IMPROVING MANAGERIAL APPROACHES TO INFORMATION TECHNOLOGY

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Advances in information technology should be viewed by management not only as inherently desirable in themselves, but also as sources of potentially valuable improvements in planning, operations, control and performance evaluation. Hence, it is appropriate that all such proposals should be evaluated in terms of their expected yields of faster, more complete, more accurate and more effectively integrated information flows. In addition, however, primary emphasis should also be given to the magnitude of resulting contributions to the competitiveness, profitability and growth of the firm relative to the time, investments and costs involved.

Keywords: management, information technology, information systems, productivity

INTRODUCTION

Recent and prospective advances in information technology have generated an expanding literature concerning its potential.[1] Although even generous estimates of such potentials seem attainable eventually, actual benefits so far have fallen significantly short of enthusiastic expectations. Accordingly, this paper will review some of the needed components of an effective managerial approach to the development of information technology in individual firms. The judgements presented are based on my field studies of the factors which seem to have inhibited the more rapid exploitation of this still emerging technology.

DISTINCTIVE CAPABILITY AND POTENTIAL OF INFORMATION TECHNOLOGY

Most management is still largely unaware of the broad capability and potential of information technology. This is because perceptions have been limited by exposure only to proposals which emphasise small and localised applications offering only those benefits which accord with conventional criteria for evaluating new equipment and facilities.[2] Experience has demonstrated, however, that information technology also offers an array of additional distinctive capabilities.[3] Fundamentally, it represents a general process of cumulative advances in technology and in managerial controls rather than a succession of discrete and unlinked innovations. One feature of this development involves the continuous pressure of information technology towards encompassing increasing sectors of successive operations. Thus, computerising the controls of a given machine operation commonly offers the attractive prospect of extending such controls progressively to preceding and to succeeding operations, as well as to the movement of parts among them, with disproportionately small additional costs and investments relative to the resulting gains in production efficiency and costs.

Such capabilities facilitate not only the rapid and efficient output of any given product in specified volumes, but also the fuller utilisation of production facilities through the rapid shifting of output from one product to another in accordance with the programmed instructions guiding the computerised controls. Still another benefit is that the same production facilities can be utilised for longer periods because these technologies permit continuing adjustments over time to a wider array of changes in product designs and production methods resulting from market pressures as well as from internally generated improvements.

A second feature of information technology is that it can facilitate the integration of staff as well as of line functions. For example, the planned rate and composition of input could readily be co-ordinated with associated adjustments in various inventory levels, with the issuance of procurement orders and even with delivery commitments. But such operating control could also be built into a system encompassing personnel allocations, facilities maintenance, cost evaluations and a variety of other managerial controls, including performance evaluations.

A third feature is that, because information technology is still a vigorously developing form of technology, management can expect continuing increases in the capabilities of existing installations in contrast to the progressively declining performance characteristics of most machinery and equipment within a few years of installation. Substantial improvements in computers, in programming, in instrumentation and in network designs are still emerging, yielding important gains in the speed, flexibility and precision of operations, in managerial awareness of operating problems and results, and in system responsiveness to needed adjustments. It is also worthy of emphasis, in view of the increasing dispersion of many corporate and governmental operations, that information technology and closely associated communication technologies offer powerful contributions towards meeting increasing managerial needs in effectively guiding the procurement, production, marketing and financial operations of geographically dispersed parts of a firm.

As a result of these multiple and still growing capabilities, information technologies are gaining increasing recognition as sources of significant improvements in the productivity, flexibility and cost effectiveness of international operations. In addition, one may also anticipate growing recognition of their prospective contributions to improving the external competitiveness of firms through more comprehensive and continuously updated analyses of changes in input and product markets.

