SWP 7/97 EVALUATING CUSTOMER SUPPORT REQUIREMENTS AT THE PRODUCT DESIGN STAGE

DR KEITH GOFFIN
Operations Management
Cranfield School of Management
Cranfield University
Cranfield
Bedfordshire MK43 0AL

Tel: +44 (0)1234 751122
Fax: +44 (0)1234 751806
Email: k.goffin@cranfield.ac.uk

The Cranfield School of Management Working Papers Series has been running since 1987, with approximately 430 papers so far from the nine academic groups of the School: Economics; Enterprise; Finance and Accounting; Human Resources; Information Systems; Logistics and Transportation; Marketing; Operations Management; and Strategic Management. Since 1992, papers have been reviewed by senior members of faculty before acceptance into the Series. A list since 1992 is included at the back of this paper.

For copies of papers (up to three free, then £2 per copy, cheques to be made payable to the Cranfield University), please contact Wayne Bulbrook, Research Administrator, at the address on the back of this booklet.

ISBN 1 85905 101 4

EVALUATING CUSTOMER SUPPORT REQUIREMENTS AT THE PRODUCT DESIGN STAGE

Keith Goffin
Cranfield School of Management, Cranfield,
Bedford MK43 0AL, England, UK
Tel: 0044 (0)1234-751122
Fax: 0044 (0)1234-751806
Email: k.goffin@Cranfield.ac.uk

EVALUATING CUSTOMER SUPPORT REQUIREMENTS AT THE PRODUCT DESIGN STAGE

ABSTRACT

Good product support is an essential element in the successful marketing of high-tech products, since it plays a key role in achieving customer satisfaction. Typical forms of support include installation, user training, maintenance and repair. Although product design influences product support, it is an area on which comparatively little research has been published and one which has largely been ignored in the new product development literature. This article describes an exploratory investigation of how companies evaluate support requirements of high-tech products at the design stage. A survey and a case study give insights; the results indicate some of the ways support is evaluated during new product development and show the need for further study. Experience gained from the research allows recommendations to be made on the approach needed if researchers are to provide a more definitive understanding of the role product support plays in the development and marketing of high-tech products.

INTRODUCTION

Product support is the name given to the various forms of assistance that companies offer customers to help them gain maximum value from high-technology products. Typical forms of support include installation, documentation, maintenance and repair services (generally termed *field service*), user training and equipment upgrading. The term *service* normally refers to maintenance and repair issues, whereas the broader term *support*, which emerged in the eighties, also covers issues such as user training and upgrades [14]. Good product support plays a key role in achieving customer satisfaction [34], it gives companies a competitive advantage and it can be a major source of revenue [1],[44]. However, support is a neglected area on which little has been published: "although field service has been noted as a competitive edge, information on the subject... is lacking" [25].

Product design has a strong influence on product support [32], but many companies do not consider support until late in the design cycle [33]. Additionally, functionally organized new product development (NPD) often leads to difficult to repair products and consequently "excessive warranty and field service costs" [2]. In contrast, *Design for Manufacturability* (DFM) is a widely applied technique used in product development to reduce manufacturing costs [30]. It has been recognized that a similar approach to DFM is needed to evaluate product support requirements during NPD [6] [28].

This article investigates how companies evaluate support requirements at the design stage and whether they use approaches which are similar to DFM. It describes a survey of high-technology companies—the first detailed empirical investigation of how support is evaluated—and a case study. The results indicate some of the ways companies evaluate support at the design stage and demonstrate that more research is needed to provide a better understanding of the role evaluating support plays in NPD.

LITERATURE—Product Support

There is much evidence of the importance of high-tech product support: as a source of revenue; as an essential factor in achieving customer satisfaction; and as a means of gaining a competitive advantage.

Product support, which is also called *customer support*, can be a major source of revenue. The total worldwide market for high-tech support is estimated at $400 billion [9], with approximately $200 billion of this in Europe. In the computer market "as a percentage of revenues... for many companies [support] now represents 35% or more" [45].

