Product customisation and manufacturing strategy

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Abstract Reviews literature from manufacturing strategy, flexibility, agile manufacturing, and aspects of industrial marketing and highlights fragmented and inadequate treatment of fundamental issues relating to product customisation. Through synthesis of the literature and the analysis of four case studies – in the manufacture of fork-lift trucks, electro-mechanical devices, small telecommunications systems and stationery products respectively – presents a novel model of the customisation process. Identifies typologies of customisation problem-solving situations and custom-build option types. Demonstrates the importance of the relationship between the degree of design activity and volume of manufacture, and of the distinction between products that are custom-built from options, and those that involve some custom-designed elements. Proposes a range of potential roles for customised products to support management decision making in the selection of appropriate business activities.

Introduction
Product customisation has recently attracted interest due to the emergence of “mass customisation” (Kotler, 1989; Pine, 1993; Kotha, 1995). In industrial markets, however, customisation is nothing new, and has always been significant. The treatment of this issue in the manufacturing strategy literature is sparse, however, and frameworks for linking customisation to broader manufacturing, marketing and organisational issues are lacking.

The objective of this paper is to redress this to some extent, and it presents a model that accommodates product customisation, manufacturing strategy and aspects of industrial marketing. The paper begins by reviewing the treatment of customisation in the manufacturing strategy literature and industrial marketing literatures. It then reports case-study research carried out by the authors. The final two sections use a novel model to discuss important aspects of customisation identified from the research.

Product customisation: typologies, concepts and organisational issues
A number of writers in industrial marketing and related fields have considered product customisation. They propose various typologies and, in various ways, propose relationships between customisation types and organisational issues.
Shapiro (1977, pp. 17-21) identifies three types of industrial product lines:
(1) Proprietary or catalogue products.
(2) Custom-build products.
(3) Custom-designed products.

Konijnendijk (1993) used the categories make-to-stock, make-to-order and engineer-to-order, which combines logistics design issues and notes that “exceptions/specials” are the biggest problem in a make-to-stock environment. Sharma (1987) suggests the following:

- Standardised products:
  - with no options
  - with customer-specified options
  - modified to customer specification
- Customised product produced to customer specification.

In their automotive industry work, Fisher et al. (1994) distinguish between “fundamental” variety and “peripheral” variety, further subdividing the latter into “package options” (e.g. all the parts needed to provide air-conditioning) and “stand-alone options”. These can be seen as subdivisions of the “custom-build” class of Shapiro. Lampel and Mintzberg (1996) propose five levels of customisation, progressively moving upstream in the supply-chain from customised distribution through to customisation from design onwards. These various schemes are summarised in Table I (Konijnendijk’s categorisation is omitted due to the combination of design and logistics issues).

Categorisation is only the first step. At the highest level of abstraction, this paper argues that organisation design is linked to product structure. Whilst a few authors explore this link (Henderson and Clark, 1990; Sanchez and Mahoney, 1996), it has been neglected in comparison to the widely-researched topic of organisation structures and the new product development process (e.g. Wheelwright and Clark, 1992). Focusing more specifically on customisation, Shapiro (1979) and Blois (1980) propose frameworks (see Figures 1 and 2) linking the degree of customisation to the following dimensions:

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<tr>
<td>Catalogue</td>
<td>Standard, no options</td>
<td>Segment, customer-specified options</td>
<td>Package options</td>
<td>Pure standardisation</td>
</tr>
<tr>
<td>Custom-built</td>
<td>Standard, customer-specified options</td>
<td>Customised standardisation</td>
<td>Stand-alone options</td>
<td>Segmented standardisation</td>
</tr>
<tr>
<td>Custom-designed</td>
<td>Standard, modified to customer specification</td>
<td>Tailored customisation</td>
<td>Customised product</td>
<td>Pure customisation</td>
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Table I.
Both authors advocate concentration on a limited combination of these dimensions – for example, not combining low-cost customised products with high-volume standard products. In doing so, the theory of the “focused factory” (Skinner, 1974) is extended beyond the production plant, effectively into “focused” applications engineering and sales organisations. Shapiro comments:
the degree of customisation in a product line or line of services marketed is beginning to appear to be the most important product policy variable for industrial goods producers and many other types of companies (Shapiro, 1979).

For Blois (1980b), distinctive competence results from the very link between functions, rather than being an attribute of one function or another (e.g. Snow and Hrebniak, 1983). Shapiro (1987) specifically relates this interfunctional linkage to “custom producers” where “the profits are made at the interfaces of the functions, not in any single function”. These are early statements of a key idea in both the core competence (e.g. De Leo, 1994) and network (Biemans, 1995) literatures.

Although some of the writers mentioned already have identified types of customisation, when they relate product customisation to organisational issues, it is characterised as either low or high, present or absent. The relative subtlety of the typologies is lost. Easton and Rothschild (1987) go further than this in two ways. First, they identify a crucial discontinuity:

... a watershed in the marketing process is achieved ... when the product changes from one which is producer-specified to one which is customer-specified ...

Second, they identify a wide range of organizational implications of passing through this discontinuity:

In doing so, it opens up opportunities to tie in customers by establishing stable, long-term relationships, which create local barriers to entry (Håkansson, 1982). It achieves this at the cost of establishing a wholly different marketing system, and one in which the management of relationships rather than the manipulation of the product mix is the key skill....An acceptable marketing strategy requires the matching of the potential of the production process with customer requirements.