SOME REQUIREMENTS FOR HARNESSING THE POTENTIAL OF INFORMATION TECHNOLOGIES

Information technologies are still commonly exemplified by narrowly limited applications, demonstrating the continued widespread unawareness of the need for comprehensive planning to help maximise benefits from these investments. The initial objective of such planning should be the formulation of a strategy for development and application of the successive stages involved in achieving a system capable of serving expanding needs over a period of years. But this is frequently neglected in the rush to acquire some capabilities responsive to the particular needs of whichever group initiates such a request. After all, responsiveness to narrowly focused requests has become the common basis for capital budgeting allocations, which usually result from managerial evaluations of an array of competing requests for equipment acquisitions. Such procedures are inappropriate, however, for responding to proposals which involve the progressive implementation over several years of successive components of an envisioned complex system of processing capabilities, because intermediate acquisitions may not yield sufficiently attractive benefits until mutual reinforcement is achieved by completing the plan. The resulting strategy should accordingly provide the basis for specifying the basic equipment capabilities to be provided at each stage of implementation, along with the array of specialists needed and the developing performance targets to be achieved.[4]

In order to implement such plans, provision would obviously have to be made for acquiring the needed equipment and software as well as for any required hiring and training of new and existing technical, supervisory, programming and operating personnel. Such efforts would, of course, have to be reinforced by educational programmes to gain the broad understanding and support of all relevant sectors of management. In turn, effective utilisation of resulting operating capabilities would require adaptive modifications in the production planning and control system, in the accounting system, in the allocation of the labour force and perhaps even in procurement activities.

Beyond such early stages of implementation, it is usually necessary to consider a number of further supportive efforts. One of the most important in many cases involves the possible need for changes in the existing organisation structure in order to take advantage of the newly available potential for increasing the integration of hitherto separate units. Another involves periodic consideration of possible changes in product specifications, in product mix or in processing capabilities in order to take advantage of emerging improvements in equipment, software or instrumentation, as well as shifts in market demand.

SOME BASIC EFFECTS OF MAJOR APPLICATIONS OF INFORMATION TECHNOLOGY

After the preceding review of the far-reaching potential of comprehensive information technology systems, and of the complex requirements for achieving progress towards such benefits, it may be helpful to review some findings from my field studies concerning experiences with their application. One of the most common findings centres around the narrowly limited use of information technology being made so far in US manufacturing firms beyond the 'first level' applications centred around accounting, and finance operations and company communications. Within production operations, for example, such applications are still commonly restricted to computer control of individual machines or of limited production cells. Integrated control of entire production lines is seldom encountered. But the span of such unified controls is being gradually extended as a result of growing experience and resulting confidence in planning and managing increasingly complex systems, and in adapting them to operations differing widely in speed, quality standards and product variability.

A second widespread finding is that achieving effective and profitable operations, even of computer aided manufacturing systems which cover only limited segments of production activities, often takes several years. This reflects the complexity of accompanying efforts to reduce progressively the need for human judgements in guiding operations and to maximise acceptable throughput by anticipating and minimising all possible sources of undesirable variations in production rates and quality for a flexible mix of output. Thus, a gas tank welding application by General Motors was still unable to produce consistently acceptable products after 18 months. And an integrated cell producing tractor transmission units in a Caterpillar plant managed to reach planned output and quality levels only after three years. But capitalising on the accumulated experience then enabled engineers to exceed that target by 40 per cent within the following two years — and this level was quickly duplicated by later installations. Incidentally, such progressively widening quality requirements also tend to extend all the way back to specifications for purchases of inputs.

Thus the exciting potential of new technologies, including information technologies, frequently attracts pioneers who only belatedly discover the often substantial problems to be overcome before commercial benefits are achieved. And it must be recognised that even technologies which have been applied successfully by some users may require extensive adaptive adjustments before they can be applied successfully to the distinctive product, process and marketing needs of other users.

A third finding has emphasised the need for a more thorough appreciation of the extent to which existing technologies are built into not only the production equipment, but also into the expertise of the technical personnel, the skills and organisation of labour, and the structure of managerial prerogatives and responsibilities. Each of these represents powerful and mutually reinforcing commitments to preserving existing production and organisational arrangements, except for small, gradual and localised changes. The influence of such deep-rooted commitments is perceptively captured in the poetic lines:

> With their eyes firmly fixed upon the past,
> They backed reluctantly into the future.

