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INNOVATION DURING IMPLEMENTATION: CONFIGURATION AND CAPM

James Fleck

UNIVERSITY OF EDINBURGH

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ABSTRACT

In this paper some issues concerning the nature of technological development are examined, with particular reference to a case study of the implementation of Computer Aided Production Management (CAPM). CAPM is an example of a configurational technology, built up to meet specific organizational requirements. It is argued that there is scope in the development of configurations for significant innovation to take place during implementation itself, through a distinctive form of learning by "struggling to get it to work". Some policy implications are outlined in conclusion: the need to recognize the creative opportunities available in this type of development, and the need to facilitate industrial sector-based learning processes.

Revised version of a paper originally presented at an ESRC/DTI Research Initiative on New Technologies and the Firm and Technology Study Group Conference, University of Stirling, School of Management, 6/7th February, 1991.

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This paper is an outcome of discussions with Robin, Juliet, and other colleagues in Edinburgh PICT, in particular Alfonso Molina, and in the Department of Business Studies. I would like to thank them all for their help and support.

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INNOVATION DURING IMPLEMENTATION: CONFIGURATIONS AND CAPM

CONTENTS

1. Introduction

Implementation, the process of getting technologies -- especially complex ones -- to work as commercially successful operating systems, became increasingly recognized in the 1980s as a key phase in the overall development of technology (Rhodes and Wield 1985, Leonard-Barton and Kraus 1985, Voss 1988). However, the creative effort required to achieve effective implementation is not always fully appreciated by the people involved in introducing new technology, far less by those concerned with devising policies for innovation. This is unfortunate because opportunities for *innovation during implementation* are thereby missed, and, in far too many cases, total failure results.

In this paper, I endeavour to outline the basic mechanism through which implementation is achieved and the potential for innovation opened up. Opportunities for innovation are not uniform, of course, across all situations, but vary according to the nature of the technology employed, among other factors. In this respect, *configurational* technology, built up from a range of components to meet the very specific requirements of the particular user organization is important (Fleck 1992). Configurations *demand* substantial user input and effort if they are to be at all successful, and such inputs can provide the raw material for significant innovation. A case study of the introduction (or, more accurately, the attempted introduction) of computer aided production management (CAPM) -- a particularly good example of a configurational technology -- is used to illustrate and develop the argument.

Implementation is often characterized as an organizational learning process. As we shall see, the specific implementation / innovation process with configurations is a matter of "learning by struggling to get it to work". Improvements and modifications have to be made to the constituent components *before* the configuration can work as an integrated entity. This can be usefully distinguished from the similar processes of "learning by doing" and "learning by using" identified by authors such as Arrow (1962) and Rosenberg (1982). These refer to the important incremental improvements that flow from progress up the learning curve (learning by doing) and from progressive modifications to an already functioning technological entity (learning by using). As such they represent improvements made *after* a functioning entity is achieved.

Moreover, the micro-processes of innovation during implementation have correlates at the macroeconomic level. In particular, the overall patterns of development differ from the linear model in which innovation is followed by diffusion of the same technological entity in essentially unchanged form across a sector or the economy as a whole. This latter pattern is adequately described by the general class of epidemiological diffusion models (for example, see Mansfield 1968, Davies 1979, Stoneman 1983). In configurational development, however, the processes of innovation and diffusion are collapsed into one another, in what might be called a process of "innofusion" (Fleck 1987). In terms of the biological metaphor, models of *speciation* rather than *population growth* (which are what epidemiological models essentially are) are appropriate for describing innofusion. Although these macro issues are not directly addressed in this paper, they are important in considering policies appropriate for configurational development, as outlined in the conclusion.

2. Computer Aided Production Management: CAPM

Computer-aided-production-management (CAPM) is a general term referring to the use of computers in managing and controlling the materials, machinery, and manpower employed in manufacturing industry. In a field where acronyms are notoriously prolific, the term CAPM has not become widely accepted, being mainly espoused by the British Science and Engineering Research Council's programmes in the UK.

Many disparate activities are involved in production management. Over the last decade or so these have become progressively computerized, and latterly, progressively integrated together into larger systems. The ultimate (though still somewhat distant) goal is computer-integrated-manufacture (CIM). In CIM, a variety of tasks in different organizational departments are computerized and linked together, as schematically represented in Figure 1. At the heart of these systems one usually finds some form of computer-based inventory and materials control system, generally designated by the commonly recognized term, "materials requirements programming" or "MRP I" for short.

