Some considerations of the cost and value of information

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This paper discusses some of the factors which influence the cost of, and the value derived from, data processing and management information systems. Although most management information systems provide the information about the internal operations of a business needed for operational and tactical decision making, there are generally inadequacies in the information available to describe the external environment and the internal business organisation, both of which are needed for strategic decisions.

The relation of information to the perception of the manager is discussed and the paper concludes with a survey of some of the areas which need more research. The references provide a bibliography of recent literature on the subject.

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1. Introduction

Despite the vast investment on computer systems to provide more and better information, there is still little known in a formal sense about how to design or synthesise effective information systems. The majority of published work consists of general discourse (of which this is an example!) and case studies.

All management information systems must of necessity face many problems intuitively. As some guide to intuition, this paper surveys some of the work which has been done pertaining to the effects that quantity, quality and timeliness of information have on the cost and value of providing it. The paper also discusses some areas for research into information systems.

2. Costs

The simplest feature is cost. Provided one knows or has decided what data one is collecting and processing, the form and manner of the management information to be presented, the frequency of processing and the degree of timeliness required, one can in theory estimate the cost. It may be a crude estimate but it should be of the right order if produced by a competent data processing manager or consultant. Technological progress in hardware and software is continually reducing costs and shifting the economic boundary of jobs. Add to this the increased experience of introducing computer systems and one sees that for a given level of a complexity the costs are falling and the risks lessening with the passage of time. There are two kinds of costs associated with the new systems; non-recurrent (in data processing equipment, analysis, basic design and development and programming time, change-over and implementation costs) and recurrent (in staff and equipment for running and normal developments). The main non-recurrent costs are:

(*a*) *Equipment costs*

These do not increase linearly with the amount of processing. There are likely to be price breaks dependent on the volume and frequency of processing and the timeliness of reporting. Each of these may require extra equipment at a certain stage, e.g. to reduce delays in reporting may require data collection equipment, random access devices or greater processing power and real time control is likely to require stand-by equipment.

(*b*) *System development costs*

These depend on the current systems, the degree of integration attempted, the sophistication of the system and the quality of the management and the systems staff. Extra systems analysis, synthesis and educational effort will be needed to implement any radical departure from current methods. Problems with new codes (e.g. part numbers) and collecting data for basic file construction often give particular problems. Experience suggests that installations have generally tended to err on the side of too little systems work rather than too much, that insufficient analysis has been performed, that too little educational effort has been made, that designs have been insufficiently flexible and insufficiently documented and that the systems implications of error reports have been insufficiently investigated.

(*c*) *Installation and change-over costs*

These depend on similar factors to the systems development costs. They include costs of parallel running and retraining costs of any staff with altered job content. There are also costs associated with the risk of failure, namely opportunity costs of advantages foregone or costs of lowering morale and operating an inefficient system. As would be expected, the risk of failure is dependent on the methods used for systems analysis (e.g. Norris (1968)).

(*d*) *Recurrent costs*

These are the obvious ones of equipment, staff and stationery, programming and systems maintenance.

3. Management control information

It is conventional (e.g. NCC Systems Analysis Report (1967)) to consider 2 main areas of computer operation,

(*a*) Data processing;
(*b*) Management control information.

Data processing is the provision and maintenance of the basic data and records required for operational

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control, including, e.g. payroll, invoicing, sales ledger and stock recording, whilst management control information is information needed for effective decision making. However this distinction is largely a matter of degree as both data processing and management control information are produced to help control the organisation, data processing being associated with well defined and routine tasks considered essential or of high value and management control information with less well defined tasks of uncertain value.