Hence, successful applications often require carefully developed and extended periods of orientation as well as training programmes in order to minimise insecurity and consequent resistance. Effecting major changes in a firm's technology is also difficult because substantial investments, painful readjustments in operations and worrisome shifts in organisational structure usually represent cumulative early impacts, whereas production, marketing and financial benefits represent only anticipated benefits at some uncertain future date.

A fourth finding is that, although there can be no option about adopting demonstrably successful technologies already used by competitors, there is a very important choice involved in deciding when to adopt such new technologies. The history of technological progress offers many illustrations of both the advantages and disadvantages of being a 'pioneer', an 'early follower' or a 'laggard adopter', depending on the accuracy of evaluations of early forms of emerging technologies. But my studies suggest that the penalties of belated adoption are likely to be progressively greater in proportion to the breadth of operations to be affected.

Thus, the penalties of belated adoption of equipment or processes which replace only narrow subsectors of existing operations are likely to be eliminated within a few months after the substitution is made and rendered operational. But innovations which impinge on multiple or wide sectors of operation are likely to require extended periods after their acquisition to explore and effect the complex array of re-adjustments necessary to ensure their effective re-integration into the entire operating system. This is especially likely to be true of information technology systems because of their broad range of interacting effects. Hence, delays in initiating such acquisitions — and the associated processes of learning and progressive adaptation — tend to exact larger and longer lasting competitive disadvantages.

Still another of our empirical findings has been that the sound development and utilisation of increasingly comprehensive information technology systems seems to require integration into more encompassing performance evaluation systems. In manufacturing operations, for example, such systems should integrate three levels of measurement and appraisal:

1. the 'network of productivity relationships';
2. the 'structure of costs'; and
3. the 'managerial control ratios', which identify the remaining primary determinants of profitability.

As will be shown below, the resulting analytical framework can facilitate tracing the probable effects of innovations in operations on productivity, costs and profitability, in addition to tracing the sources of past changes in profits back to underlying adjustments in costs and productivity relationships, as well as in product prices, output levels and capital utilisation.[5]

A PRACTICAL ANALYTICAL FRAMEWORK

As shown in Figure 1, the network of productivity relationships consists of six interacting linkages. Three represent changes in the direct input requirements per unit of input:

1. man-hours per unit of output;
2. materials volume per unit of output; and
3. fixed investment per unit of productive capacity.

The first of these has been commonly used both in management practices and in economic analyses. Although such an aggregate measure may be adequate for preliminary appraisals, more penetrating analyses of associated consequences would also have to consider any major adjustments in the skill composition of the labour force and in the proportions of direct versus indirect (and hence less variable) labour. The second, which is commonly omitted from economic analyses involving production functions, is usually of very great importance since purchased materials account for more than half of production costs in most manufacturing industries. The third measures changes in capacity instead of output per dollar of fixed investment because fixed investment buys capacity rather than output, thereby necessitating the clear separation of such capacity from its rate of under-utilisation. The remaining three linkages in Figure 1 cover any changes in the proportions in which these inputs are combined as a result of substitutions, or of changes in utilisation rates, which affect the ratio of man-hours to materials volume or the ratios of actively-utilised fixed investment to man-hours and to materials volume.

This productivity network has three distinctive characteristics, reflecting the complexity of the industrial changes to be encompassed by management efforts to improve performance. First, changes may originate in any of the six links, but their effects must then be traced through the entire system in order to determine the integrated results. For example, mechanising some manual operations would first increase the ratio of actively-utilised fixed investment to man-hours. This would tend to reduce man-hours per unit of output, while the attendant increase in fixed investment might alter its ratio to capacity. And if the innovation also reduced scrap rates, the output per unit of materials volume would increase.