On this view, suppliers of customer-specified products do not just need to be quantitatively different from other suppliers – more integrated between functions, say – but they have to be qualitatively different in some way or other.

Manufacturing strategy
Manufacturing strategy theory arguably has its origins in Selznick (1957). The illustration he gives of “distinctive competence”, using the Gar Wood boat company (Selznick, 1957, pp. 42-56), showed how the whole organisation found it difficult to shift production from high quality craft to low-cost, mass production.

Selznick’s emphasis is on the difficulty of changing the distinctive competence, and less on the competitive advantage or disadvantage it affords. Of course, Skinner developed this specifically for the manufacturing function with the theory of the trade-off (Skinner, 1969, 1974). Skinner’s concept of the “manufacturing task” has subsequently been elaborated into competitive criteria (Wheelwright, 1978), competitive priorities (Leong et al., 1990), order-winners (Hill, 1985; 1993) and other variations on this theme. Skinner himself identified important variables, but tended to offer inconsistent groupings: “lowest total cost...time and customer satisfaction” (Skinner, 1969, p. 140);
“costs, deliveries, lead times, quality levels and reliability” (Skinner, 1969, p. 144); “cost, quality, lead times, reliability, changing schedules, new product introduction, or low investment” (Skinner, 1974, p. 115). Other writers have attempted to be more parsimonious; Figure 3 captures the broad thrust of this development.

It is notable that:

- delivery speed has only intermittently been included;
- some criteria have been greatly elaborated, e.g. flexibility and quality;
- recently, innovation has been added to steady-state concerns;
- service aspects have been added latterly.

In this development, customisation has not figured a great deal. It may be implied in the objectives of “service” or “innovativeness” that have been added to the list latterly. It may also be an aspect of quality, of which Garvin (1987) identifies eight dimensions. Two of these in particular can now be seen to relate to the typologies of customisation previously discussed:

Performance: “...refers to a product’s primary operating characteristics ... performance rankings, however, are difficult to develop, especially when they involve benefits that not every consumer needs...The ‘superior performer’ depends entirely on the task.”

Features: “Features are the ‘bells and whistles’ of products and services...To many customers...superior quality is less a reflection of the availability of particular features than of the total number of options available. Often, choice is quality: buyers may wish to customise or personalize their purchases.”

Customisation involves an intimate connection between product design and manufacture but, whilst some manufacturing strategy authors (e.g. Hayes et al., 1988; Wheelwright and Clark, 1992) have addressed design issues by taking in product development as a research theme, they still treat it as an occasional, aberrant distraction from the “true” operations task of converting material. Hayes and Wheelwright (1979) simply conflate low volume with customisation, whereas, although low volume often implies high variety, it may or may not coincide with customisation. Hill (1981, p. 41) mentions “standardization vs. customisation” but does not indicate how this marketing decision (as he frames it) determines manufacturing strategy.

Figure 3.
Evolution of competitive criteria

<table>
<thead>
<tr>
<th>Skinner's various combinations</th>
<th>Cost</th>
<th>Quality</th>
<th>Delivery reliability</th>
<th>Flexibility</th>
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<tr>
<td>Skinner, 1969, 1974</td>
<td>Cost</td>
<td>Quality</td>
<td>Delivery reliability</td>
<td>Flexibility</td>
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<td>Wheelwright, 1978</td>
<td>Cost</td>
<td>Quality</td>
<td>Delivery reliability</td>
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<tr>
<td>Hayes et al, 1988</td>
<td>Cost</td>
<td>Quality</td>
<td>Delivery reliability</td>
<td>Flexibility</td>
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<tr>
<td>Chase, 1990</td>
<td>Cost</td>
<td>Quality</td>
<td>Delivery reliability</td>
<td>Flexibility</td>
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Finally, product customisation may be implicit in flexibility which, as already discussed, is included in some schemes of operations objectives. Flexibility and related concepts have generated a whole literature in their own right and the next section briefly reviews these concepts as they relate to customisation.

The new manufacturing: flexibility, agility, post-industrialisation and mass customisation

The discussion of flexibility here will be restricted to the ability to change the product to suit customer needs, although the flexibility literature refers to a much broader range of issues. The emphasis of the literature, particularly that deriving from manufacturing strategy, has been to identify categories of flexibility and the technical and organisational attributes that provide them (Slack, 1983, 1991; Gerwin, 1987, 1993). Customisation probably relates most closely to product flexibility in Slack’s scheme (although this refers to the ability to introduce new products, not necessarily customised) and to mix and modification flexibility in Gerwin’s – although again, neither of these necessarily involves customisation. Many of the requirements for customisation are inherent in these flexibility schemes, but none addresses the issue head-on. The adjective “strategic” has increasingly been added to “flexibility”, in some cases to indicate changes at a higher level of aggregation (Upton, 1994), in others somewhat gratuitously. Although largely in the latter category, Sanchez (1995) does add a little to the previous formulations by bringing in “coordination flexibility” which relates to ways of linking design, manufacturing, customers and suppliers in such a way as to provide the relevant type of flexibility.