But one soon sees the fallacy in this. Quicker invoicing may produce faster payment, more accurate invoicing may reduce losses because customers will query mistakes on the high side but not on the low, a quicker and more accurate payroll may improve goodwill, and, in general, greater speed and accuracy may produce greater confidence in the system. Each affects the nature of the overall control of the company. Rather than distinguish between data processing and management information I think that a more rewarding approach is to consider the information flow and decision requirements of any business or production system. An overall view of the information and decisions is shown in **Fig. 1.**

From strategic decisions (i.e. major policy decisions such as product specification and design, capital equipment purchase and company organisation structure) flow tactical decisions such as decisions on methods of manufacture and modifications to design. These are then implemented, e.g. by getting material control and process control systems ready, and the day to day operations carried out. This is the planning and action phase. Starr (1964) makes the point that production, in the general sense of production of goods or services (see Fig. 3) consists of a production system and a control system. To date, most OR and computer studies have been concerned with the control systems (e.g. production control, inventory control, quality control, cost control).

Accepting the distinction between the production system and the control system we see that strategic production system decisions are based to a large extent on:

(*a*) the external environment;

(*b*) the sociological (organisational) implications within the company. Few companies provide this kind of information from their management information systems and this is the area which intuitively should give greatest return on investment.

Because management information systems do not provide this information we often limit definition of the management information system to company transaction originated data (e.g. Thompson (1964)) and concentrate on the material and information flow as outlined in **Fig. 2.**