Second, because of the inevitability of such interactions within an integrated production system, an observed change in any of the six links need not have originated in that component. Instead, it may represent merely a passive adjustment to a change originated elsewhere in the system. Indeed, the originating innovation cannot be identified from the resulting measurements — it requires specific knowledge of the changes introduced by operating personnel. For example, increases in output per man-hour may have been caused by the purchase of more highly fabricated inputs, or by changes in production equipment or even by shifts in product mix.

Third, the effects of changes in any of these links on the rest of the network also depend on accompanying changes in output and capacity levels, as well as on utilisation rates, because of differences in the relevant flexibilities of inputs of materials, labour and fixed investment. Hence,

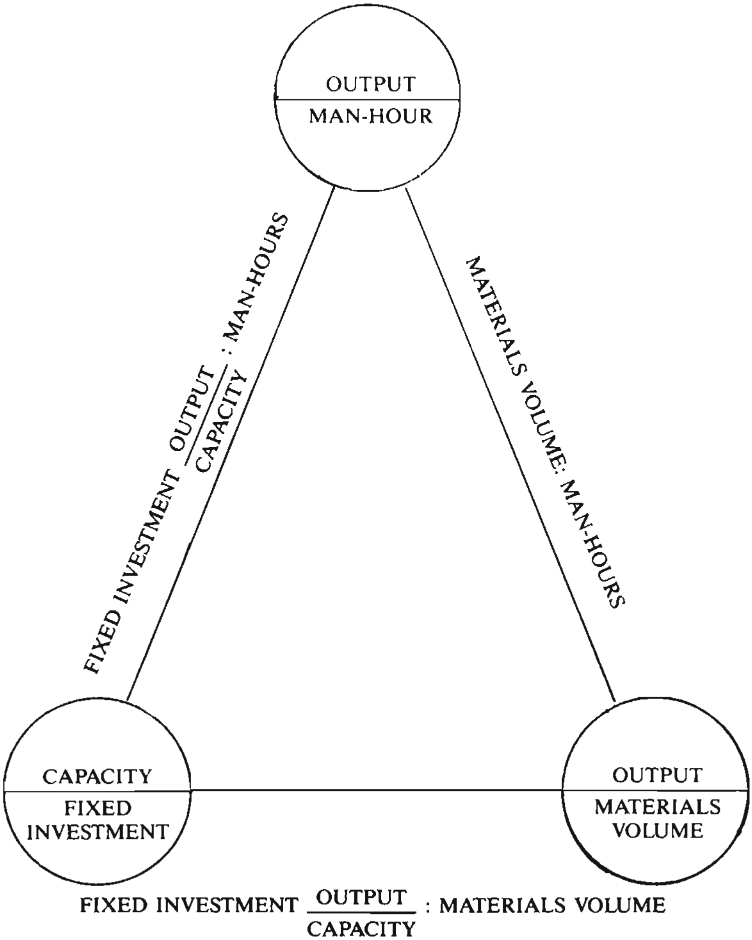

Figure 1: Network of productivity relationships

attempts to generalise about the effects on the network of given types of innovations tend to be highly vulnerable. For example, an increase in the ratio of capacity to fixed investment may be of little benefit if accompanied by a decrease in capacity utilisation. Similarly, an increase in output per man-hour may be attributable to the purchase of more highly fabricated inputs rather than to increased efficiency in internal labour efforts.

In any event, the economic desirability of any combination of changes in the productivity network obviously cannot be determined from such input-output measurements alone. They must first be integrated with accompanying changes in the structure of costs, as shown in Figure 2. The initial stage of this two-step process involves determining the effects of changes in each unit input requirement on its unit cost. Contrary to the convenient common assumption that factor prices are not affected by reductions in unit input requirements, field studies demonstrate that these are quite likely to interact (especially in the case of labour and materials), thereby tending to reduce expected savings in unit wages costs and often in unit material costs as well as a result of accompanying increases in the productivity of these inputs. Hence, it is critical in seeking cost control to gain the joint involvement of procurement and labour relations, as well as of engineering and management, in considering alternative decisions.

