

An Investigation into manufacturing Technology Sourcing Practices

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Introduction

Over many years the literature has given particular attention to product sourcing and the associated relationship between a manufacturing company and its component supplier; see for example Higgins (1955), Buchowicz (1991) and Bruck (1995). There is, however, a second set of sourcing decisions that occurs in companies, and that has been almost completely ignored by the literature. This is the area of manufacturing technology sourcing. These sourcing decisions are concerned with the origins of the equipment used within a factory to produce products.

Within the literature that does exist on manufacturing technology sourcing, an interesting distinction has been casually observed between Japanese and US manufacturers. Some Japanese companies have a much greater involvement with the specification, design and manufacture of their production technologies than do their equivalent US manufacturers. Such distinctions have, in recent years, led to major changes in the practices of Western-based manufacturing companies. Therefore, in the ongoing search for ways to improve the performance of manufacturing companies, it is valuable to understand the practices of US manufacturers and whether these practices can be improved. The present paper describes such a study carried out by the authors.

This study has revealed a number of interesting conclusions. Primarily it has reinforced the view that American companies usually prefer to buy rather than make their production equipment. Indeed, some companies have divested from equipment manufacture as part of a process to regain business focus. In contrast, a small selection of companies are vertically integrated into the technology source. They believe that such an approach can make a difference to the performance of the resulting technology. Furthermore, even in the companies that prefer outsourcing policies, competitive pressures may force them into greater involvement with equipment manufacture than they would like. This tends to occur in instances where there is a reliance upon unique manufacturing capabilities for the competitiveness and differentiation of products. In these cases, integration into equipment manufacture may be the only sustainable policy in the long term.

Background

Technological change is one of the principal drivers of competition. Technology affects competitive advantage and industry structure, and can worsen as well as improve a firm's competitive position (Porter, 1985). Competent technology management is frequently a crucial element in the success of a firm. Skinner (1985) argues that a persistent pattern seen in the autopsies of the major operating crises of large corporations, and of the final failures of small companies, is the inability of one or more key managers to understand and manage the technologies of their business. Technology strategy is a firm's overall approach to the management of technology (Porter, 1985). Samson (1991) notes that technology strategy involves acquiring, managing and exploiting product and process technologies which are consistent and supportive of a firm's business strategies.

In the present paper we will exclusively consider one element of technology strategy, namely the sourcing of manufacturing process technologies. We define such technologies as the physical manufacturing processes, methods, techniques, tools and equipment by which products are made or services rendered. The manufacturing technology sourcing decision is concerned with the extent to which a company is involved with the specification, design and manufacture of a new production technology. This particular sourcing decision has received little attention in the literature. However, every company makes a manufacturing technology sourcing decision whenever a new production facility is acquired.

Fine & Whitney (1996) are two of the few authors that have investigated manufacturing technology sourcing practices. In their work they have noted a contrast in the behaviour of Japanese and US manufacturers. They have observed that some Japanese companies buy many of the components that go to make up their products, and they

themselves manufacture much of their own production equipment. Fine and Whitney give a principal reason for this being that the Japanese manufacturer believes that "you learn by trying not by buying".

In contrast, a recent emphasis in American industry has been a focus on core competencies and a divestment of non-core activities. In many companies, technology manufacture is seen to be one such non-core activity, causing a time and resource distraction from the core business. For example, Giffi (1990) is critical of top management teams that attempt to save a few dollars by "...doing it ourselves". They therefore favour outsourcing, applauding Motorola for having a formal policy of "do not create what already exists somewhere else". Such an approach does, however, rely on a technology to already exist elsewhere, and there to be no additional benefits from an alternative design. Fine and Whitney sum up this situation succinctly by suggesting that a US manufacturer would argue that "our business is cars, not robots".

Fine and Whitney do submit, however, that their work is based on observation and speculation. They recommend that research should investigate this contrast in more detail. On this basis, a valuable contribution to this research area is to understand more thoroughly the behaviour of US-based manufacturers. In particular, it would be beneficial to know what are the common manufacturing technology sourcing practices, and how and why such practices are adopted.

The Research Process

The aim of the research reported in the present paper has been to carry out a study that explores and describes manufacturing technology sourcing practices within US-based organisations. In particular the following questions have been addressed:

1. What manufacturing technology sourcing decisions do organisations actually practise?
2. Are these sourcing decisions conscious intentions?
3. How are these sourcing decisions formed?
4. What factors feature in a rational process of forming sourcing decisions?