A number of authors, converging from a number of different directions and bringing with them a variety of labels for apparently similar phenomena, have identified allegedly extreme forms of flexibility. Doll and Vonderembse (1991) discuss the “post-industrial paradigm”; Bettis and Hitt (1995) identify a “new competitive landscape”; Kidd (1994), Duguay et al. (1997) and Burgess (1994) are among those discussing “agile manufacturing” and Pine (1993) and Kotha (1995) have identified “mass customisation” as being “the emerging paradigm for competitive advantage” (Kotha, 1995). Goldman and Nagel (1993) hold that the agile manufacturing enterprise should be a “totally integrated organization” and develop this into “virtual organizations”, which come about by the combination of “agile” firms via IT. Duguay et al. feel that they have even gone beyond agility, identifying the “paradigm” of “flexible/agile production”:

- **Flexibility** – the capacity to deploy or redeploy production resources efficiently as required by changes in the environment.
- **Total flexibility** – the ability to deliver high-quality product tailored to each customer at mass-production prices.
- **Agility** – the ability to alter any aspect of the manufacturing enterprise in response to changing market demands.
• **Flexibility/agility** – an ability to adapt rapidly and with constant coordination in an environment of constant and rapid change.

Interestingly, many of the authors temper their extravagant claims for these approaches elsewhere in their writing: the concepts are criticised as little more than syntheses of what has come before (Kotha, 1994; Burgess, 1994, p. 27), or else they have limited applicability: “mass customisation taken to an extreme can position the firm as trying to be all things to all people” (Kotha, 1994 – emphasis in original). Even in his own description of a mass-customising firm, Kotha notes that a mass-production plant and a (much smaller) mass-customisation plant operated in parallel, satisfying separate markets. The few applications that have been documented involve the use of information systems to allow customers to specify products’ configurations from a range of options, i.e. custom-building based on modular designs. The only element of custom-designing is the relatively simple translation of customer dimensions – usually anthropometric dimensions – into parametric variations in the product, e.g. bicycle frame size (Kotha, 1995) or the dimensions of jeans (Pine, 1993). Most examples are in consumer products.

On agility, Burgess (1994) comments that it is not clear that there exists “an identifiable manufacturing characteristic called agility”. Despite the use of metaphors involving Sumo wrestlers (which are not agile) and ballet dancers (which are, apparently) Kidd (1994) does not develop a distinctive construct.

Underlying many of the concepts discussed in the preceding paragraphs is the integration of processes using microprocessor-controlled production and information technology. Lei and Goldhar (1991), keeping their feet rather more firmly on the ground than some of their colleagues in the field, discuss the potential of computer-integrated manufacturing (CIM) to provide low-cost, high variety products. The mass customisation work, as typified by Kotha (1995), emphasises the use of IT and microprocessor-controlled production machinery, particularly in linking the customer-specification process with the relevant manufacturing process variables required to make the product. The mass customisation work uniquely depends on modular product design (cf. Pine, 1993; Kotha, 1995) and this is a feature also strongly emphasised by Sanchez (1995) and Sanchez and Mahoney (1996). Mass customisation seems to map directly on to the “total flexibility” concept of Duguay et al. (1997). However, this sheds a little light on a small area of activity. These types of product allow customisation by choice from a predetermined and finite range of options, differing little from the “modular production” concept of Starr (1965).

In summary, the flexibility literature, while relatively generic, has not tackled customisation head-on; in the agility and mass-customisation work meanwhile, the customisation discussed has been either trivial or along narrowly-prescribed dimensions, and there has been a headlong rush to provide the agility or customisation by computer integration. While this may well be part of the process in some cases, Crowe (1992) is correct to observe that “integration is not synonymous with flexibility”.
Linking design and manufacturing

Customisation and aspects of flexibility depend on particular types of relationship between the design of a product and its manufacture. Some writers have attempted to conceptually model the difference between, and the links between, design and material conversion. These prove useful in the analysis to follow and are presented here.

Jouffroy and Tarondeau (1992, pp. 167-8) state that an “industrial strategy” (their term for manufacturing strategy) should concern both the design cycle and the manufacturing cycle. Harrington (1973, pp. 12-23) uses similar concepts:

The design cycle refers to the events occurring in the development of a specific product design, while the material cycle refers to the events occurring in the production of an individual piece of material taken from raw stock through to finished article.

The distinction made by Håkansson (1982, p. 382) between problem-solving and transfer abilities is very similar, although it considers activities inside and outside the production function (this extension parallels the extension, by Shapiro, of the focused factory noted earlier). Table II indicates the similarities between the concepts introduced by these contributors.

Håkansson (1982, p. 32), if anything, develops the idea further than the others, associating with each type of ability a general aspect and an adaptive aspect, i.e. specific to one customer. He suggests that the latter is often neglected, as, indeed, do Blois and Shapiro.

Research issues and method

Research question

The literature on customisation is fragmented. Manufacturing strategy research hardly discusses it at all; other schemes, from industrial marketing and elsewhere, identify some relevant issues, but do not explore the links between them. Closer examination of “mass customisation” shows it to have limited novelty and restricted applicability. The research question, then, is to identify how manufacturing strategy theory could be extended and developed to incorporate product customisation as the central issue it appears to be in many industrial markets.