Lele and Sheth [34] identify product support as fundamental to customer satisfaction. Similarly, Athaide et al [4] identify that the strategic activities which are essential to the successful marketing of complex, technology-based products include "product customization, information gathering on product performance, product education and training, ongoing product support".

Product support is important in many sectors; in both of high-tech and low-tech settings [40]. Even for simple domestic appliances, 75% of dealers who sell these products perceive service as a selling point [26]. However, support is particularly important for high-tech products [31][37], and good field service gives a competitive edge to companies in electronics [25]. Purchasers of many types of technical equipment consider support during their purchasing decisions [24][27] [43].

Although the importance of product support has been recognized, its role in the development of new products has not been widely researched. Many articles in the NPD literature point out that manufacturing requirements need to be evaluated at the design stage but make no mention of support requirements (see, for example [20], [36], [38]). This is surprising, since one well-known study shows that product support plays a role in the success of new products: "where the firm offers superior technical support and customer service with its new product, success rates are markedly higher" [16]. However, the lack of focus on evaluating support during NPD may be the result of it being one of the most complicated and difficult parts of product development [21].

The Success of DFM

Design for Manufacturability evaluates manufacturing requirements at the design stage, enabling the development of products which are easy and cost-effective to produce. A wealth of literature describes DFM techniques and the successes attributed to them (see, for example, [10], [30], [39], or [46])

DFM "stresses that seemingly insignificant decisions made during the initial design phase will affect manufacturing throughout the product's life cycle. Most products can be designed for easy manufacture and assembly if manufacturing is considered early in the design process" [47]. The DFM process has various levels including *Design for Assembly* (DFA) and *Robust Design* (designing production lines for efficient manufacturing) but DFA is the most important of these [10] .

Design for Assembly techniques check whether product designs will be easy to assemble and stimulate product simplification. This results in a reduction of the number of components, thus reducing both material costs and assembly times. Two of the main DFA techniques are the Hitachi Method [39] and the Boothroyd Method [11], both of which evaluate designs by assigning quantitative scores based on the number and type of parts used. The Hitachi method, for instance, allocates a number between 0 and 100, with a higher score indicating a better design (i.e. one which is easier to assemble)—a score of 80 or more is desirable for efficient manufacturing [39]. DFA techniques allow production costs to be estimated and so alternative designs can be compared objectively.

DFM/DFA has played a strong role in manufacturing. One study found that DFA had led to striking reductions in both the number of components and assembly operations required in a range of products [30]. Another study concluded that DFM/DFA "can play a major role in reducing costs and increasing productivity" [11]. The success of DFM has led to the realization that other factors (including support) need evaluating at the design stage. Notably, the evaluation of one factor—recycling—is becoming increasingly important and *Design for Recycling* (DFR) evaluations are used in many industries [42].

A note of caution needs to be raised with DFM. Although the literature attributes many successes to DFM, limitations have also been identified. Some of these are technical and some relate to the way in which DFM is implemented. From a technical perspective, DFM techniques do not account for design tolerances [15]; and promote uni-axial assembly which may not always be desirable [5]. During implementation, DFM increases the manufacturing department's influence over the design process and this change in decision-making power can lead to friction within the product development team [5]. Consequently, "successful implementation of the DFM strategy requires cultural changes that allow for better communications among all subsystems, promote team work, and integrate the efforts of those involved in product and processes decisions" [49].

Is the DFM Approach Relevant to Support?

The essence of DFM is that manufacturing requirements are fully evaluated at the design stage and quantitative goals set for all aspects of ease-of-manufacture. It has been suggested that something similar to DFM is required to ensure that support issues are fully considered during NPD [6][28].

Although it is important to design products so that they can be easily and cost-effectively serviced [22], service requirements typically do not receive enough attention at the design stage [6]. Therefore, "those who do quality planning for service activities can learn much from the experience of formalized quality planning in design and manufacturing"[28].