The inquiry method has been to carry out a series of short case studies at a range of US-based manufacturing plants. The case study methodology has been adopted from Yin (1994), and in all, 14 plants have been studied. These plants have been chosen from a range of sectors which include automotive, motorcycle, aerospace, construction and agricultural sectors.

In each plant, recent technology acquisitions have been studied. The researchers entered each plant with a proposition and an associated data collection protocol that guided the investigation. Each case study has sought to describe the sourcing decision chosen, how the decision was formed, the rationale that has supported the decision, and the organisational context. Cross-case analysis has then been carried out. This has identified the favoured practices, how policies are generally formed, and the range of factors that can influence the choice of a technology source.

The propositions used for the first three research questions deserve a brief description, and this is given in the remainder of this section.

Possible Manufacturing Technology Sourcing Decisions

Yin (1994) advocates that the researcher should have a proposition of the form of the phenomena under study to act as a guide to data collection. therefore, it is necessary to speculate the types of manufacturing technology sourcing policies that may exist, along with the methods through which they may be formed. On this basis, a company may choose to be involved to a greater or lesser extent in technology specification, design and construction. We have broadly defined the technology sourcing options available to a company as:

1. Choose technology from supplier specification.
2. Develop technology specification with a supplier.

3. Develop technology general design with a supplier.
4. Develop technology detailed design with a supplier.
5. Construction of technology in-house.

For each technology acquisition investigated, the researchers attempted to describe the chosen policy in these terms.

Possible Forms in which a Manufacturing Technology Sourcing Decision may Exist

The previous subsection has considered the technology sourcing option available to a plant. It is also important to explore the possible forms in which a sourcing decision may itself exist. To do this a parallel may be drawn with the strategy literature. Mintzberg (1987) argues that intended strategy refers to a formal intention, whereas an emergent strategy can be observed when a non-intentional pattern can be recognised in past actions. Therefore, as a strategy may be defined as a pattern in a stream of decisions, it is also apparent that both an emergent and non-intentional decision can be recognised in past actions. This intended and emergent distinction may be used when seeking to identify the form in which a manufacturing technology sourcing decision exists in a manufacturing plant. A decision outcome may be explicitly declared and can be referred to as intended policy.

Processes by which Manufacturing Technology Sourcing Decisions may be Formed

The process refers to the mechanism through which a decision is formed in an organisational setting. The term decision process is often only associated with a formalised decision-making activity. If such explicit processes exist in an organisation they are likely to be documented and self-evident. However, less obvious forms of decision making may exist. For example, Mintzberg et al. (1976) investigates unstructured processes where a rationale process is apparent in hindsight. Such a situation may exist when personnel in a company are forming a sourcing policy in the action of acquiring a new production facility. On the basis of empirical work, Mintzberg has developed a flow diagram that illustrates in detail the activities that may occur in an unstructured decision-making process. Using this flow diagram as a guide, the data collection protocol has been designed to explore the activities that may occur if a policy is formed by an unstructured decision process.

A decision may be formed by other methods that seem to be less rationale, for example where a decision is made through emotion, tradition, beliefs etc. Similarly, a decision process may appear to be absent or external to the particular situation being studied. Such a situation occurs when operational managers in an organisation are presented with a policy that has been formed by an interventionist chief executive officer.

On this basis, at least three decision processes may occur to form technology sourcing policies in an organisation. These are as follows:

- Formalised: explicit and documented decision-making process.
- Unstructured: rationale for making decisions apparent in hindsight.
- Evolutionary: process apparently absent. Decision formed by emotion, tradition, beliefs, or decision given from outside.

In each case study the researchers have sought to document the predominant decision process used in forming the manufacturing technology sourcing decision.

Overview of Research Findings

This section is structured as follows. In the first subsection the actual practices observed at plants are discussed; the following subsection considers whether these policies were intended or emergent. The third subsection examines the methods through which policies were formed, and the final subsection presents the motives that featured in the decision process.

The research method has been applied at 14 manufacturing plants. To enable this industrial research, and to ensure future cooperation with researchers, the identities of the companies involved have been protected. Therefore, no

reference will be made to companies individually; they will be referred to as plants 1-14. However, a number of companies were exceptionally helpful in this research, and we wish to acknowledge the help of the staff at CASE, Caterpillar, Ford, Foxboro, Harley Davidson, Honda, McDonnell Douglas, Nypro, Pollak, Teledyne Laars and United Electrical Controls.