The review allows the construction of a provisional model. Customisation appears to involve a problem-solving stage and a transfer stage (Håkansson, 1982) and the relationship between these depends on the category of customisation. The output of the process depends on some level of performance, most conveniently expressed in terms of the operations objectives. Flexibility in some way affects the performance outcome. This outline model is shown in Figure 4 and is used as a basis for data-collection and subsequent theoretical elaboration and synthesis.

<table>
<thead>
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<th>Table II.</th>
<th>Design and material cycles: parallel concepts</th>
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<td>Harrington (1973)</td>
<td>Design cycle</td>
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<td>Jouffroy and Tarondeau (1992)</td>
<td>Design cycle</td>
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<tr>
<td>Håkansson (1982)</td>
<td>Problem solving</td>
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**Research design and data-collection**

The conceptual framework drawn together from the strands of the literature reviewed does not comprise constructs of sufficient validity to enable measurement by survey instrument. For example, there are wide-ranging understandings of what “customisation” means, what constitutes a “standard product”, or by what dimensions we might describe a manufacturing strategy. More generally, the practical limitations of the survey process in addressing anything but the most simple descriptive issues – for example, doubts about who actually completes the questionnaire, whether they will be able or willing to access accurate data, whether there are “accurate” data on such questions – resulted in an early rejection of the survey approach.

The original motivation for the research, and the formulation of a research question which is in part concerned with the process interaction between customisation and strategy, led to the case study method as the final choice. As

![Diagram of product customization](image_url)

**Figure 4.**
(a) A preliminary model of product customization; (b) The extended model of product customization.
Yin (1989) comments, the case method is suited to situations where the researcher is attempting to answer a “how?” question as well as or instead of a “what?” question. It is also suited to situations where phenomena and the context in which they exist are difficult to separate. Both of these conditions apply to the present research.

Case selection was derived from the theory in the following ways. First of all, the view apparent in much of the manufacturing strategy literature, and made explicit by New (1992), is that the plant is the most useful unit of analysis. Given this, an effort was then made to include a range of product technology complexity based on a simple assumption that microprocessor-based product technology may be more readily customised than mechanical products, and that technology complexity will have other implications on customer demands and the way in which manufacturing responds to them. Similarly, a range of process technologies was covered, to understand the interaction between customisation and what is, after all, one of the basic manufacturing strategy decision areas (e.g. Hayes and Wheelwright, 1984). The nature of the relationship between the focal plant, other plants (where appropriate) and other functions, particularly marketing, was another key issue. This comprised both organisational and geographic dimensions. Also, both industrial and retail markets were included, and the former covered both end-users and original equipment manufacturers (OEMs). Finally, of course, the cases all reflected situations where customised and non-customised products were mixed, or customisation was causing concern in some other way. The cases, then, were chosen for theoretical reasons, not by “sampling logic” (Yin, 1989) and, by varying along the dimensions discussed, an attempt was made to include “polar types” (Pettigrew, 1990). Table III summarises this research design.

Data-collection consisted of interviews, analysis of documentary evidence and observation within the plant. The interviews typically began with “gatekeepers”, in most cases senior production or general managers but, in one case, the personnel manager. These individuals provided contextual information on the organisation and its specific production concerns, formal manufacturing strategy (if any) and, very importantly, indications as to the key informants within the organisation. The interviewing and other data-collection activity then proceeded via, for example, marketing and design personnel, production management and operators. Although the interviewees tended to be in rather similar roles from one case to another, the data-collection process was informed by a case-study protocol (Yin, 1989) that identified, based on the literature, the key research questions to be answered, rather than dictating the sources to be used. Data-collection followed “trails” of evidence as the need arose. A crucial method of data triangulation (Easterby-Smith et al., 1991, p. 134) was to examine a small number of contract histories within each case, to enable confirmation of general themes through specific instances. This was carried out by having free access to files held by, for example, applications engineers, documenting the contract from initial enquiry through to mature
production. In various, ways, then, this made it possible to understand the process by which the design cycle and the material cycle interact, the way in which customisation came about, and the consequences of this.

The case studies
In order to present the material in a little depth even within present space constraints, two of the four cases are summarised here.

Case 1 – Molloy materials handling
Molloy manufacture fork-lift trucks. The plant studied, UK1, has been in operation for over 30 years, and currently produces mid-sized products. A second UK plant, UK2, was created about ten years ago to produce small, standardised, low-priced products. Before this, each truck had practically been designed to customer specification. Five years prior to the research, UK1 had been re-equipped to produce a product-range much more standardised than hitherto. A third plant produces larger trucks.

UK1 has recently produced 3,000-4,000 trucks per year. The process began with relatively low value-added materials, with frames and bodies being cut from
bar and sheet stock and welded on flexible manufacturing systems (FMSs). Components such as seats and tyres were bought in, but common machined structural components were made in the machining section utilising computer-numerically-controlled (CNC) machine-tools. This used Kanban planning and control; the frame-building and assembly process used Materials Requirements Planning (MRP). There were three assembly lines, with products grouped by size.

Products were distributed by one dealer in the UK and by agents outside the UK. The UK dealer’s offices were linked to the plant’s MRP system via a computer terminal by which they specified custom-built trucks, choosing from a menu. About 20,000 permutations were possible. Dealers committed to certain aggregate sales several months in advance, with details being specified at the time of ordering. Typical leadtimes promised were 12 weeks.