The effects of such productivity-induced changes on total units costs also depend in turn on the proportion of total costs accounted for by each. For example, a 10 per cent increase in output per man-hour accompanied by only a 5 per cent increase in hourly wage rates would reduce unit wage costs by 5 per cent.[6] But if wages account for only 20 per cent of total costs, this would tend to reduce total unit costs by only one per cent. Moreover, even this slight reduction might well be offset by increases in unit materials or capital costs if these were involved in the innovations which caused the increase in output per man-hour.

In view of these interactions, it is important in planning productivity improvements to take account of the specific cost proportions in each application. In US manufacturing industries, wage costs commonly range from 5 to 40 per cent of total costs (averaging about 18 per cent), and material costs range from 35 to 85 per cent or more (averaging about 56 per cent), which indicates the prospective impact of equal percentage reductions in these unit costs on total unit costs. Incidentally, the proportion of total costs accounted for by interest and depreciation is frequently over-estimated, actually accounting for less than 10 per cent in most US manufacturing industries, even in such reputedly capital intensive industries as steel.

The third tier of interactions, as shown in Figure 2, covers the other determinants of changes in profitability. These include the effects of productivity changes not only on total unit costs, but also on product quality and product-mix, as well as other characteristics which may affect the prices to be charged and the quantities which can be sold.[7] Changes

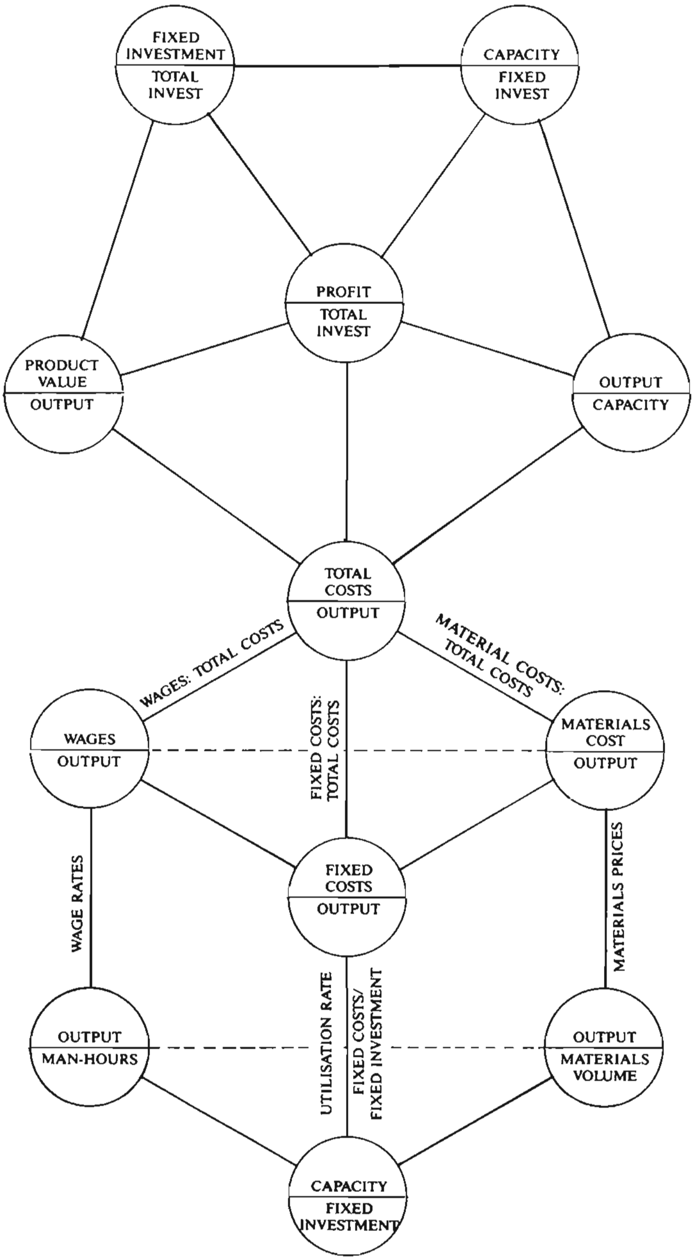

Figure 2: Productivity network, cost structure and managerial control ratios

in the rate of profits on total investment may accordingly be regarded as the product of interactions among the five factors in the following 'managerial control ratios':[8]