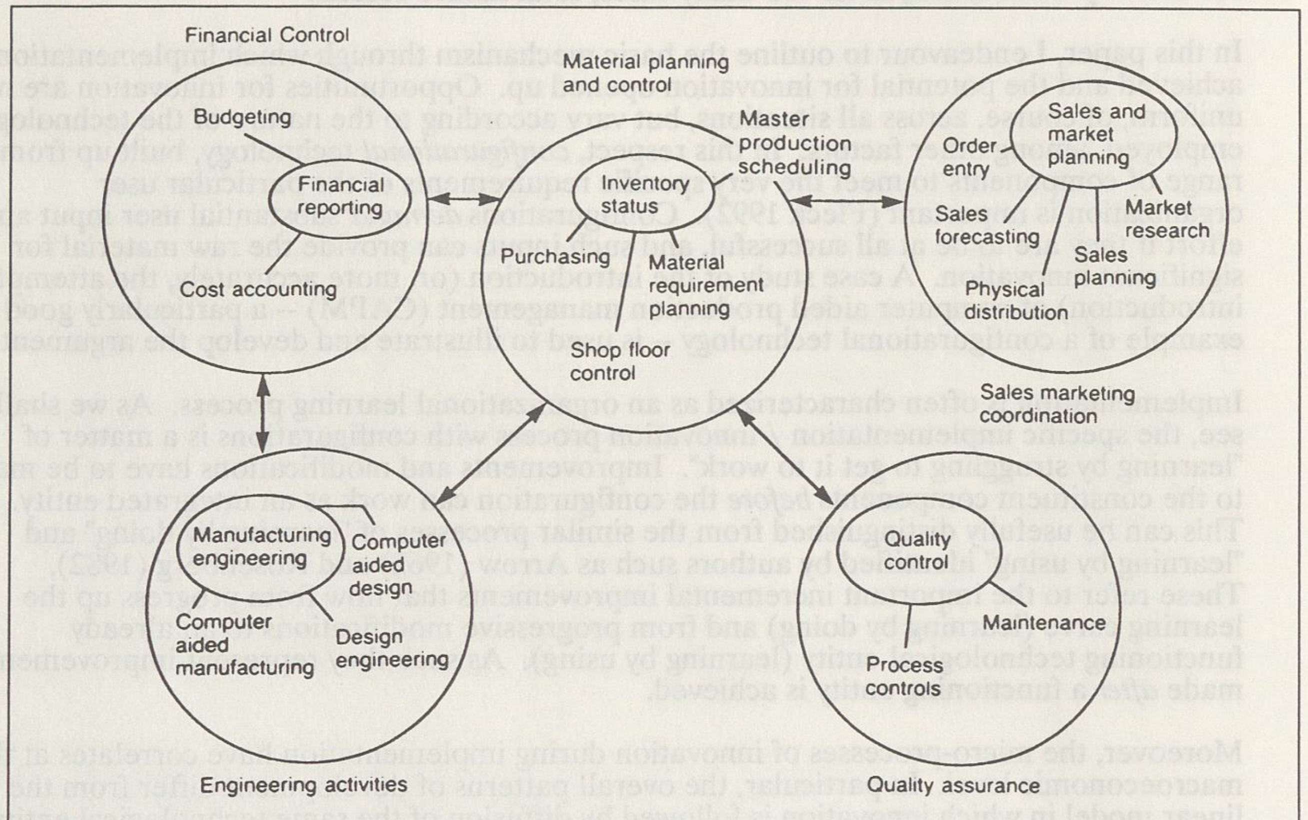

FIGURE 1: Schematic Overview of CIM (Source: Miller and Vollman 1985)

More extensive variants of these systems also provide facilities for capacity planning; i.e., for scheduling the use of manufacturing resources more generally -- including machinery and manpower -- as well as controlling material flows. These are usually termed "manufacturing resource planning", or "MRP II" for short (Schroeder *et al.* 1981). Figure 2 depicts the basic logic of such systems. Suppliers in this area typically offer a range of modules ostensibly designed to work together, each of which constitutes the computerization of a specific production task. We shall see some examples in connection with the case study addressed.

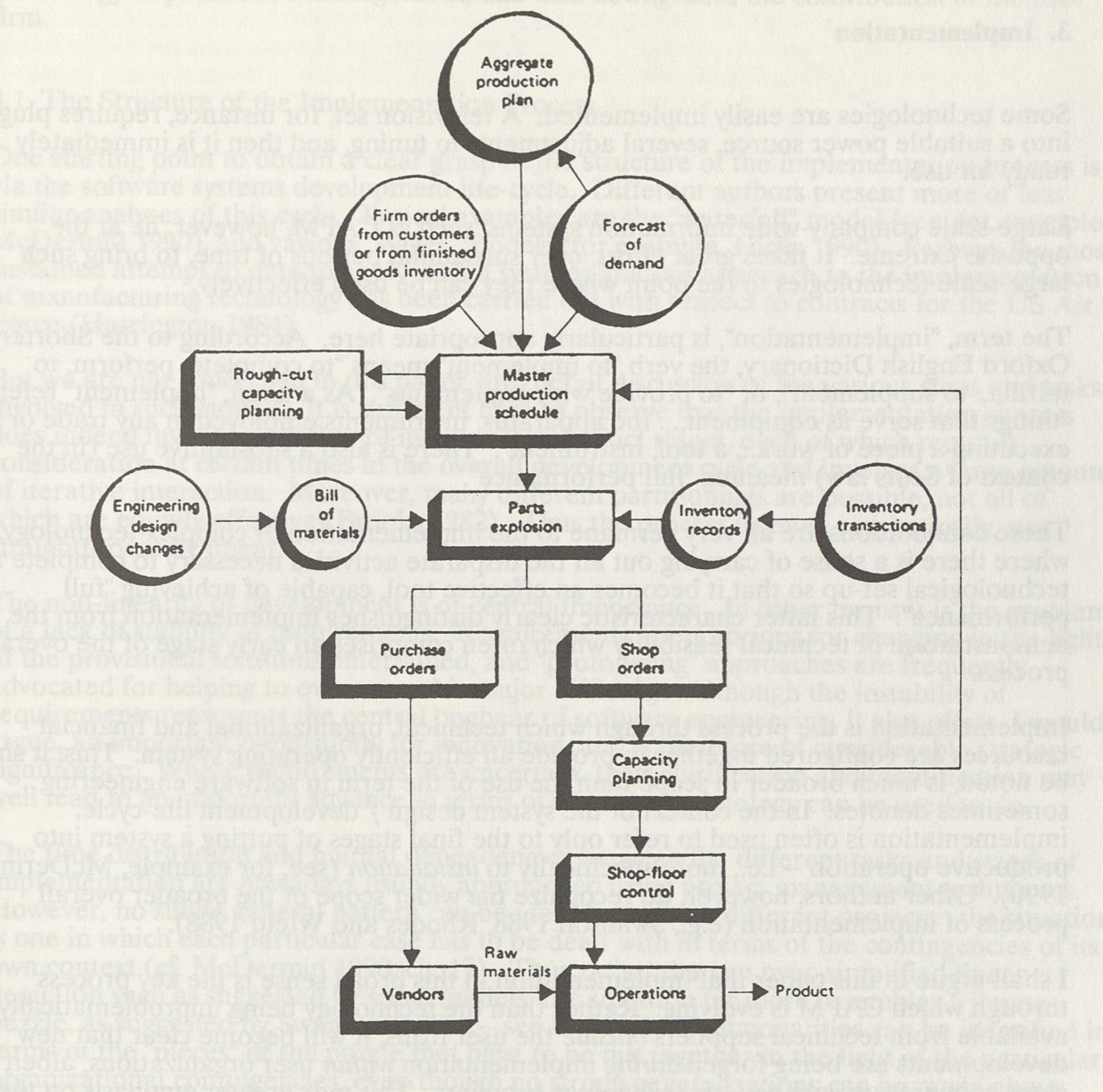

FIGURE 2: The Basic Logic of MRP II (Source: Schroeder 1989)