However, more customers were asking for custom-designed features not offered as options. The percentage of trucks requiring some element of custom-design had risen from 20 per cent to 35 per cent in four years, with some product lines requiring over 60 per cent. Over the same period, total volumes fell by about 20 per cent.

Custom-design work could not be accommodated on the assembly lines so, at the appropriate point in the process, trucks would be extracted from the main plant and taken to the custom workshop. Here, skilled fitters carry out the bespoke work. More than half the custom-design trucks involved over ten hours’ work, a 25 per cent increase in labour hours over a non-custom-designed truck. This had two main consequences. First, it was common for dealers to specify custom-design work well into the leadtime, i.e. after placing an order for a custom-built truck, and this led to unpredictable increases at short notice in the amount of overtime worked in the custom workshop. Although custom workshop labour hours were only 10 per cent of person-hours worked in the plant, it was disproportionately expensive due to the type of labour and the proportion of overtime involved. Second, delivery performance was poor. Detailed analysis carried out as part of the research indicated equally poor delivery for both custom-designed and non-custom-designed trucks, i.e. there was interference between the two.

The product range was designed for custom-building, with dealers constrained to select acceptable combinations of options by the computer system. But as soon as any custom-design feature was required, custom-design engineers had to carry out the design work, however trivial, to guarantee safety. The custom-design engineers were part of the technology function; the applications engineers, who liaised with customers to define the performance required for the particular lifting tasks in hand and who were involved in all custom-design trucks and some custom-build trucks, were part of the marketing function. Custom-design also required the manual intervention of materials management to incorporate custom-designed items into the truck’s bill of materials. Items bought in specially for the custom design were often procured at very disadvantageous terms compared with standard materials.

There was considerable evidence of a deep-rooted “culture of customisation”. Longer-serving design and applications engineers were nostalgic for the old
days when “we used to do anything”, i.e. customise the trucks very heavily. The plant manager commented that Molloy “beat their chests” about exceptionally difficult custom-design jobs, e.g. through the trade literature. The design engineering effort is treated as a general overhead and the costing system only passes on to the customer the extra basic material costs and an estimated extra assembly labour cost. There was no business framework for making decisions about which orders were worthwhile; the design engineering supervisor could only comment that custom-design “is supposed to pay its way overall”. The main constraint to accepting customers’ orders was design engineering capacity, but the marketing manager’s view was that, in the then prevailing depressed economic climate, “no one’s walking away from business”.

Case 2 – Murphy devices
Murphy is an international firm making electronic and electromechanical devices, mostly supplied to original equipment manufacturers (OEMs). This case study was carried out at the firm’s main UK plant and concentrated on a range of products, the Acme range, for use in particularly hostile environments. These were manufactured in the same plant as a number of other product-lines, all of which were made to lower specifications, being used in less arduous circumstances. Some of these other products were produced in very high volumes – up to 500,000 per year – compared to the Acme range, where only a few hundred of any one individual product might be made in the whole product life cycle. The Acme range was 30 years old and, in the words of the engineering manager, had been “customised beyond recognition”. The range was perceived to be profitable, but there was concern at the level of development work involved in customisation, and delivery performance was poor.

The salesforce were Murphy employees, but had a pseudo-market relationship with the production plants. If more than one plant made a particular product, the salesforce would play one site off against the other for (transfer) price and delivery. Some Acme products were required in higher volumes, but the sales affiliates placed orders for these with parent plant overseas. This had become the norm by a difficult-to-disentangle combination of more advantageous transfer prices from the overseas plant and a scaling-down of UK manufacturing operations. The UK site tended to be left with the very low-volume and often heavily customised Acme products.

Salespeople would submit project requests for new variants. Hardly any of the products made were “catalogue” products. Some requests involved minor differences in mounting details; others saw the devices being incorporated into systems, control panels or sub-assemblies for the OEM. Increasingly, the OEMs were designing their product and then expecting suppliers to fit their components into whatever constraints had been defined; previously, the OEMs would design the OEM product around the suppliers’ standard components. Often the detail of devices like those supplied by Murphy were left until late on in the OEM design programme, so time would be short and the constraints largely non-negotiable.
The project request was initially submitted to a product manager, who would balance the commercial merit and engineering design resource requirements for the new product. The initial response, if the project was deemed to be viable, would be to give a quotation to the salesperson, based on the volumes projected. There might also be an early requirement to submit design drawings or even prototypes. Typically, this stage required quite intense work and a rapid response; the subsequent build of the new OEM product might not start for a year or two. The initial build run might last two years; then the spares after market would last for 20 or more years.

There had been a company-wide move to eliminate non-core manufacturing processes which, at this plant, had meant the sub-contracting of certain upstream activities such as casting and machining. Although some parts manufacture continued, the key process was final assembly. Some parts, including the technological “heart” of the product, were bought in from the same parent plant that acted as internal “competitor” for some of the finished products. Other parts were sourced locally. Assembly of Acme products was carried out in a dedicated “plant-within-a-plant”, under a production manager dedicated to the product-line. However, the same production planning and control system was used for Acme products, typically produced in batches of ten, as for other products with daily quantities of several thousands.

There were often long intervals between successive batches of a particular product. As the degree of customisation – and hence the product-specific process requirements – became greater, it was necessary to “re-learn” the process for each product. The delay between design and initial production also meant that the design engineer had to re-immersce him/herself in the particular requirements of the product once it “hit” the shopfloor.