Manufacturing Technology Sourcing Practices Observed

A summary of the predominant practices at the plants studied is given in Table 1. As illustrated here, there was indeed a preference amongst the US-based plants to limit their involvement with specification, design and manufacture of their production equipment. The predominant practice was to be involved with the specification of a technology, but then to outsource design and manufacture. Some exceptions to this practice did exist. One plant regularly became not involved with the manufacture. As will be discussed further below, this was an intended policy within this organisation. Two other plants became unintentionally involved with technology manufacture, as this was the only way they could acquire an important technological capability. Only one plant became fully and intentionally involved with technology manufacture. Intriguingly, although this was a US-based plant, it belonged to a Japanese corporation.

	Choose Technology from Specification	Develop Technology Specification	Develop Technology General Design	Develop Technology Detailed Design	Technology Construction	Total
Frequency of Practice	14 (all plants)	8 (plants 2,3,5, 6,7,8,13,14)	4 (plants 2,3,6,14)	3 (plants 2,3,6)	3 (plants 2,3,6)	—

————— Extent of integration increasing —————>

TABLE 1. Manufacturing Technology Sourcing Practices

These findings lead us to confirm that US plants tend to have some independence from suppliers for knowledge about the design of their technology, but are totally dependent on outside resources for technology construction. On this basis, a contrast between the US and the Japanese has again been seen to exist. Furthermore, two additional issues are apparent for the companies studied. First, there is a trend for a progressive increase in the extent of outsourcing, from the activities of technology specification through construction. Second, the extent of vertical integration varies across technologies within a plant. Where complete vertical integration did occur, it was only for specific technologies.

Form of the Manufacturing Technology Sourcing Decision

The technology sourcing decisions exhibited by the plants were of various forms, as illustrated in Table 2. Only six of the plants studied had made explicit decisions about their involvement with specification, design and manufacture of their technology. Intriguingly, although six conscious policies existed, there was no consistency. For example, one automotive manufacturer intended not to be involved with the design and manufacture of equipment, whilst a second chose to be fully integrated. These intended sourcing policies existed where manufacturing capabilities were somehow instrumental in differentiating a product in the market. Indeed, there appeared to be a direct relationship between the role of manufacturing capabilities in a business and the existence of an intended manufacturing technology sourcing policy. Four companies had intended policies to avoid involvement in technology design and manufacture. However, in two instances the companies were forced into technology development. Again, this occurred where manufacturing capabilities were very important to the business. Here, the technology sourcing policy conflicted with the desired role for manufacturing in the business strategy of these companies.

Decision Form	Choose Technology from Specification	Develop Technology Specification	Develop Technology General Design	Develop Technology Detailed Design	Technology Construction	Total
Intended Policy	No plants	2 (plants 5,7)	1 (plant 14)	No plants	1 (plant 6)	4
Combined Intended and Emergent	1 (plant 4) (further integration forced)	1 (plant 13) (further integration forced)	No plants	No plants	No plants	2
Emergent Policy	5 (plants 1,9,10,11,12)	1 (plant 8)	No plants	No plants	2 (plants 2,3)	8

TABLE 2. Form of Manufacturing Technology Sourcing Decisions

On this basis, it is apparent that intended sourcing policies do exist where manufacturing capabilities are instrumental in differentiating a product in the market. By contrast, technology sourcing decisions may have an emergent nature where the manufacturing capabilities predominantly have a limited influence on product competitiveness. Hence, there does appear to be a direct relationship between the existence of an intended policy and the role of manufacturing capabilities in a business. This relationship can be illustrated graphically, as shown in Figure 1. This figure shows how the awareness of a technology within an industry can change over time. For example, in the early 1970s Computer Numerical Control (CNC) technology was emergent and few applications existed, but today this technology is pervasive throughout manufacturing industry. This figure also shows our view of the relationship between technology life cycle and the form of a technology sourcing policy.