CAPM may be taken as referring to the deployment of computers in production management rather generally, with systems ranging from the employment of only one computer-based module (often a parts database) to any degree of complexity up to fullblown CIM.[1] CAPM systems (or rather configurations), therefore, may be made up of a varying range of particular software modules, selected according to the needs of the user companies. In the case study[2] discussed in this paper, attempts were made to implement components of MRP, and there were originally plans for the eventual development of a "grand system", covering more of the areas of CIM indicated in Figure 1.

3. Implementation

Some technologies are easily implemented. A television set, for instance, requires plugging into a suitable power source, several adjustments to tuning, and then it is immediately ready for use.

Large-scale company-wide information systems, such as CAPM, however, lie at the opposite extreme. It takes great effort, over substantial periods of time, to bring such large-scale technologies to the point where they can be used effectively.

The term, "implementation", is particularly appropriate here. According to the Shorter Oxford English Dictionary, the verb "to implement" means "to complete, perform, to fulfill,... to supplement"; or "to provide with implements". As a noun, "implement" refers to "things that serve as equipment,... the apparatus, instruments employed in any trade or in executing a piece of work... a tool, instrument". There is also a substantive use (in the context of Scots law) meaning "full performance".

These connotations are all very germane to the implementation of complex technology, where there is a sense of carrying out all the disparate activities necessary to complete a technological set-up so that it becomes an effective tool, capable of achieving "full performance". This latter characteristic clearly distinguishes implementation from the demonstration of technical feasibility which often comprises an early stage of the overall process.

Implementation is the process through which technical, organizational and financial resources are configured together to provide an efficiently operating system. This, it should be noted, is much broader in scope than the use of the term in software engineering sometimes denotes. In the context of the system design / development life-cycle, implementation is often used to refer only to the final stages of putting a system into productive operation -- i.e., more specifically to *installation* (see, for example, McDermid 1990). Other authors, however, do recognize the wider scope of the broader overall process of implementation (e.g., Swanson 1988, Rhodes and Wield 1988).

I shall argue in this paper that implementation in this broad sense is the key process through which CAPM is evolving. Rather than the technology being unproblematically available from technical suppliers *outside* the user firms, it will become clear that new developments are being forged *during* implementation *within* user organizations, albeit in close cooperation with generic technology suppliers. This puts greater emphasis on the crucial role of people *inside* the user firm and hence greater emphasis on the organizational

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[1] A good idea of the range of modules and systems included under the umbrella of CAPM is provided by a recent report on the SERC research initiative on CAPM (SERC 1991).

[2] The case I will discuss is drawn from an Edinburgh PICT project nearing completion -- the Organizational Shaping of Information Automation. One of the main aims of this project was to explore organizational influences on the development of examples of company-wide information technology automation. Consequently, we considered a range of different organizations using purportedly very similar technology, at least as far as basic functions were concerned. Broadly speaking this technology was CAPM.

structures within which and through which they operate. This helps to explain some of the particular features of the user-supplier relationships that may be observed, and also points up the strategic scope and creative opportunity that is in fact available to user organizations in this type of technology development. The resulting picture is more challenging, but, I believe, much more enlightening and promising than the conventional view. That view tends to see the situation in terms of the mere routine application of information technology to production management, and thus downgrades the contribution of the user firm.

3.1 The Structure of the Implementation Process

One starting point to obtain a clear grasp of the structure of the implementation process is via the software systems development life-cycle. Different authors present more or less similar analyses of this cycle. Typical examples are the "waterfall" model (see, for example, McDermid 1990), and various "stages" models (for example, Hicks 1990). Perhaps the most sustained attempt to date to apply such a systems analysis approach to the implementation of manufacturing technology has been carried out with respect to contracts for the US Air Force (Harrington 1984).

But we are not concerned in this paper with detail discussion of the various steps and tasks involved in such models. It is sufficient here to observe that the implementation process does indeed involve a number of more or less distinct stages, each of which requires consideration at certain times in the overall development cycle and involves a large amount of iterative interaction. Moreover, many different partitionings are possible, not all of which are equally effective (Brooks 1982). Thus the process is, most emphatically, not straightforwardly linear.

The non-linearity of development is of central importance. In other terms it is the problem of a lack of stability of requirements. Requirements are notorious for changing in the light of the provisional solutions entertained, and "prototyping" approaches are frequently advocated for helping to overcome this major difficulty. Although the instability of requirements represents the central bugbear of software engineering, it also offers, I would argue, an important opportunity for innovation, and is therefore of considerable strategic significance. Where requirements are uncertain, their clarification and identification may well lead to an important advance in terms of what the technology can be used to do.

The time distribution and mutual dependencies between the different tasks and stages of implementation are nowadays usually approached using project management techniques. However, no single general pattern can be identified across different projects: the situation is one in which each particular case has to be dealt with in terms of the contingencies of its own context (cf. McDermid 1990, ch. 17). Thus rather than an over-simplified linear depiction such as suggested by some models, the situation far more resembles a jigsaw puzzle, as suggested by Swanson (1988) -- see Figure 3. Commonalities can be identified in terms of the "pieces" of the puzzle that have to be put together in the light of the particular organizational contingencies, even though no strong generalizations can be made about sequencing or the overall pattern of dependencies. Learning how to solve the puzzle for a particular technology and organization constitutes the implementation process, and requires a variety of different sorts of expertise.