1. average product prices (value of product/physical output);
2. average total unit costs (total costs/physical output);
3. the rate of capacity utilisation (physical output/productive capacity);
4. the productivity of fixed investment (capacity/fixed investment); and
5. the internal allocation of total investment between fixed assets and working capital (fixed investment/total investment).

Taken together, these represent the integrated contributions of procurement, engineering, manufacturing, marketing, personnel and finance. In the short run, changes in profitability tend to be dominated by interactions among the first three factors. Over the longer run, however, profitability tends to be affected by interactions among sustained changes in all five factors. Finally, it should be emphasised that pressures for adjustments in the entire system may be initiated in each of the three tiers of Figure 2. Thus, market-induced changes in output levels and product-mix can effect adjustments not only in the cost structure, but also in the productivity network. And such readjustments can also be generated by market changes in relative factor prices or supply availabilities. Hence, it is necessary to consider interactions among all three tiers when analysing past changes, as well as when evaluating alternative future adjustments. Accordingly, in appraising the effects of technological innovations, consideration must be given to potential impacts:

1. on the productivity of each input and on its proportionate mix with other inputs within the productivity network;
2. on the input qualities, mixes and prices in the structure of unit costs as well as on cost proportions; and
3. on the product designs and product mixes which affect the managerial cost ratios as well as the productivity network and cost structure.

SOME SUMMARY IMPLICATIONS

Effective development and utilisation of information technology should be recognised as involving a systematic long term programme of progressively broader applications, rather than an array of independent acquisitions of whatever components promise acceptable rates of return during periodic evaluations of alternative capital allocation proposals. Because of the necessity of developing the personnel, equipment, software and organisational foundations for building a sound information technology programme, such an undertaking is unlikely to offer high rates of return on a 'net present value' or 'discounted cash flow' basis, using the 25-35 per cent or higher discount rates commonly used in evaluating prospective new technologies.[9] Rather, like the introduction of research and development programmes in many industries, it requires justification on the basis of its critical contribution towards maintaining effective competitiveness over a number of years.

Effective planning of an information technology programme would benefit from an early broad perspective which envisions the general sequential stages of development. But effective implementation requires identification of internally coherent subsectors within the larger system as the foci of successive component applications. Resulting efforts would then facilitate understanding of the detailed requirements of effective information technology systems, including equipment capabilities, personnel training and the design of data flows to integrate performance requirements with managerial controls and the reporting of results.

However successful the early information technology programmes prove to be, periodic revisions are bound to prove necessary for several reasons. For example, this relatively new technology is certain to keep developing for many years to come, thereby offering new capabilities and economies. In addition, the firm's product designs, product mixes and production technologies will keep changing, thereby necessitating responsive adaptations. And changing pressures and opportunities in input as well as product markets are bound to induce additional adaptive adjustments — especially as operations are extended internationally.[10]

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$$\frac{\text{PROFIT}}{\text{TOTAL INVEST}} \equiv \left(\frac{\text{PRODUCT VALUE}}{\text{OUTPUT}} - \frac{\text{TOTAL COST}}{\text{OUTPUT}}\right) \times \frac{\text{OUTPUT}}{\text{CAPACITY}} \times \frac{\text{CAPACITY}}{\text{FIXED INVESTMENT}} \times \frac{\text{FIXED INVESTMENT}}{\text{TOTAL INVESTMENT}}$$

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