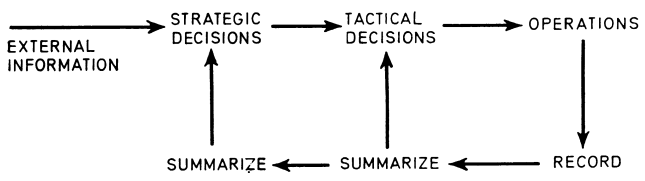

Fig. 1. Strategic and tactical decisions

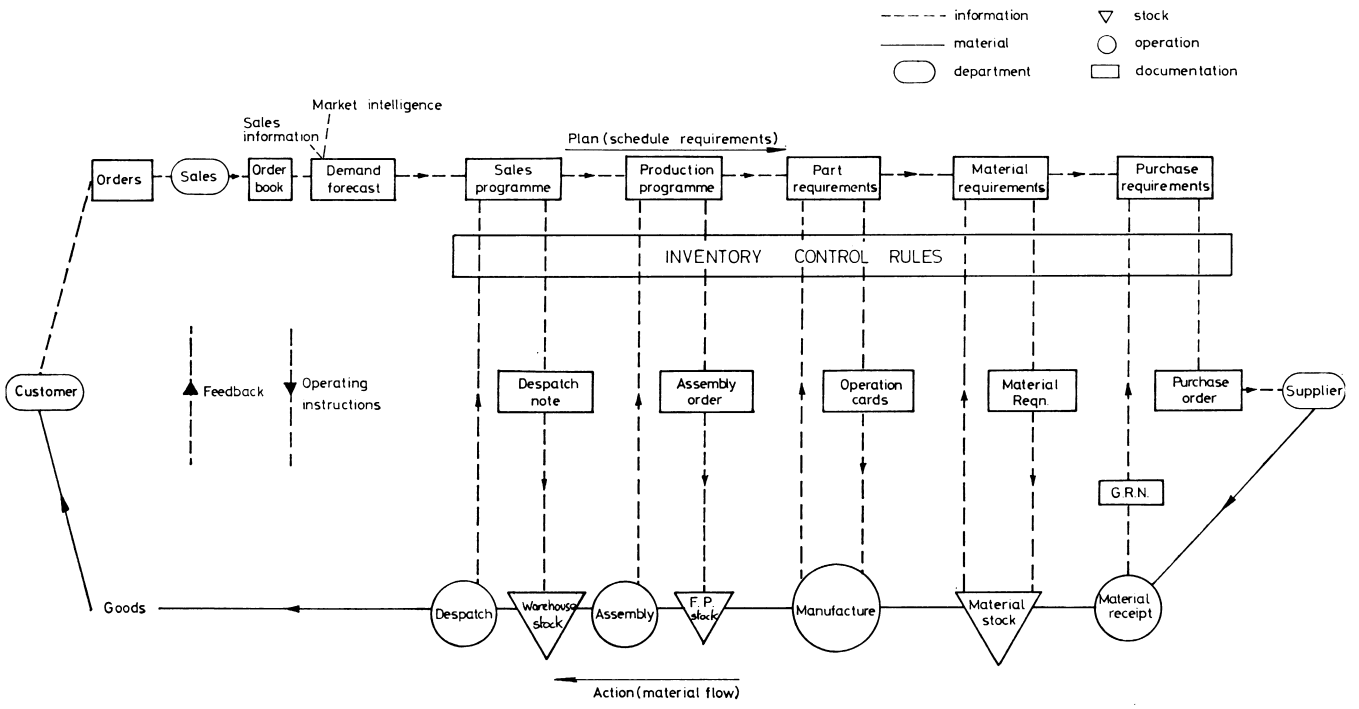

Fig. 2. Simplified information and material flow for production control

The outcome is that management information systems are usually transaction originated and designed according to the conventional wisdom. This seems to be that analysis should precede synthesis, and that the starting point for the design of a management information system is a detailed analysis of 'what is', in order, logically (by eliminating duplicate reports) and intuitively, to obtain an idea of 'what should be'. The decision of 'what should be' is commonly influenced by a set of assumptions.

1. Managers can manage better with more information.
2. Information is of greater value if produced more quickly.
3. Give a manager what he wants or what he thinks he wants.

These were developed in detail and criticised by Brough (1968). Ackoff (1967) points out and criticises two more common assumptions.

4. That more inter-departmental communication improves performance.
5. A manager does not have to understand how a management information system works.

Another common assumption popular with systems designers and programmers is that it is good to:

6. Make information logically consistent, e.g. if there is a plan, report performance against it.

For reasons of practicability (e.g. Norris (1968)) and what is an acceptable rate of change or the organisation (admittedly dependent on the pressures put on it), it is sensible to base the management information system on the current system. But many computer systems to date have proved to take longer and be more resistant to change than clerical systems. One thus has a situation in which criticisms may be levelled at current management information systems on three counts. First, that the 6 assumptions produce too much information of the wrong sort; second, that many information systems tend to reinforce the current organisational structure and reduce the flexibility of the organisation to change, and third and most important, many information systems do not provide information relating to the external and internal environments on which to base strategic decisions. As argued later, information is motivating, and so this lack of the right kind of information itself limits the rate of development of the management information system.

What are the requirements of production systems? As control systems, production systems are open, i.e. their effectiveness is determined in large measure by whether the market wishes to buy the goods or services produced as shown in **Fig. 3.**

Brough suggested that business is an open system living off its environment and that business must adjust to the environment off which it lives. But I suspect that this biological or cybernetic model for matching the market ought to be broadened to include changing the environment (market), e.g. by advertising and educational effort. In cost effectiveness terms (e.g. Stratton (1968)), before one can attempt a solution of a problem one needs a statement of the operational task and the environment (scenario). In the present discussion, the operational task would be the provision of information

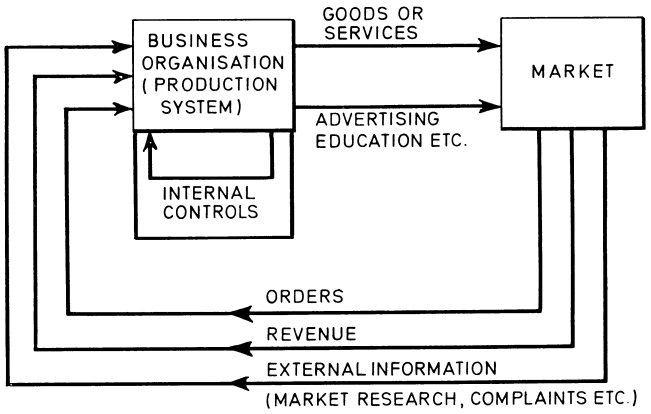

Fig. 3. A production system and its control

and the environment would be the external as well as the internal environment, not only now but for the life of the management information system. In other words because it is not known what the environment will be, there is risk associated with any estimate of information requirements.