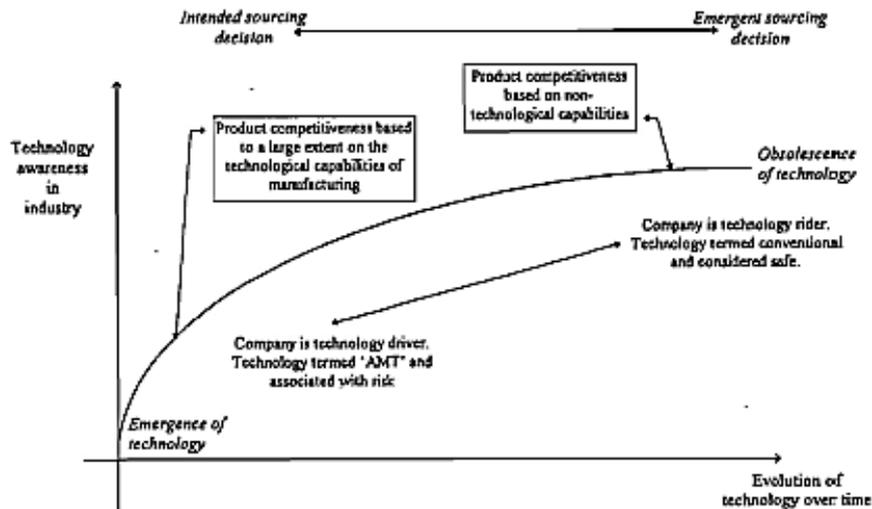


FIGURE1. A Relationship between Manufacturing Technology Life Cycle and Sourcing Decision.

Methods through which Decisions were Formed

The decision processes that were practised are shown in Table 3. There was a complete absence in our sample of a formalised decision process for determining a manufacturing technology sourcing policy within an organisation. Only those plants that have an intended policy can be expected to have used an explicit decision process to form this policy. In this study, no plants at all demonstrated such a procedure for establishing the source of a manufacturing technology.

	Category of decision process		
	Formalised process	Unstructured process	Evolutionary or absent process
Intended Policy	No plants	1 (plant 14)	3 (plants 5,6,7)
Combined Intended and Emergent Policy	No plants	1 (plant 13)	1 (plant 4)
Emergent Policy	Cannot exist	2 (plants 2,3)	6 (plants 1,8,9,10,12)

TABLE 3. Decision Processes through which Manufacturing Technology Sourcing Decisions were Formed

Factors that Featured in Choosing Manufacturing Technology Sourcing Policies

Staff at each plant were asked to give reasons for the sourcing decisions that were practised. Through a cross-case analysis these factors have been amalgamated and then commonality explored. In this way five categories of factors have been identified to represent the range of arguments given for sourcing actions. These reasons are presented below, and summarised in Table 4.

Factors Influencing Sourcing Decision	Description	Potential Benefits from Outsourcing	Potential Benefits from In-House Sourcing
Business Focus	Focusing on core business activities	Reduces the range of activities with which a company is involved and so retains time and resources	Can strengthen control and expand involvement in core activities
Efficiency of Manufacturing Technology Acquisition	A better built manufacturing technology can be measured in terms of; cost of technology; time taken to acquire technology or technologies in sufficient volume; quality conformance of the technology to a specification	Access to specialist knowledge and resources. Indirect access to knowledge of competitors and other industries. Scales of volume may favour supplier hence reduce cost, time to acquire, etc.	Improves fit between product requirements and production capabilities. Hence, reduces un-utilised capabilities, and so reduces cost, etc. Same builder/user encourages high quality standard
Manufacturing Technology Capabilities	Concerned with the production capabilities of the manufacturing technology, and can be defined in terms of production rate, reliability, accuracy, etc.	Access to specialist knowledge and resources. Indirect access to knowledge of competitors and other industries.	Improves fit between product requirements and production capabilities. May provide higher performance equipment. Builder/user share same project goal
Manufacturing Technology Support	Concerned with ensuring the productive operation and continuous improvement of a technology	Expertise of same or similar technology in other companies will help to quickly trace fault and repair equipment. Legally enforceable service agreement, may help to reduce disruption caused by breakdown. In some circumstances, service personnel may be retained on site at company	Same builder/user means that resources and knowledge available at the discretion of the company. Avoids leverage and logistic issues with suppliers. Favours continuous development of technology, and also technologies at product suppliers
Defence of Unique Manufacturing Capabilities	Technology is in some way unique and important to competitive edge	May be achieved through patents and agreements	Knowledge retained within host company

TABLE 4. Factors that Feature in Manufacturing Technology Sourcing Decisions

Retaining Business Focus.

This category is concerned with focusing and developing the core activities of a business, and avoiding distraction into other activities.

Avoiding unnecessary integration may ensure the availability of time and resources for the development of a company's core business. This situation is captured, though somewhat idiosyncratically, by the quotation "our business is cars, not robots" (Fine & Whitney, 1996). However, such a view of a business may not be possible if there is an inadequate technology supply base.

The definition of core activities may also favour in-house technology sourcing. A company may define its core products, and then express a need to control the technologies used to produce these. One form of control may be considerable integration into the technology source. This situation was - observed at plant 6, where the involvement with equipment construction occurred where the products produced were integral to product design or defined product character. When presented with the quotation given above, staff at this plant retorted "machine manufacturers only make machines, we make [our product]". The implication is that external suppliers are focused

on the design and manufacture of a technology, rather than appreciating the subtleties of producing the host company's product.