The UK market for Acme products had been opened up by de-regulation and this offered the prospect of new entrants. Historically this had been a very concentrated market and there was a strong emphasis among the salesforce in keeping the competition out of accounts altogether. This involved supplying heavily customised products, possibly at a loss, in order to avoid competition for the less customised and, ostensibly, more profitable products. Winning orders in this market hinged on two things. First, in the very concentrated market, potential customers usually had built up experience of how Murphy had performed in the past. The second factor was the response to the initial request, in terms of what Murphy could offer technically and at what price. Any claims about delivery speed or reliability or about conformance quality were promises about a quite distant future and were seen by customers as of secondary importance.

Case analysis and discussion
This section will summarise the analysis of the cases and develop the proposed model linking product customisation to key manufacturing strategy concepts. The analysis has been based on all four cases, albeit that only two have been described here due to space constraints. The more elaborate version of the
model is presented here in Figure 4. The two main stages of the customisation process, problem solving and transfer (Håkansson, 1982), are linked to customer expectations, product architecture, customisation type, flexibility, the trade-off and manufacturing strategy competitive criteria. The remainder of the paper explains the model and its implications for theory and practice.

**Process and structure of customisation**

*Problem-solving and demand-side issues*

The cases show the interactive and often extended nature of this stage in the process. The expectations of the customer change and can be influenced by the interaction with the supplier, as discussed in the IMP literature (e.g. Ford, 1990).

In some problem-solving cycles, there is an emphasis on problem-definition, in others, on solution-realisation. For example, one Molloy customer specified a particular brand of safety switch: this required no problem-definition effort but, as it transpired, required a considerable amount of solution-realisation in the shape of locating a supplier, procuring and designing in the part. On the other hand, considerable problem-definition work may be required – for example, to calculate or otherwise establish loading and environmental conditions for a Murphy switch – but the solution realisation may be trivial; indeed, it may transpire that a standard product will suffice. This suggests a categorisation of problem-solving situations, as in Figure 5a, and a need for interaction between various individuals under various circumstances (Figure 5b).

Problem-definition typically involves salesperson, applications engineer and customer, while solution realisation involves the design engineer and the applications engineer. The role of the product manager varies considerably and may include aspects of none, one or both parts of the process. The problem-definition stage is very influential. For example, at Murphy, involvement in an OEM project was typically late and therefore there was little discretion in problem definition. The relationship between customer and salesforce before the project is thus crucial here. For example, it determines when the sales engineer will first be aware of a forthcoming opportunity and when the customer will begin to divulge information that will enable the sales and applications engineering staff to become involved in problem-definition.

The cases also indicate that the motivation for customisation of one form or another is very variable. Some examples include:

- choice for its own sake: it is the process of being involved in problem solving *per se*, rather than the customised outcome, that matters;
- some importance is attached to having different features, most of which are required by all customers;
- considerable need for features that are positively unattractive to other customers;
- need for higher basic performance possibly with features as well.
These examples are not exhaustive, but begin to show the varying degrees to which, and ways in which, aspects of the specification are negotiable.

Although the emphasis here is on design solutions, the problem-solving stage also shapes the mutual understanding of the competitive criteria for the transfer stage (i.e. the usual manufacturing strategy criteria). The problem-solving stage is thus an opportunity for the manufacturer to understand and possibly influence the customer’s expectations for the transfer cycles.

**Design specification and customisation type**

In process terms, problem solving results in a design specification. Conceptually, the solution realisation process is “refracted” through the product architecture (e.g. Ulrich, 1995) and results in a particular customisation type. For example, relatively trivial customised benefits on Molloy FLT's result in significant custom-design work because the architecture, embodied in the way options can and cannot be permuted by the computer system, is restrictive. The design specification and the process by which it is achieved thus determine, before any product is made, the firm’s performance on some of the operations objectives, namely certain aspects of quality, service and cost.
Furthermore, the possible motivations for customisation open up a number of ways in which the problem-solving process might be influenced to the manufacturer’s advantage.

Regardless of whether the product as defined by the specification is a customised product, the marketing communications involved in problem solving and, to a lesser extent, transfer, may be customised (Blois, 1980; Lampel and Mintzberg, 1996). For example, although a Molloy truck may involve considerable custom-design work, the problem-solving and transfer processes may be perfectly standard – carried out through the dealer network and delivered and invoiced in exactly the same way as for a standard product. On the other hand, a customer may have a dedicated major account salesperson rather than the normal dealer contact, but order standard products. The marketing communications and sales administration aspects of problem-solving and transfer processes respectively may, therefore, be customised independently of each other. Manufacturers must examine the subtle interplay between these dimensions and assess whether they can substitute one for the other.

Transfer and supply-side issues
The product customisation types have so far been described from a customer-facing or benefit-based perspective. Customisation also influences the functions involved in providing the products – manufacturing, procurement and engineering or design. The distinction between custom-build and custom-design has emerged as the most important because the transition to custom-design gives rise to the need for design engineering and various materials management interventions. This distinction has been drawn in some of the typologies of customisation (e.g. Hutt and Speh, 1992; Sharma, 1987; Mintzberg, 1988) but the implications for manufacturing have not been examined in such schemes. Where an attempt is made to understand the manufacturing consequences, customisation is reduced to a simple continuous variable, of which there is “more” or “less” (e.g. Shapiro, 1979). Only Easton and Rothschild (1987) allude to the process implications of a discontinuous typology of customisation.