Carrying over an argument applied to the use of OR for development decisions (*see* Klein and Meckling (1958)) there is much to be said for setting up a system which may incorporate new information requirements rapidly and efficiently, and where there are uncertainties about a proposed system, e.g. about using a new scheduling system for production control, one experiments or simulates to prove this out separately. The early decisions relate to the basic framework and leave areas of flexibility on which decisions are made nearer the time of implementation. In this way new ideas may be incorporated if they are sufficiently developed but, if not, one still has a workable system. This approach would have avoided many mishaps in information systems and software development.

4. Measures of effectiveness

What is the measure of effectiveness of an information system? Any system, be it the production system or the control of the production system, only incurs costs and any value results from the external environment i.e. the customer or society. This is discussed in Drucker (1964). However, one may impute value to information, probably in not easily quantifiable terms, on the basis of the better quality decisions which can be made using it. With this convention one would hope that total value would exceed total cost, otherwise there is no point in producing the information.

One will therefore get a situation roughly as in **Fig. 4,** where 'information' is some function of quantity, timeliness, accuracy and method of categorisation, and where the problem is to maximise the quantity (value-cost) for the system. However, as McDonough (1963) says, in the past 'we have collected our costs through a cost accounting system and have compared them to a value judgement derived by intuitive insight'.

In 'practical' terms this means that one determines the information requirements by an intuitive assessment of current and future needs including organisational flexibility and sets this against the cost of providing such

information. In 'research' terms it means further investigations are needed, some of which are discussed in Section 6. It needs emphasising that the problems of measurement of the effectiveness of an information system will continue for as long as the objectives of the system remain vague. Davis (1965) suggests (quoting partially from Bryant) that the persistence of evaluation problems seems to be related to:

1. Lack of well defined objectives.
2. Lack of meaningful models.
3. Uncertainty concerning measures of effectiveness.
4. Difficulty of determining test problems.
5. Difficulties of determining system scope.
6. Problems of security or proprietary interest.
7. Disinterest expressed through lack of 'punishment procedures' for poor system design.
8. Lack of quantitative evaluation criteria.

A survey of the concepts of systems analysis and the procedures for applying these concepts will be found in Borko (1967) and a discussion of the evaluation of information systems, mainly information retrieval, is given by Rees (1967).

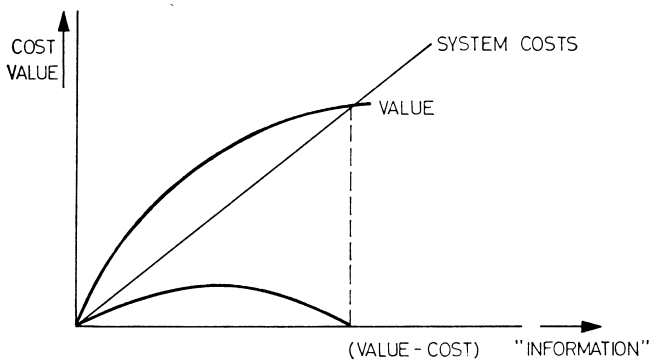

Fig. 4. Cost and value of 'Information'

5. Management information and perception

Drucker (1964) discusses some of the problems facing the provision of management information. He distinguished between 'control' which deals with the future and 'controls' as measurement and communication (our management information) which deals with the past.

Paraphrasing and adapting his arguments somewhat, we need to ask what management information is needed to give 'control'. This information must provide motivation to become 'control' and this motivation is dependent on the method of presenting information i.e., the structure of the presentation, and the 'perception' of the manager. In other words we must use the fact that information is goal setting and value setting. One particular problem is choosing the right category or unit. The majority of value of sales is provided by a few products, the value of stocks by a low percentage of parts, the majority of ideas come from a few people, labour unrest from a few troublemakers or poor managers etc., yet nearly all data processing systems concentrate on total numbers, how many parts are late, how many customers' complaints received etc. We tend to concentrate more and more of our efforts on the less important, and data processing systems tend to reinforce this trend.