Evaluation, at the design stage, of how a product will be serviced has been called *Design for Serviceability* [22] or *Design for Service* [42].Suitable goals for service requirements need to be set before the start of development [12],[48]. And, ideally, the evaluation should cover not only service but all aspects of product support—such as easy installation and customer training [35]; and *upgradability* (easy product hardware and/or software upgrades) [17].

It is proposed that the evaluation of *all* aspects of product support at the design stage should be termed *Design for Supportability* (abbreviated in this article to *DFS-II,* to distinguish it from Design for Service / Serviceability [DFS]).

How Product Design Affects Support

Design influences both the amount of support necessary and the way it can be delivered [19]. Decisions taken at the design stage affect product reliability and consequently how often products require maintenance [32]. Similarly, modular design can reduce repair costs [23] and fault-finding is made easier by good diagnostics [3], [29]. In addition to repair and maintenance, design also influences user training and upgradability. Therefore "design characteristics such as... supportability have a great impact on both the effectiveness and cost aspects of the system" [8].

Although the need to evaluate support requirements is recognized in the literature, only sparse information is available on how it is normally conducted. Four articles discuss the degree to which support requirements are considered during NPD:

- "Support needs are considered late in the design cycle" is the conclusion of one article but no empirical data is given to support this view [33].
- A survey of UK manufacturing companies, found that 40% of these companies "fully" considered service requirements at the design stage [13]. However, a limitation of this study is that different respondents may have had very different understandings of what "fully" means, in this context. (No attempt was made to check if those who claimed to "fully" evaluate support were more thorough in their approach than other respondents who answered "partially").
- Case study research at six electronics manufacturers identified that these "leading" companies assigned field service personnel to give inputs during new product development—"customer service, facilitated by a team approach, is part of the company culture"—but did not report in detail how support was evaluated at the design stage [25].
- A broad survey of NPD practices identified that field/customer service personnel were only "occasionally involved in new product work" [41].

Design for Serviceability (DFS) / Supportability (DFS-II)

Two articles in the literature discuss in detail how products should be designed to meet support requirements. In a conference article, Livingston described how Rank-Xerox consider customer support needs [35]. They recognized that total lifetime costs to the customer (usually called *cost-of-ownership*) are critical and these can be minimized by reducing the costs of each and every aspect of support. This is achieved through a design stage evaluation of installation, maintenance, repair, etc. Design goals are set for a host of factors including: ease-of-use; ease-of-cleaning; less-frequent or easier maintenance procedures which can be conducted where possible by the customer; clear failure diagnostics and; ease-of-repair (easy disassembly and re-assembly with minimum tools). Rank-Xerox found that it was necessary to have a clear management process for deciding where design priorities lie, as different departments may have opposing objectives. For example, manufacturing's objective is to reduce assembly costs, which may lead to a product which is easy to manufacture but hard to disassemble and re-assemble for support engineers at the customer site. A limitation of Livingston's article is that specific examples of the service/support goals are not given.

The second article concentrates on the serviceability aspects of product design saying "a new design idea is surfacing in the market battle for product supremacy: serviceability" [48]. DFS software is described which calculates total disassembly and re-assembly times and identifies labor and parts costs [42][48]. The software is based on the Boothroyd DFA method, extended to give estimations of not only manufacturing times but also maintenance and repair times in the field. The apparent drawback to the DFS software is that it focuses on service (maintenance and repair) aspects which are still very important for some products (cars for example) but may be less relevant to today's high-tech products. This is because new technologies are leading to ever more reliable products and the emphasis is shifting away from maintenance and repair to less tangible aspects of support such as user training or software support. These need evaluation because the associated costs are high—for example software support costs are typically 6% of revenues in the software industry [7].