Here a comparison is made between the firms’ deliberate and emergent (Mintzberg and Waters, 1985) offerings; the deliberate offering is that included in sales and marketing literature, the emergent is what was actually being made. This is summarised in Figure 6, where the vertical axis is not a continuum from “high” to “low” customisation used by Shapiro (1987) but comprises discrete categories (Easton and Rothschild, 1987). The Figure shows that, in at least three of the four firms, a mismatch has occurred whereby the division between custom-build and combined custom-build and custom-designed products has been crossed. Once that line is crossed, a new range of activities, interfaces and uncertainties is invoked. In some cases, this mismatch has developed gradually by an accumulation of operational decisions in design, marketing and manufacturing; in others (most notably Watt), it has existed from the launch of the products in question.
Within the elements that are custom-designed, there are further distinctions to be made. The two which emerge as important in the Molloy case in particular are design work content, and special manufacturing labour. Particularly where both of these are high, the need for design-manufacturing integration is great.
Options: essential features and “optional extras”
The Molloy and Murphy cases in particular demonstrate that there are options that must be specified one way or another, e.g. a FLT must have tyres of some sort, but the customer chooses which. There are other options which are truly “optional extras”: a FLT may or may not require lights.

Furthermore (e.g. Kotha, 1995) there are some options which are specifiable simply in parametric terms, e.g. the frame size of a bicycle, derived from the customer’s inside-leg measurement. The specification of such “parametric” options may be continuous or discrete. The Molloy case illustrates the potential inflexibility of an FMS with the latter option type. Here, the manufacturing system had complete mix flexibility so long as the options were specified at the discrete intervals it was designed to produce but, where the specifications fell in between the intervals, the system proved very inflexible.

In addition to the parametric options, there are substitutional options which, whether optional extras or essential, are specified in either/or terms. For example, a Watt switching system has either Italian or Spanish as its operating language, with no sense that one is bigger than the other – just different. These custom-build option dimensions can be combined in a matrix such as in Figure 7.

Any optional feature can be categorised into one of the boxes in the matrix. Analysis of options along these lines can inform the design of product architecture and the manufacturing system. The case examples have demonstrated the danger in having a manufacturing system that works in discrete parametric terms when demand is, or moves towards, continuous parametric. Parametric options require entirely different forms of capability from substitutional: the former is largely a matter of the product flexibility of a single stage in the manufacturing process, the latter has more to do with materials management and product architecture. The boundary between essentials and optional extras is also an important one. The more features that fall above the line, the more the labour content, planning variables and costs are likely to be consistent. However, customers may feel better served if they have what they perceive to be optional extras. This can be very product/market specific.

Patterns of customisation
The discussion so far has concentrated on how the characteristics of a single problem-solving sequence relate to organizational and manufacturing issues. This section looks beyond that and takes account of: the relative timing of the
problem-solving and transfer stages; the number of repetitions of transfer stages for each problem-solving stage; and the role of any single problem-solving and transfer pair in the broader relationship with a customer or group of customers.

**Problem solving and transfer: timing and repetition**

The transfer process involves the physical transfer of the tangible product to the customer and, as appropriate, assembly, component manufacture and procurement. The problem-solving cycle may be closely followed by the transfer cycle or there may be a long delay between the two; there may be one transfer cycle or many. Figure 8 represents this for the four firms.

For any company, this pattern determines many of the scale economies and information system requirements for the whole manufacturing/engineering system. Low transfer cycle repetition (e.g. Molloy) implies many problem-solving cycles. This makes the automation of problem solving attractive in cost terms. It also requires clear and standardised communication of specification to manufacturing, i.e. the solution-realisation-to-transfer link. High transfer cycle repetition (e.g. Watt) makes design-for-manufacture, cost minimisation and reliable and optimised supply-chains more important. Decisions about the precise level of vertical integration are critical. If there are long intervals between problem-solving and transfer cycles (e.g. Murphy), then mechanisms are required that promote continuity, e.g. extremely explicit process specifications and purchasing requirements for bought-in parts. Where volumes are low and batches infrequent (Murphy again), the need for these aspects of “collective organisational memory” are even more important. Figure 9 summarises the general points, which have been illustrated with reference to the case studies.

Finally, these patterns also influence the way in which performance is controlled against expectations. The outcome of the problem-solving stage will
determine how well the product eventually specified meets the customer’s requirements; the outcome of the transfer stage or stages will determine delivery speed, reliability and conformance quality. Both problem solving and transfer present opportunities for customer service, and both incur costs. From the business perspective, the provision of appropriate cost accounting and control mechanisms is vital. For example, Murphy did not have any useful way of relating actual achieved costs to original quotes which, in many cases, had been made years earlier. The centralised, standard production control and accounting systems were organised on a product-line or process basis; a more appropriate focus for Acme products would have been the customer account.

**Role of customisation**

Blois (1980) notes that customised products may be produced outside the normal production capabilities of the firm to satisfy a large or otherwise important customer. This extra dimension – the broader relationship between customer and supplier – has been treated at length by the IMP literature (e.g. Ford, 1990), but it is instructive here to examine the role of customisation in each case.