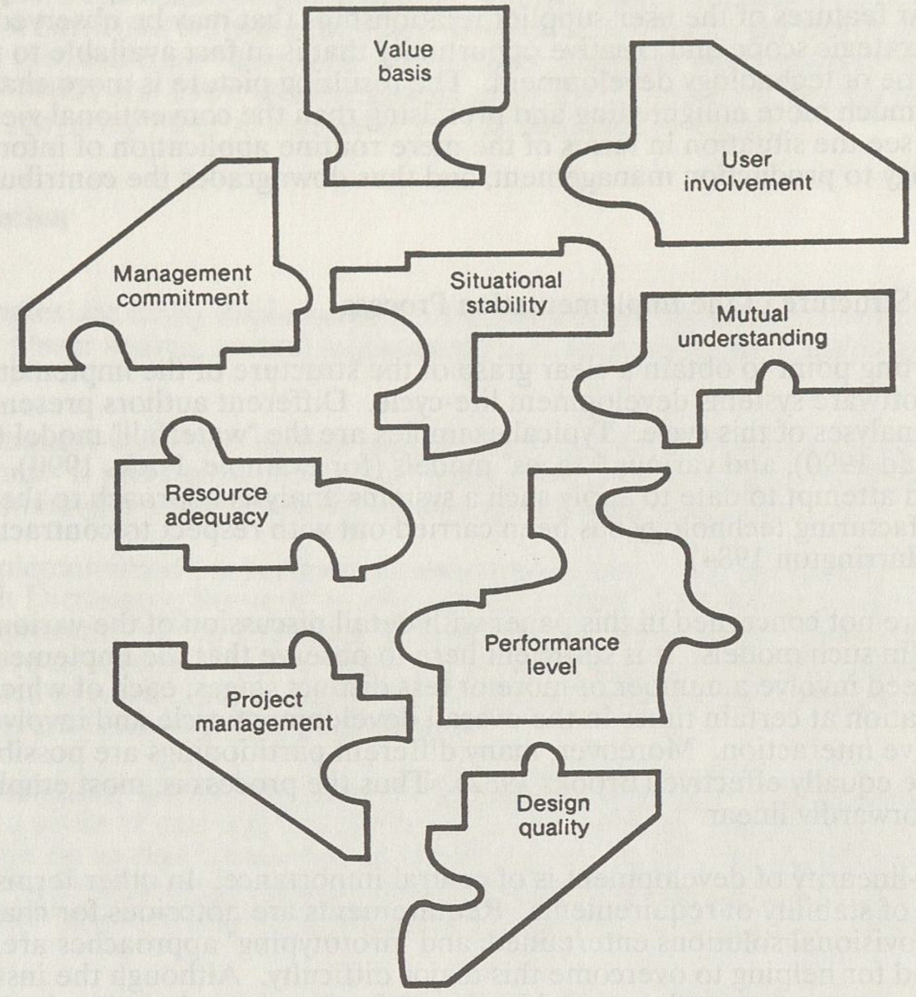

FIGURE 3: The Implementation Puzzle
(Source: Swanson 1988)

3.2 The Fundamental Implementation Equation

In terms of the essential inputs of expertise to the implementation process, we can usefully summarize the situation in a simple statement - the fundamental implementation equation:

successful implementation = *generic technology knowledge* + *local practical knowledge*

The local practical knowledge component is, of course, highly contingent to the particular firm concerned. It deals with the specific "knowledge base" (Georghiou *et al*. 1986), built up over many years of experience in carrying out the firm's business. Moreover, this local component is usually distributed among the many operatives involved in day-to-day activities. In many cases, this knowledge is *tacitly* embodied in skills and practices which have been gradually formed over a period, and are not available in any other centralized or formalized form. In such cases, therefore, users constitute the only available repository of the local knowledge component which might be essential for achieving successful implementation.

Large-scale, company-wide and even sector-wide configurations of technology are highly specific to particular operating requirements and environmental contingencies. In these cases, the right hand term of the equation, the local knowledge element, becomes a crucial source of innovation. Over a number of successful instances of implementation, local knowledge becomes more and more absorbed into generic knowledge; i.e., firm specific knowledge becomes appropriated by suppliers. At the same time, the generic technology becomes implemented in a form suitable for exploitation by the user.[3] As suppliers' experience accumulates over time and across a particular sector, the immanent possibilities for sector specific technology developments become thoroughly explored and progressively developed (indeed almost literally crystallized) into actual artefacts.

As this happens, the suppliers' understanding of specific requirements possibilities grows. Eventually in some cases, we move away from a situation in which more or less unique configurations reflecting local contingencies are important, to a situation where requirements are so clear and stable that standard or *generic* systems emerge. In these latter cases, development becomes more and more technically oriented, often in terms of defined efficiency or performance measures, and more and more in the hands of the suppliers. However, this is not an inevitable outcome. The variety afforded by configurations which continue to incorporate organizationally specific requirements and bodies of knowledge and practice, may *always* be a source of competitive positioning and differentiation.

Assembly line production technology is a case in point. While at one time it appeared that a stable system -- Ford's single product-dedicated, high-volume task-fragmented line -- had emerged, there were limitations intrinsic to the way in which less technical components, such as models of work organization (Williams 1988) and quality control were incorporated. This led to declining quality and productivity and increasing labour turnover. As a response, and precisely because of the configurational possibilities of the situation, various quite different configurations were explored: the Volvo Kalmar approach with autonomous working groups; the Toyota "jidoka" system; and Just-In-Time layouts such as U-shaped and parallel lines. These appear to be culminating in what the directors of the MIT International Automobile Study have dubbed "lean production" -- a radically different paradigm for manufacturing (Womack *et al*. 1990).

Just as with Schumpeter's famous dictum about the fundamental discontinuity between railroads and stagecoaches, there is no way that the lean production paradigm could be attained by merely adding in more high-tech automation or optimization algorithms -- as GM's fruitless and enormously expensive efforts in the 1980s have singularly demonstrated. Lean production is a radically different configuration of components, some common to the previous mass-production paradigm, and some peculiarly new.

Moreover, it is interesting to note that, in different industry sectors, markedly different recognition appears to be accorded to the relative value of the local and generic elements of the fundamental implementation equation.