Acquiring a Manufacturing Technology more Efficiently

A better-built manufacturing technology can be measured in terms of: cost of the technology; time taken to acquire the technology or technologies in sufficient volume; and/or quality conformance of the technology to a specification. The benefits of outsourcing are that the focus of a supplier on the production of a particular technology may favour cost etc., specialised knowledge and resources may be available, and there may be a benefit through scales of volume. Similarly, a supplier may be able to gain access to knowledge in the industry, other industries, or competing manufacturing companies. This may mean that the time to acquire a technology can be significantly shorter than if a company attempted in-house development.

In contrast, outsourcing may mean the acquisition of a standard machine, having a series of capabilities that actually exceed those required by a company. Such capabilities will be reflected in higher technology cost. In-house manufacture may provide an adequate technology at a lower cost. Similarly, a company may be able to capitalise on its own manufacturing experience and facilities to reduce technology cost. This was apparent with plant 3, where the company produces pneumatic test equipment and was well placed to provide its own testing facility. This also meant that if the company should need purchase equipment the employees were well experienced to do so. Likewise, the quality of the technology may benefit from in-house manufacture, as there is likely to be a closer association between technology builder and user.

Acquiring Better Manufacturing Technology Capabilities

This is concerned with the production capabilities of the manufacturing technology, and can be defined in terms of production rate, reliability, accuracy etc. These capabilities may favour product design, such as a novel forging method enabling improved strength characteristics of a crankshaft (plant 7). Alternatively, they may provide a competitive edge through manufacturing, such as providing high-volume, low-cost production of small electromechanical components (plant 5).

The benefits to a company of involvement with technology construction include first-hand knowledge of the product and the associated production task. This favours tailor-made development of a technology to suit products. Subsequently, there is likely to be a greater awareness of the technological capabilities and this can aid product development.

A company is also likely to consider a project goal in terms of integration within its manufacturing system; this may differ from the goals of an external supplier. For example, staff at plant 8 criticised the understanding that suppliers have of a host company's manufacturing system.

Supporting a Manufacturing Technology Better

This is concerned with ensuring the productive operation and continuous improvement of a technology in use. Plant 6 gave one reason for integration into technology supply as being that the expertise gained could be used to develop technologies within its product supply base. A benefit of external technology suppliers is that they may have expertise, gained within other companies, to quickly trace a fault and repair a technology. Furthermore, this responsibility may be legally enforced through a service agreement. Such a warranty may help to counteract the cost and disruption of a breakdown. If a company is a large customer, such as plant 7, a supplier company may actually agree to permanently retain personnel at the company's site to deal with breakdown situations.

The benefits to a company of building a technology are that the knowledge and resources may be immediately available and within the control of the company if a breakdown occurs. This avoids issues about having to have sufficient leverage with suppliers and, similarly, logistics problems. This also favours continuous development of the technology, and provides a knowledge base that can also be used to improve technologies at the company's product suppliers.

Defending a Unique Manufacturing Capability

A technology may be somehow uniquely important to the competitive edge of a company's products. A manufacturing capability may be such that it enables product differentiation in a market. In such a case a company may attempt to prevent a competitor from gaining access to a technology. The technology source may have a number of consequences if the defence of a technology is important. It is possible, though unlikely, that a company will outsource equipment manufacture to defend a technology. Technologies can be defended in this way by business agreements or legally binding patents.

In-house construction of a technology means that knowledge can be retained within the host company. In this way a company may avoid the risk of sharing its competitive advantages with other customers of its suppliers.

Conclusions

This paper describes research that has explored a variety of US companies to understand manufacturing technology sourcing policies and how they have been formed. A number of important conclusions can be made from the findings of this research.

First, there does indeed appear to be a trend with US companies to limit the extent of integration into the technology source. This is in contrast to the practices noted at Japanese manufacturers.

Second, few companies have an intended manufacturing technology policy. Where they do exist, the manufacturing function as a whole has an important role in the companies' business strategy. However, only in exceptional circumstances can a policy of limited integration actually be realised in practice. We have observed a number of cases where integration was not intended, yet has been forced because a conflict with business strategy.

Third, no formal methods of forming a manufacturing technology sourcing decision exist. We feel that this goes some way to explaining why conflicts between sourcing policy and business strategy occur. There appears to be a real need for such a process within manufacturing industry.

Finally, factors that do influence a technology source have been identified and grouped into five categories. These factors will now provide the basis of a methodology that can be used to help a company formulate a manufacturing technology sourcing policy.

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