Murphy made some of their customised products so as to allow competitors “no visibility in the account” with certain customers. The market is concentrated and the success of the business depends on the way the few customers it has are handled. On the other hand, Molloy’s senior management wish to “beat their chests” about extreme customisation projects, demonstrating their technological capabilities to the sector and commitment to the individual customer. In this case, however, there is less evidence that it is necessary to do the “nuisance” customised jobs to retain approved- or sole-supplier status and hence secure the supposedly more profitable high-volume standard business. Their customers

![Figure 9. Timing and repetition: process implications](image-url)
either always want extreme customisation (e.g. special livery, industry-specific attachments) or never. Furthermore, as a dealer is usually involved, the evolution of the customer account is obscured from the factory’s view.

Customisation can also be done simply because it attracts a higher price and, potentially, a higher profit, in a relationship closer to a “spot” market. Some of Sappho’s contracts were like this. They have established a minimum return they wish to make on their capacity at certain times of the year, and accept or reject jobs on the basis of their ability to achieve this minimum return or higher. Jobs are chosen on their immediate profit potential, apparently with little impact either way on the likelihood of Sappho being asked to quote on future requirements.

Finally, organisations may become involved in customised or specialised products as a way of forcing themselves to develop new capabilities. Watt learned from its experience of making one of their systems to the exacting standards of specific export market territories.

The above illustrations suggest a number of roles for customisation that might be described as shown in Table IV. An important decision for the firm is how much customised business to take on, and this will depend on the role customisation plays. This decision is indicated by the line “volume required” and would be termed a “handling” problem by Håkansson (1982).

Where customisation is used as an entry barrier, the relationship with and sales potential of each customer and the cumulative effect on the operation of all such customers’ needs must be carefully monitored, so that either a conscious change to operations can be made to support this, or the customer portfolio can be changed. (As a senior manager commented at one of the firms “The customer is always right, but I can choose my customers…”)

Customisation as a vehicle for learning requires care in ensuring that lessons learned are valuable and truly transferable, and that the people involved are those best placed to effect the transfer. Where customisation is symbolic, then the effects and intentions need to be understood clearly. If the operation is essentially inappropriate for producing heavily custom-designed products, then it would be counterproductive to actively create the impression in the market that the firm “can do anything”. Finally, the “profit taker” should accept any profitable products and design the operation accordingly, i.e. provide adequate design engineering capacity and appropriate cost accounting system.

All these potential roles for customisation suggest different supporting roles for manufacturing and related functions. Sappho’s special edition jobs are relatively pure “market” transactions, and the material conversion stage is of paramount importance in terms of resources and, in the final analysis, cost. Thus, approaches such as Hill’s, where orders for various customers are aggregated for the purposes of determining order-winning criteria, are appropriate, because longitudinal or relationship issues are not important in their markets for customised products. (This is discussed in Spring and Boaden (1997).)

On the other hand, it is contended that such an approach has severe limitations in cases such as that of Murphy, where the material cycle is a
relatively small part of the interaction involved in a contract, many of the relationships with individual customers are long-standing, and there simply are not that many potential customers (particularly for Acme products).

Customisation type can be linked to capacity – in both production and design engineering – and the requirements of the particular type of customisation involved. This is indicated schematically in Figure 10.

Although this Figure could be used as a vehicle for analysis, in so far as there is a need for consistency of policy between the three nodes, because of space limitations it will not be illustrated here.

**Conclusions**

The research has enabled the synthesis, represented in summary form in the model of Figure 4b, of a number of important manufacturing and marketing concepts. This model captures some of the complex connections between these concepts and demonstrates, above all, the need for a systemic approach to customisation decisions and policies. While it is no surprise that the coordination of decisions between manufacturing and marketing appears desirable, the analysis presented...
here gives a new level of discrimination in categorising customisation approaches. These categorisations are no mere academic exercises but, as the cases begin to show, have direct practical implications in many areas of the business.

Integration between functions becomes particularly critical when, due to the need for custom-design, engineering activities become part of routine, repetitive operations. Analysis of patterns of design and production work content and of timing and repetition of the problem-solving and transfer cycles will identify priorities for integration efforts. The integration can be achieved by:

- understanding the role of customisation for particular customers or segments;
- agreeing across functions on criteria for which business to accept and how to cost the work;
- adopting cost management and organisation structures that are consistent with the role and criteria;
- use of information systems.

The most important aspect of the nature of customisation is whether or not there is a custom-design element involved. Any amount of original design work changes the process fundamentally; secondary to this is the quantification of how much design and special production activity is involved. Where the customisation is by custom-building, the overall process implications are less severe, but there are further distinctions to be made, namely, whether the options are substitutional, continuous parametric, discrete parametric and whether they are essential or optional. These distinctions have particular significance for process technology flexibility, production planning and materials arrangement.

This type of analysis relates principally to manufacturers’ current and recent activities. But the issues captured in the model indicate important considerations for the development of new products, particularly the way that product architecture can so strongly influence the ability of manufacturing to respond to changing market needs.
Finally, although there are many product and process technology issues at the centre of customisation, it is also necessary to recall the problem highlighted by Selznick (1957) of changing a firm’s “distinctive competence”. Without a willingness among management to reflect on the business, rather than functional, rationale for making customised products, “specials” will continue to be a drain on scarce organisational resources, rather than a carefully considered strategic weapon.

References