In manufacturing industry, for instance, especially where mechanical engineering is concerned, the generic component appears to be the most highly valued, while the

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[3] This two way process of knowledge transfer is, of course, at the root of negotiations over the make-or-buy decision with respect to the supply and development of new technology.

suppliers dominate. Typically one finds that users pay royaltics to the suppliers for further use of the new implementations developed, even where they incorporate the firm's own local knowledge. The situation appears to be somewhat different in the financial services sector. Here the local, finance-specific component appears to be relatively highly valued. The balance of power lies more with the users, rather than the suppliers, and royalties flow to the user involved in the original development.[4]

It is an interesting question as to why this should be so. Is it the higher value placed on information as such in the financial services sector? Is it a greater degree of competition among suppliers? Is it the richness of the potential rewards in financial services? Or is it an indication of the relative novelty of technology development in financial services compared with manufacturing?

4. Case study: Company B

Company B was a large diversified engineering company, with historical roots in Scotland and a range of activities around the world. The part of Company B with which we were concerned covered two different sites. One site, employing 500 people, manufactured two major product lines, initially as two separate business divisions, though latterly moving towards integration. The first involved the assembly of large heavy electrical transformers with some minor fabrication work (for the outer casings). These products were all one-offs, made to contract, although the generic structure of each transformer (core, windings, insulating oil, outer casing, connection gear) was essentially standard and really quite simple. The precise rating and characteristics of each transformer, however, had to be individually calculated for each customer's requirements: for example, different lengths of copper had to be wound on to steel laminate core material, precisely cut to dimension.

The second product division on the first site manufactured and assembled two ranges of heavy electrical motors (for compressors etc.). These were also made as one-offs to customer order. Again the generic product structure was relatively simple. Only some 20 basic parts were involved, along with many small bits and pieces bolted on. The products were customized to provide specific operational and torque characteristics.

The second site, employing about 300, manufactured a range of lighter duty transformers. These were similar in structure to the big transformers made at the other site, and were manufactured using much the same process, but tended to be made in small batches, rather than as one-offs.

In all cases, the production processes throughout were almost entirely manual. Many semi-skilled / unskilled women and men were employed, the latter doing some of the heavier lifting tasks. A few specialist machines were used for numerically-controlled mitre cutting of steel laminates, and ovens were used for eliminating moisture from the windings. The low-volume, high-variety production profile essentially precluded a high level of manufacturing automation.

In the early 1980s, the company decided to introduce a large MRP II system. This system -- comprising the modules illustrated in Figure 4 -- was supplied by a large American computing concern (which we shall call "Supplier C"). It is recognized in the text book literature as a standard (out of the 200 or so systems available). Moreover, this particular system (let us call it SCMRP, short for Supplier C's MRP) was explicitly modelled on the MRP guru "Ollie" Wight's recommendations. Wight has claimed trenchantly that it is a misconception that:

> "Each company requires a unique "system" designed for them to solve their unique problems. In practice the problems of scheduling a factory, scheduling the vendors, and coordinating the activities of marketing, engineering, manufacturing and finance are not particularly unique company to company. There is a standard logic for MRP, and we have yet to see a company that had to reinvent this logic, or for that matter, one that tried to reinvent it and made it work." (Source: Newsletter from Oliver Wight, 1977 - quoted in Schroeder 1989).

This makes our case particularly interesting. According to the above, and in light of the standard nature of the MRP system adopted, it should provide a test case for the straightforward *standard installation* of such systems, rather than anything approaching the innofusion model outlined above.

What do we find?

The process of implementation of the SCMRP system was a sorry tale of almost unmitigated disaster.

First, as was clear from the various and sometimes contradictory views expressed in our interviews, there was evident confusion and uncertainty about the scope and intent of the original system. For instance, top management (the Financial Director) appeared to envisage a very large scale system, integrated across both sites, and all divisions. But in actuality, development took place at individual site level. Moreover, this confusion appeared to have resulted in too big and sophisticated a system being purchased; one suitable for the turnover of the company as a whole, rather than the turnover of the separate sites - the actual level for application.

The confusion was further compounded by the usual sorts of local company politics:

> "the Computer Services Manager went out the door. Unfortunately he went out the door with most of the knowledge of the system because he hadn't written anything down. He left no records. He instructed his people to destroy everything, so I came into a department with no written knowledge." (Interview, Computer Operations Manager, Company B, 1989)

Second, each site in fact evolved its own distinct approach to implementation (perhaps further reflecting tensions between managers on the different sites). In particular, as indicated in Figure 4, each site made use of a quite different selection of the available modules of the overall system, clearly revealing the configurational nature of the technology.

Third, originally a grand integrated system combining separate packages for computer-aided-design (CAD), MRP II, and a Financial System was envisaged (again, it would appear, by the very top management). But, although these packages were all supplied by the one company (who also supplied the computer mainframe), it turned out they could not communicate with one another, although the suppliers "knew where all the hooks were" to link them up. Indeed at a very early stage, apparently (it was very difficult to establish conclusively precisely what happened because of the prevailing uncertainty), the supplier

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[4] This contrast was possibly one of the major findings from an associated research project on innovation in the financial services sector -- Strategic Innovations in the Financial Services Sector: The management of Computing Expertise. The results for this project are currently being written up (Fincham *et al.* forthcoming).

was going to develop a drawing office management system specifically to mediate between the CAD and the MRP II packages. This was to be designed specially for Company B, using them as the "guinea pig", in consideration of which they would get the work done free. However: "some of the people in Supplier C moved on to other places, time passed etc.", and this never came to anything.