THE RESEARCH

The literature review demonstrated that although product support plays a key role in the marketing of high-tech products:

- There is a lack of detailed information on when and how companies evaluate support requirements during new product development.
- Methods similar to DFM are needed for evaluating support during NPD.
- Empirical research into all aspects of product support is required

Consequently, an investigation of product support and NPD was conducted in two stages; a survey supplemented by a single case study. The survey of high-tech companies investigated two research questions:

1) How do high-tech companies evaluate support requirements during new product development?
2) Are quantitative goals used to focus the attention of the design team on service and support requirements?

The case study on support at a high-tech company was made to give a deeper understanding of the complexity of support requirements and product design. The two stages were complementary in that they gave different insights into how product support is evaluated during high-tech NPD.

METHODOLOGY—Survey Design

The survey of high-tech companies collected data on how support requirements are evaluated at the design stage. The questionnaire needed to avoid the limitations of a previous survey [13] described earlier and therefore the questions were carefully worded to avoid ambiguity. In addition, background data were collected which could be used to cross-check the significance of responses to specific questions. To illustrate how this background data was used, one question will be explained in detail.

One question investigated whether companies use quantitative goals for evaluating installation requirements during NPD. However, installation was not necessarily important for all respondents' products. Appendix A shows the question which checked whether respondents' companies set quantitative goals for installation (*Question 22)* and, in addition, *Question 10* cross-checked whether installation was important for all respondents' products. It can also be seen that Question 22 required respondents to specify the measure—providing more specific information. In general, the questionnaire aimed to identify when and how support issues are evaluated during NPD and to establish the importance of each of these issues for respondents' products.

Due to the volume of data required on respondents' companies, their products and their support planning, the survey instrument was lengthy. However, this was necessary to make a meaningful analysis. Thorough piloting of the 12 page questionnaire was conducted and it was decided to make the survey anonymous, as many of the questions were perceived by the pilot sample to be sensitive.

Sample

The sample chosen for the survey was a professional organization whose members work for high-tech companies—the Association for Services Management International (AFSMI). The UK chapter of this association has 600 members from high-tech companies (covering computing, electronics, telecommunications, medical electronics, etc.—Appendix B gives full details). The Association was chosen for the survey because the members have an special interest in support and, for an exploratory study, this was seen as a suitable group.

A series of pilot interviews with members of the Association indicated that companies were not thoroughly evaluating support at the design stage (similar to the view given in the literature). Additionally, it appeared that any evaluation at the design stage was normally limited to setting goals for improved reliability and quicker repair time—other aspects of support were normally ignored. These points were chosen to be addressed in the exploratory study.

Case Study Design

Due to the complexity of the topic, there were limitations on the level of detail which could realistically be captured with a postal questionnaire. Therefore, a second part of the research used case study methods to look at one company's approach to evaluating support. For this, a similar approach to the exploratory research of Hull and Cox [25] was adopted, namely the co-operation of an acknowledged leader in the area of product support—Hewlett-Packard (HP)—was obtained. This allowed a case study on the support aspects of one of their most successful medical products to be conducted. Good product support is particularly important for medical equipment—for instance good operator training and quick repair are essential because products are used in critical care situations. For the exploratory study, the choice of a product where support is *extremely* important was seen as a more effective approach than choosing an industry where it is less important.

The case study was conducted in 1996 by holding extensive interviews with development and marketing personnel and inspecting relevant documents (where permitted, these were copied).

