then lower-than-planned stock over-issues may result).

- To learn from successes achieved in detecting errors from error effects. This may involve human input in the form of confirmation or otherwise of deductions, as validation from other sources external to the database will be required in most cases. Successes could provide additions to the sets of forward rules referred to in (3) above. On a more complex level, successes could allow the building of hypotheses about backward relationships (deducing cause directly from effects).

The above approaches require considerable changes to integrated production control systems; in particular, some form of 'supervisory' system will be required. This system will examine transactions as they occur, and also refer back to previous transactions in the case of problems or shortfalls in system performance. Major use of artificial intelligence based tools will be required as well as a number of heuristic aids.

There are now a number of artificial intelligence (AI) orientated computer languages widely available, for example Prolog and Lisp. An additional area of development is that of expert systems; these are designed to enable knowledge such as that possessed by human experts in specific fields to be utilised by non-experts. Current application areas of

expert systems include medical diagnosis, oil exploration and chemical analysis.

Other than specific applications such as those listed above, AI tools are still very much at the development stage. Considerable additional work is needed, both to further understanding of error/inconsistency relationships, and to develop artificial intelligence tools to filter information as it is processed within production management systems.

In the short term, limited success may be achieved by the development of 'bolt-on' systems which could be added to existing production control packages. Such systems would have access to transaction files and would be supplied with details of system performance shortfalls. A limited range of techniques would be applied to produce suggestions for manual analysis.

Conclusions

Information inaccuracy in MRP-based CAPM systems causes major performance problems. This apparent increased sensitivity to inaccuracy (in comparison to ROPC-based systems) is due at least in part to the removal of intermediate 'information filters'. The problems caused by information inaccuracy can be kept to manageable proportions by the continued application of adequate organisational and financial resources, as has been demonstrated by the minority of organisations that have achieved successful implementations of MRP/MRP2.

Further mechanistic computer integration of the 'islands of automation' will increase both the potential for undetected errors and the amplification of their effects; the stability and manageability of the

system will be reduced further. The level of integration currently achieved within the MRP-based information systems is taxing the abilities of organisations to manage them, therefore the 'more-of-the-same' approach appears inappropriate.

The development of effective learning (self-educating) information validation systems to the level of practical applicability is a long-term project, and is not amenable to short 'crash' programmes. Work in this field needs to be developed further before major problems occur in the integration of the islands of automation.

Information in the MRP system database is of considerable use outside the immediate day-to-day manufacturing environment, as MRP2 systems demonstrate. The MRP database, often in extended form, is already used in various organisations by other areas such as design, sales, purchasing and accounts. Such extensions of its use are relatively safe, as the users are 'knowledge experts' within their own areas and can perform the function of information validation.

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