In the event, some elements of the CAD package were implemented, albeit to differing extents in the drawing offices for the machines and for the transformers (though Company B claimed that it already had better in-house programs). Only a few of the MRP II modules were ever used, as already noted above, and the accounting package was abandoned:

> "efforts were being made to implement [the accounting package], the Ledgers system. It was just foundering. So one of the first decisions I made, it really stopped, there was nothing being done, so I decided because this system was horrifically expensive, and maintenance was more than if we bought a new accounting system every year and threw it away. The maintenance was colossal and we were spending all this money on maintenance on a system we couldn't use. So I took [the package] off the system altogether and I cancelled the maintenance on it. I decided it was just outwith our capabilities. We would look for a system that was manageable, even maybe a PC-based system". (Interview, Computer Operations Manager, Company B, 1989)

Fourth, several major problems were encountered in trying to get the system into operation:

(a) The package as designed could cater for integer units in the Bill of Materials (essentially the structure of related parts making up the product), but could not easily cope with measured parameter variation -- so many metres of winding, such and such a volume of oil, etc. Yet these were crucial for the customized manufacturing operation in which the company was engaged. Different products designed for particular customers differed not in their generic structure, but in the amounts and distribution of materials used, which provided the distinctive operating characteristics required.

(b) The package as offered ostensibly contained a "contract traceability" function. This was essential given the make-to-contract nature of the business carried out by Company B. In particular, materials traceability was required by the Ministry of Defence. But it became apparent in the development process that this function did not work properly. The suppliers had developed the system and used it widely in their own operations, where they had also tested it. But their own manufacturing environment was make-to-stock, and consequently they had not used the contract traceability function before in the quite different make-to-contract environment. Again, therefore, it appeared that Company B were the unwitting and unlucky guinea pigs.

(c) During the commissioning of initial modules in Company B, all sorts of major system bugs came to light. According to the MRP Project Manager, there were over 100 major faults. The time taken to fix even the most trivial faults was 9 months to a year, and sometimes the suppliers took no action. As a result, Company B had to take its own action -- in some cases (at the one site where they had the expertise) going into the source-code themselves and reprogramming it; in others fixing in "patches" received from the supplier (which was US-based, as noted). Yet this package was reputedly a standard product some 10 years old!

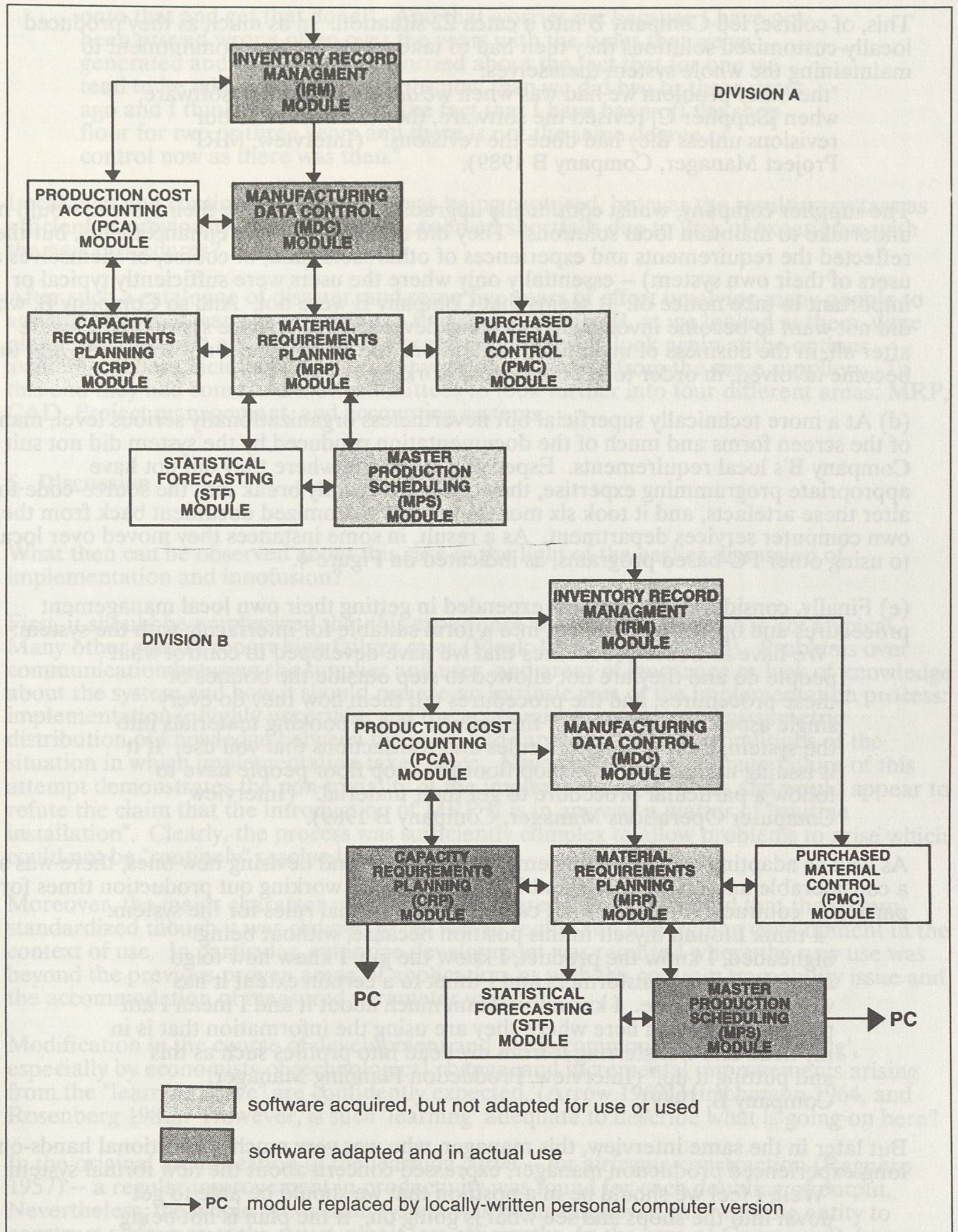

FIGURE 4: Company B CAPM Configurations

This, of course, led Company B into a catch 22 situation. In as much as they produced locally-customized solutions they then had to take on an ongoing commitment to maintaining the whole system themselves:

> "the other problem we had was when we *did* customize the software, when [Supplier C] revised the software, they did not revise our revisions unless they had done the revisions." (Interview, MRP Project Manager, Company B 1989).