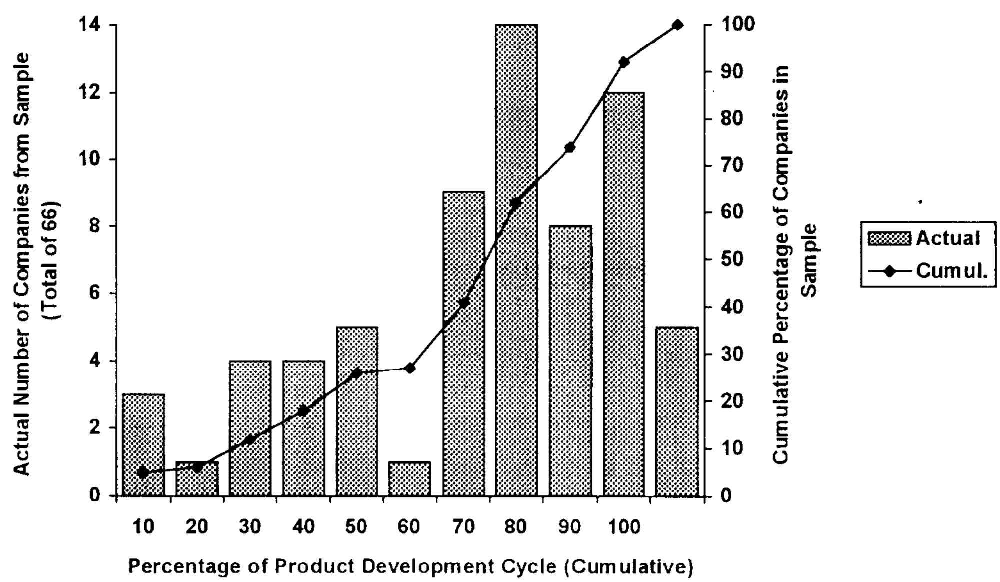
RESULTS OF THE SURVEY

Sixty-six companies responded from the 600 questionnaires mailed; a fairly low response rate (11%) but comparable to that of a similar survey of UK manufacturing industry [14]. The current survey gives the first empirical data on how companies plan support and covers 66 *different* companies. (It is interesting to note that although the survey was conducted in 1989-90 and an update is now required, no similar investigation has, to date, been published.) The key results of the survey will be discussed, including the timing and scope of support planning.

The Timing of Product Support Planning

A measure of how much emphasis is placed on evaluating product support is the time at which companies start *detailed planning* of support. Figure 1 shows the cumulative time at which planning starts, expressed as a percentage of the total product development cycle (x-axis). The y-axis has two scales. Firstly, the columns and left-hand axis show the stage in the development cycle at which companies start their detailed planning. For example, it can be seen that 3 companies start their planning in the first 10% of the development cycle and one company starts between 10 and 20% into the cycle. The y-axis has a right-hand scale for the cumulative percentage of the companies which have started their planning by each stage of the development cycle. It can be seen, for example, that after 50% of the development cycle has passed, approximately 30% (17 companies) have started their detailed planning of support issues. Consequently, as shown, 70% of companies begin their support planning in the second half of product development.

Figure 1: The Timing of the Planning of Product Support during the Product Development Cycle (Results from 66 Companies).



The Scope of the Evaluation

Two pieces of information from the survey allow a closer look at the scope of planning undertaken. The first of these is whether a formal document is used to summarize how a product will be supported and whether this document is reviewed within a company. This type of document (often called a *Product Support Plan*) is used by 53% of companies

(Table 1). It is interesting to note that this type of document is more common in the computer industry, with 82% of computer companies using this type of document compared to 43% of companies from other sectors.

Table 1: Use of Formal Support Planning Documents (At 66 High-Tech Companies).

Type of Company	Companies Using Documents	
Computer companies	15 replies	82%
Other companies	20 replies	43%
All companies	35 replies	53%

The second piece of information on the scope of support planning was the areas covered. Table 2 shows the eleven different areas, ranging from installation to upgrades, covered by companies in their evaluation of support. On average, individual companies considered seven of these areas in their support planning. However, it must be noted that, referring to Figure 1, the time at which this evaluation takes place relative to the development cycle varies widely across respondent companies. Therefore, the 71% who plan *repair philosophy* will conduct this at various stages of the development cycle.

Table 2: Areas covered in Product Support Planning.