On the subject of perception, March and Simon (1958) suggest that the greater the channelling of information processing, the greater the differentiation of perception within the organisation. This may be restated as decisions reached are related to management function and past information in addition to current information, or it is possible that two managers given the same information now, they will act differently and in conflict as a result of their previous knowledge. It is not enough just to provide information; it needs to be interpreted!

Interesting perception analyses are described in Ittelson and Kilpatrick (Chap. 8) Ames (Chap. 12 and 13) and Kilpatrick (Chap. 17) Ittelson (Chap. 20) and Kilpatrick and Cantril (Chap. 21), all of Kilpatrick (1961) which illustrates sufficiently that the provision of information of itself is not enough.

Two quotations to end this section:

(*a*) Drucker: The new controls technology has tremendous scope and power. There is a tremendous need for new and better controls (i.e. management information) and especially for controls that are quantitative and not just matters of 'opinion'. But the new 'controls' have this power and satisfy this need, precisely because they are not 'objective', are not 'neutral', precisely because they change both the events they record and observe and the men to whom they report and whom they inform... The designers of these controls . . . have to know what they can do means much more—and have to impose on themselves the responsibility appropriate to this power.

(*b*) Wiener: [in *Cybernetics* (1948), p. 164] says . . . in the social sciences we have to deal with short statistical runs, nor can we be sure that a considerable part of what we observe is not an artefact of our own creation.

(On page 162) talking about means of communication says . . . That system which more than all others should contribute to social homeostasis is thrown directly into the hands of those most concerned in the game of power and money, which we have already seen to be one of the chief anti-homeostatic elements in the community. It is no wonder that the larger communities, subject to this disruptive influence, contain far less communically available information than the smaller communities . . . Like the wolf pack, although let us hope to a lesser extent, the State is stupider than most of its components.

This runs counter to a tendency much voiced among business executives, heads of great laboratories, and the like, to assume that because the community is larger than the individual it is also more intelligent.

6. Research requirements

The scattered literature makes it difficult to know quite what work has been reported and is in progress. The first need appears to be a thorough survey and summary of present knowledge. An excellent paper surveying some of the literature is that by Amphlett Lewis (1966) and his discussion and references form a

very good framework for what follows, but it appears that many facets of information systems are not being investigated, either at the research or industrial implementation level.

The second area is the determination of well defined objectives for information systems. Because all decisions must be based on knowledge, real or assumed, the determination of the objectives of an information system leads research into organisations and management theories. A survey of some approaches will be found in Alexis and Wilson (1967) and Koontz (1961). Progress in our understanding of management processes appears to have been made by two approaches, the quantitative decision theory approach and the motivational approach. Because of the correspondence between organisations and information it seems reasonable to hypothesise that progress in the study of information systems will arise from similar studies.

It also appears reasonable to assume that decision making includes among its steps two stages, the first a decision model based on the parameters considered relevant, the second an assessment of these parameters based on the information and perception of the decision makers and both stages to be considered in terms of the overall business objectives. One then has 3 classes of problem:

(*a*) Interpreting the effect of decisions on total objectives.

(*b*) Investigations of decision models of a quantifiable nature.

(*c*) Studies of the influence of information on the assessment of decision parameters;

and these steps, in the reverse order (*c*) (*b*) (*a*) take one from the information to the assessment of its value. To investigate these experimentally is difficult: one cannot visualise experimentation in 'real' decision situations to see the effect of lack of information, e.g. of a company experimentally operating without control data. Work has therefore progressed mainly on analytic and simulation models which largely exclude the motivational effects on man and which are of value only where these motivational effects are not dominant. But, when investigating the effects of different types of reporting or categorisation one is concerned with matching the information to the perception of the manager. It may be possible to investigate some problems analytically as in Ackoff (1967) but usually the problem is to investigate subjective elements under controlled conditions. Case studies, but more promisingly, operational gaming offers the possibility of studying subjective elements in a controlled situation. One also needs to provide measures of these motivational effects. Value, decision models and some ideas on measurement are now discussed.