The supplier company, whilst continually upgrading and enhancing their system, would not undertake to maintain local solutions. They did regularly provide enhancements, but these reflected the requirements and experiences of otherusers (and, of course, of themselves as users of their own system) -- essentially only where the users were sufficiently typical or important to take notice of. It seems that Company B were not. And so Company B, who did not want to become involved in extensive development of these systems (they were after all, in the business of manufacturing motors and transformers not software), *had* to become involved, in order to get the system working.

(d) At a more technically superficial but nevertheless organizationally serious level, many of the screen forms and much of the documentation produced by the system did not suit Company B's local requirements. Especially at the site where they did not have appropriate programming expertise, they could not readily break into the source-code to alter these artefacts, and it took six months to get a customized document back from their own computer services department. As a result, in some instances they moved over locally to using other PC-based programs, as indicated on Figure 4.

(e) Finally, considerable effort was expended in getting their own local management procedures and operating practices into a form suitable for interfacing with the system:

> "We have in-house procedures that we have developed to control what people do and they are not allowed to step outside the bounds of these procedures; and the procedures tell them how they do every single aspect of their part of the system. If it is booking materials into the system, there are certain rules and transactions that you use. If it is issuing materials to the shop floor the shop floor people have to follow a particular procedure to get their material." (Interview Computer Operations Manager, Company B 1989).

As well as adapting existing management procedures and devising new ones, there was also a considerable amount of contingent knowledge about working out production times for particular contracts which required capturing into formal rules for the system:

> " I think I found myself in this position because, without being bigheaded, I know the product, I know the job, I know how to go about building transformers and I think to a certain extent it has worked against me. I know too damn much about it and I mean I am put into a position here where they are using the information that is in my head and transferring it from my head into profiles such as this and putting it up." (Interview, Production Planning Manager, Company B, 1989).

But later in the same interview, this manager, who was very much a traditional hands-on long-experienced production manager, expressed concern about the new formal system:

> "Well, I feel we should be in a position that we should be able to get down into the shops and see what is going on. If the plan is not being followed or work out, we should be in a position to say 'hey, look what have you got that guy on that job for? Get him off that and get him onto that and get that done!'. And that worries me because I have not been proved wrong often over the years with the times that we've generated and I get a wee bit worried about the fact that for one we tend to be taking longer to do jobs now than we did two or three years ago and I think that is down to the fact that I have been off the shop floor for two or three years and there is not the same degree of control now as there was then."

Local tacit and contingent knowledge was being captured, but was the resulting system as efficient as previously, or were are the observed shortfalls due to lack of experience with the new procedures?

After such a catalogue of disaster, and some five years of effort involving many people to varying extents, it was not surprising to find that Company B, as we looked at them, were planning to pull out all vestiges of the grand system and to look again at the options available. These included a smaller network-based system from the same suppliers. To this end they had convened four committees to look further into four different areas: MRP, CAD, Project management, and accounting systems.

5. Discussion

What then can be observed about this case in the light of the earlier discussion of implementation and innofusion?

First, it should be emphasized that this experience with implementation is *not* atypical. Many other studies report high failure rates (Fleck 1984, Bessant 1986). Problems over communication between the supplier and user, and areas of ignorance or lack of knowledge about the system and how it should run are an intrinsic part of the implementation process: implementation *is* highly uncertain, and the economic separation and asymmetric distribution of knowledge between the users and suppliers are basic conditions of the situation in which implementation takes place. Nevertheless, the ultimate failure of this attempt demonstrates the non-triviality of the implementation process and would appear to refute the claim that the introduction of MRP II is in any way a matter of "routine installation". Clearly, the process was sufficiently complex to allow problems to arise which could not be "routinely" resolved.

Moreover, the major character of the bugs discovered clearly indicated that the system, standardized though it was claimed to be, was in reality still undergoing development in the context of use. In particular, extensive development was required where the new use was beyond the previous proven arena of application, as with the contract traceability issue and the accommodation of measured parameter variation.

Modification in the course of development and use is commonly termed 'learning', especially by economists of technological change, and incremental improvements arising from the "learning curve" are confidently expected. (Arrow 1962, Hirschmann 1964, and Rosenberg 1982). However, is such 'learning' adequate to describe what is going on here?

In the original identification of the learning curve -- for airframe construction (Reguero 1957) -- a regular improvement in productivity was found for each doubling of output. Nevertheless, the whole production system was being employed as a working entity to construct airframes *at the outset*, albeit less efficiently. In the case of Company B, however, the learning was clearly more painful and uncertain. Rather than fine tuning an already working system, the company "learnt" that the system was not going to work for it within reasonable constraints. And the supplier "learnt" how it might extend and improve its system for future use, even though this particular application ended in failure. This is a more fundamental process of learning, much more like the trial and error nature of genuine experimentation than the secular accumulation of improvements in carrying out essentially the same activity.

In a seminal paper, Rosenberg has also discussed processes of "learning by using" as "a separate category of learning that begins only after certain new products are used" (Rosenberg 1982, p. 122). He argues this category of learning can deliver considerable economic benefit (for example by enabling "stretched" versions of airliners to be developed), and suggests that it is associated with a high degree of system complexity, as is characteristic of much software development. However, in the present case and many other examples of implementation, the state of actual *use* was never in fact achieved. We do not have in this particular context a case in which incremental improvements are made to an *already functioning* production entity through learning by using, either in embodied or disembodied forms (Rosenberg 1982). A fully functioning entity -- i.e. a viable *configuration* meeting the requirements of Company B -- was *never* achieved, even after five years of effort. Possibly the company might subsequently go on to achieve success with an altogether different configuration, having learned many lessons in their first painful adventure. But it seems clear that there is a significant difference in this type of learning from that identified by Rosenberg, or from Arrow's "learning by doing" (which was essentially intended to capture the industrial learning curve phenomena).