Number	Item	Companies Planning	
1	Installation methods	51	77%
2	User training	49	74%
3	Documentation requirements	54	82%
4	Preventive maintenance methods	44	67%
5	Repair philosophy (e.g. modular, diagnostics)	47	71%
6	Spare parts requirements	57	89%
7	Field organization requirements	53	80%
8	Technical /application support required	34	52%
9	Cost of ownership	30	45%
10	Service profit	34	52%
11	Upgrades	15	22%

Quantitative Planning at the Design Stage

The previous section discussed the areas evaluated in support planning. However, the survey also established where companies set quantitative goals for product support at the design stage (similar to DFM methodology).

From Table 3 it can be seen that 23 companies (35% of sample) set quantitative goals for *Installation Time,* and 29 (44%) set goals for *Preventive Maintenance.* The significance of the results in Table 3 requires explanation. Within the limitations of the sample size, it can be seen that certain factors are evaluated by more companies at the design stage than others. Whether or not a factor is quantitatively evaluated at the design stage is an indication of the degree of formality used in product support planning. However, the use of such measures will not necessarily lead to improved supportability—the survey did not attempt to determine whether formal planning leads to better quality support. Additionally, comparing the frequencies with which various factors in Table 3 are evaluated (e.g. failure rate is evaluated twice as often as installation time), must be done with caution. Some factors may be unimportant for certain companies (e.g. disassembly/re-assembly time is irrelevant for disposable products). However, a cross-check on the results was possible using information from a section of the questionnaire which determined product characteristics.

Table 3: Use of Quantitative Goals for Serviceability / Supportability at the Design Stage.

Number	Quantitative Goals	Companies Implementing		
		Replies	Percentage	Corrected Value+
1	Installation time	23	35%	38%
2	Preventive maintenance	29	44%	44%
3	Failure rate	47	71%	74%
4	Mean-time-to-repair (MTTR)	36	55%	55%
5	Disassembly / re-assembly time	18	27%	27%
6	Mean fault diagnosis time	16	25%	25%
7	Max. number of different parts	11	17%	17%
8	Average repair price	16	24%*	24%
9	Product ease-of-use	25	39%*	39%
10	Time to train the user	13	20%*	20%
11	Cost-of-ownership	26	41%*	41%

* Valid percentages as two respondents failed to answer this question.
+ Refer to text for an explanation of the correction.

Table 3 includes a "Corrected Value" column, which was derived by considering the product characteristics. For example, 35% of respondents set quantitative goals for installation. But is installation important for all respondents' products? Another question determined that six respondents have customer-installable products—this means that installation time is relevant for 60 out of the 66 companies. Cross-checking against the product characteristics showed that 23 respondents, who have products where installation time is relevant, set installation goals. This leads to the corrected value of 38%. Similar considerations allowed the other values to be checked. Some values show no difference between the initial and corrected value. For example, all of the respondents' products do fail and so goals related to repair like *mean-time-to-repair* (MTTR) are relevant to all respondents.

Table 3 shows that at respondents' companies the most common quantitative goals are product failure rate and MTTR; these are set by 74% and 55% of companies respectively. The next most frequently used goal is for *preventive maintenance* (29 companies i.e. 44%). All other goals are used less, especially those relating to the broader aspects of supportability. For instance, goals for product ease-of-use and the amount of time to train the user are set by 39% and 20% of companies respectively.

The survey not only identified where quantitative goals are used but also collected details of the measures (see Appendix A). Therefore, the goals and measures used by the sample companies were identified in the responses. Certain responses could be discounted as non-quantitative (e.g. "guesswork"), whereas others provided substantial detail on support planning and a wide range of factors were identified. Table 4 collates all of the measures, relating them to installation, user training, maintenance, repair and upgrades—a total of 16 measures. (Note, no single company used more than half of the measures given in Table 4.)

Table 4: A Collation of Measures for Support across the Respondents' Answers.