As we have seen the value of information derives from the actions taken as a result of it and the effects these have on the objectives of the system. These actions follow from the provision of information and its timeliness, accuracy and categorisation and the easiest of these to investigate is timeliness. An early paper by Gregory and Atwater (1957) discussed some of the effects of ageing of data. Further implications of faster presentation of information are seen in many areas

(i) In the response of a control system. This has been investigated by digital means by Forrester (1961) in his industrial dynamics studies. Other studies include those by Simon (1952) and others which are described in Holt, Modigliani, Muth and Simon (1960) by Bane (1965) and by Deziel and Eilon (1967). This class of problems would include such questions as what would be the value of earlier reporting of national trade statistics, or of using a different inventory or production control model.

(ii) The extra time available for decision making in non-competitive situations could improve the quality of decision. But how much improvement does a time increment give and how does one assess it?

(iii) In competitive situations considerable advantage is obtained by earlier information (e.g. Quade (1964) p. 210 for discussion on early information in defence situations). Allied areas where work has been done is in pest and disease control.

(iv) In design and in program debugging, conversational mode computer work, and particularly conversational graphics for design, enable information to be interpreted earlier. How much is this worth?

(v) In real time control, where advantages include psychological ones, e.g. Wilkinson (1968) when discussing the CAV real time production control system mentions the psychological effect of management taking notice immediately on hold-ups.

Another approach which appears to be potentially rewarding is the study of information systems using information theory. Assuming that management decisions are made on the basis of real or imagined knowledge and splitting decision making into:

(i) The probability assessment of events on which the decision will be based.

(ii) The decision and its outcome;

we get **Fig. 5** (A and B) representing the effects that additional information will have.

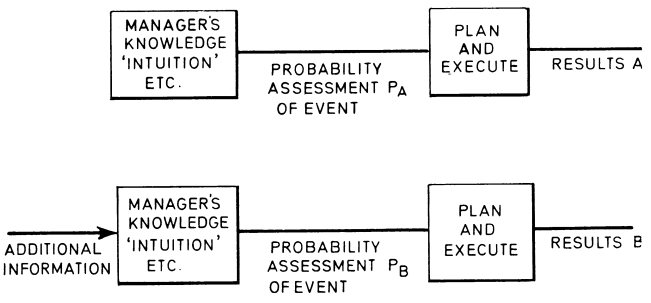

Fig. 5. Effect of information on probability assessments on which action is based

As an example (e.g. Theil (1967)) a weather forecast will improve one's assessment of the probability that a particular type of day will occur. On the basis of the probability assessment one may make decisions but the

value of this information gain is dependent on the sensitivity of the measure of effectiveness to forecast improvement. This split into two would appear to have the advantages of circumventing the subjective elements which occur in probability assessments and quantifying the results of these as information gain, and secondly allowing analytic or simulation models to act on these probability assessments to study the sensitivity of the measure of effectiveness to information gain. An example of this will be found in Owen (1967) which looks at the risks involved in uncertainties of judgement first without investing in information and secondly by initiating a study which will reduce the uncertainties. On an allied theme the paper by McNulty (1964) looks at the interactions between communication and organisation structure and discusses Morgensterns conjecture of erratic and biassed behaviour of organisational members responding to messages.

Schume *et al.* (1967) suggest that the cost-payoff function of a decision affects the probability assessment of the truth of a hypothesis, and other areas of study of interest relate to information selectively e.g. Rhine (1967) and models of the human use of information e.g. Beach (1967). There appears to be much work still to be done on the effects of accuracy and categorisation on information gain.

One last reference is a little book by Farmer (1967) which as well as being fun illustrates the sort of problems which someone somewhere should be trying to provide the answer to.

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