Furthermore, in Company B significant innovation was quite clearly required to integrate the CAD, the MRP and the Accounting packages. Its significance was pointed up by the fact that it simply did not take place, with the result that the envisaged "grand" system never came anywhere near fruition. Indeed, as indicated in Figure 4, even most of the component modules of the SCMRP package itself were never fully used. It required specialist effort to get the modules to communicate with each other (although they were supposed to be designed to make this easy), and considerable effort to get them to interface with the actual contingencies of production. In the face of all the other difficulties encountered, this was, in the end, too much development effort for Company B to sustain.

Nevertheless, important learning effects did take place at a number of levels. There *was* considerable progress in the more precise definition of component details on drawings, partly catalyzed by the demands of the SCMRP system, but also necessary due to the high degree of subcontracting in Company B. New management procedures *were* evolved for obtaining disciplined use of raw materials and preserving the integrity of the stores. New procedures for inventory management *were* instituted, including the standardization of a system for part numbering, which replaced the two previous informal incompatible systems (one from accounting and one from engineering). Likewise, the Bills of Materials were reconciled, an achievement which made use of a novel approach whereby the engineering drawings themselves of particular subassemblies were included as distinct parts in order to simplify the overall structure of the Bill of Materials. Most of these learning effects, moreover, could be retained as useful for the implementation of a different system, a more suitable configuration. Overall, it could be observed that the company had learned much about the implementation process itself, especially about effectively implementing an MRP system. In particular, the company had learned, of course, that the original SCMRP system was not suitable for its specific operating conditions.

But these learning processes, to reiterate, are distinct from either Rosenberg's "learning by using" or Arrow's "learning by doing". What we have here is a matter of "learning by struggling to get it to work". This does not merely involve fine tuning to obtain incremental improvements in the operations of an already functioning system. More fundamentally, it involves the construction and development of new viable systems, or rather configurations, in the first place. As such it represents, I would suggest, a potentially more radical form of learning, of innovation, in that on occasion novel configurations with great economic scope can emerge.

We can see the process of innofusion operating in this case. Company B did not achieve an immediate, overall successful outcome. But they did develop certain components (new management procedures, a unified parts numbering system, and some PC-based modules) and had gained valuable experience. With these, they could build a new configuration: one more likely to be better matched to their specific requirements and therefore to be successful. Supplier C for their part, had gained valuable information from this (failed) experiment in the great laboratory of real industrial life. They had probed the limits of satisfactory operation of their SCMRP system and, with what they had learned, were in a stronger position -- if they so wished -- to make further developments to extend its scope to cover parameter variation and contract-traceable applications.

With respect to the quotation by Ollie Wight, it may be observed that he is probably right as far as the basic *logic* of the manufacturing process is concerned. But a real operating system is about a lot more than the intrinsic logic of production and material flows. It is also about systems that can be used effectively by existing organizations, given the limited resources of expertise and manpower available to them. This includes, of course, the provision of appropriate interfaces to the production people, and to the existing production process itself. And this certainly is something that is more or less unique to each organization.

At the present time in Company B, the fabrication of transformers and motors depends on their accumulated experience of actually building such products, with specific requirements for contract traceability and parameter variation. These factors provide the local specific terms in the fundamental implementation equation. Putting this knowledge together with generic knowledge about CAPM technology to achieve successful implementation remains a creative challenge. It is one in which a significant part of development and learning -- i.e., the *innovation* process -- takes place *within* implementation itself.

6. Conclusion

In this paper, I have argued that innovation during the process of implementation is to be expected in the development of working configurations of CAPM, and that this analysis can help to make sense of events even in a case where attempts to employ a particular "standard" system met with almost total failure. In conclusion, the following summary observations, oriented to policy considerations, can be made:

1) CAPM can be regarded as a configurational technology where each working configuration is made up of a particular selection of components, geared to the needs of the individual organization.

2) Although particular elements, such as a materials requirements planning module, can be individually employed, it is their incorporation as components into wider operating configurations which ultimately determines their degree of success.

3) All components are potentially of importance, not just the purely technological ones, and certainly not just high-tech developments. Bodies of management procedures and local knowledge, encapsulating organization and product specific contingencies and arrangements, are essential for the effective operation of CAPM configurations. Indeed, they comprise distinct non-technical components of the overall operating configuration.

4) Existing "old" technologies and conventional practices may continue to be important via their incorporation into emerging configurations -- as for example with the incorporation of engineering drawings as "parts" in the Bill of Materials.

5) A high variability among configurations of CAPM is therefore to be expected, and reflects the relative importance of organizational and market contingencies, rather than universally-defined technological trajectories. This was nicely illustrated by the different configurations adopted by the two divisions of the case study company.

6) The uncertain and evolutionary nature of the configurational development process implies a great amount of implementation effort within the user Organization. It also gives rise to opportunities -- indeed, on occasion even the necessity -- for innovation during the implementation process itself. In the absence of such innovatory effort, failure is likely to result -- as happened in the case considered.

7) Substantial involvement in development on the part of users is consequently necessary to make the most of these opportunities. The value of the local knowledge held by users should be recognized as crucial for successful implementation, not least by the users themselves.

8) Successful suppliers of configurational technologies are likely to be those who recognize implicitly, if not explicitly, the need for a synthesis of global technological knowledge with local process knowledge. They are also likely to adopt appropriate methodologies for effectively coordinating supplier and user efforts in implementation.

9) Nevertheless, particularly with smaller user companies who lack the confidence to value their own local knowledge and who lack the expertise to handle certain aspects of the generic knowledge (such as rectifying software faults), there will be an information asymmetry. This is likely to be exploited by suppliers, a tendency exacerbated by the one-off nature of many company-wide implementation programmes, althogh mitigated by the need for long-term interaction which limits the scope for such opportunism.

10) Policy measures need to address these realities. Initiatives should aim at encouraging the overall industrial sector-based learning process, by facilitating mobility of personnel, by providing avenues for the negotiation and formation of standards, and by encouraging user participation at all levels, from top management to the shop floor. Other measures should aim at reducing the costs of experimentation and at communicating the results, both positive and negative, of such experimentation as widely as possible, especially with respect to small and medium sized companies. In short, policy formulation should recognize that, in the case of the development of configurational technology, industry is the laboratory.

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