Number	Support Aspect	Design Stage Measure	Notes
1	Installation	Time required (Human) resource / skill level Material / equipment required	Some companies use mean-time-to-install (MTTI) as a goal.
2	User training	Time to train the user Trainer's skill level	Only 20% of respondents evaluate user training.
3	Maintenance	Mean-time-between-maintenance Human resource Time per maintenance Material / equipment required	Maintenance is evaluated by 44% of the sample but none of them used all these four measures.
4	Repair	Failure rate Fault diagnosis time Mean-time-to-repair (MTTR) (Human) resource required	Failure rate and MTTR are two of the most common measures used. Fault diagnosis time was seldom used.
5	Upgrades	Time required (Human) resource required Material /equipment required	

The Effectiveness of Planning

The respondents (field service managers, quality managers, etc.—details in Appendix B) were asked to rate how well they thought their companies designed products for ease-of-support. Table 5 shows that 3% of respondents thought that this area was very well addressed at their company, 44% thought that it was "reasonably well planned" whereas 50% thought that the planning could be improved.

Table 5: The Effectiveness of Planning (At 66 High-Tech Companies).

Answer		Replies	
"Very well planned"		2	3%
"Reasonably well planned"		29	44%
"Planned, but not well enough"		18	27%
"Poorly planned"		11	17%
"Not planned at all"		4	6%
"Don't know"		2	3%
	Total	66	100%

DISCUSSION OF THE SURVEY RESULTS

The results show that some high-tech companies do not evaluate support requirements until well into the development cycle—70% do not begin until the second half of NPD (Figure 1). This result empirically confirms what has previously been speculated by several authors. A broader sample would be necessary to confirm whether this is the case in industry in general.

Is the result that support is typically considered late in the development cycle valid or could it have resulted from extraneous factors? For example, these extraneous factors could be: (a) respondents had difficulty with the wording *detailed planning* (and in fact *do* plan earlier in the product development cycle than they indicated); or (b) respondents are not involved in the early planning and therefore indicate a date later in the development cycle than when the actual planning first occurs. Alternative (a) can, in the researcher's opinion, be excluded due to evidence provided by other sections of the questionnaire. Further questions identified how support is evaluated and showed that the companies who plan earlier also tend to plan in more detail. Alternative (b) is possible and would mean that the managers surveyed were not consulted about new products. This may be the case at some companies, as 9% of respondents answered that they were not well enough informed about new products. At these companies, a superficial evaluation of support is presumably carried out by the R&D engineers or, perhaps more likely, support is neglected and service managers are not consulted (other survey responses endorse this assumption). Considering all factors, the results indicate that support evaluations are often made late in the development cycle.

The results also show that not all aspects of support are covered by companies in their planning and quantitative goals are not set for all aspects of support at the design stage. Additionally, the results indicate that the aspects of support for which quantitative goals are most frequently used are service ones. For example goals for reliability, such as annual failure rate, are more common than goals for user training.

Many respondents indicated that they thought that "planning could be improved" (Table 5). Several points have to be noted on this result. Firstly, a limitation of the question is that it only measures managers' perceptions but, for exploratory research this was seen as a valid first approach. Secondly, the sample included a large number of field service managers, as opposed to R&D managers who are more directly involved with NPD. However, if support requirements are fully considered at the design stage, then field service personnel are members of NPD teams [25]. Therefore, despite the limitations of asking managers whether support planning needs improvement, it seems likely that at 50% of sample companies improvements can be made. More data would be required to understand how improvements could be made.

A CASE STUDY: HEWLETT-PACKARD'S CMS

The case focuses on one product from the Hewlett-Packard (HP) Company—the Component Monitoring System (CMS)—a complex medical device used to monitor patients during intensive care. CMS monitors physiological signals such as the electrocardiogram and displays these signals on a screen. The name of the device is derived from the fact that various different components can be selected to make up a full monitoring system—the innovative modular design enables hospitals to choose which components best fit their requirements. CMS was designed in the mid-1980s, introduced in 1988 and six major software revisions (Revisions "A" to "F") been released to date. CMS has become the most widely used patient monitoring device in the world—and with over eighty thousand installed, customer support is a key issue.

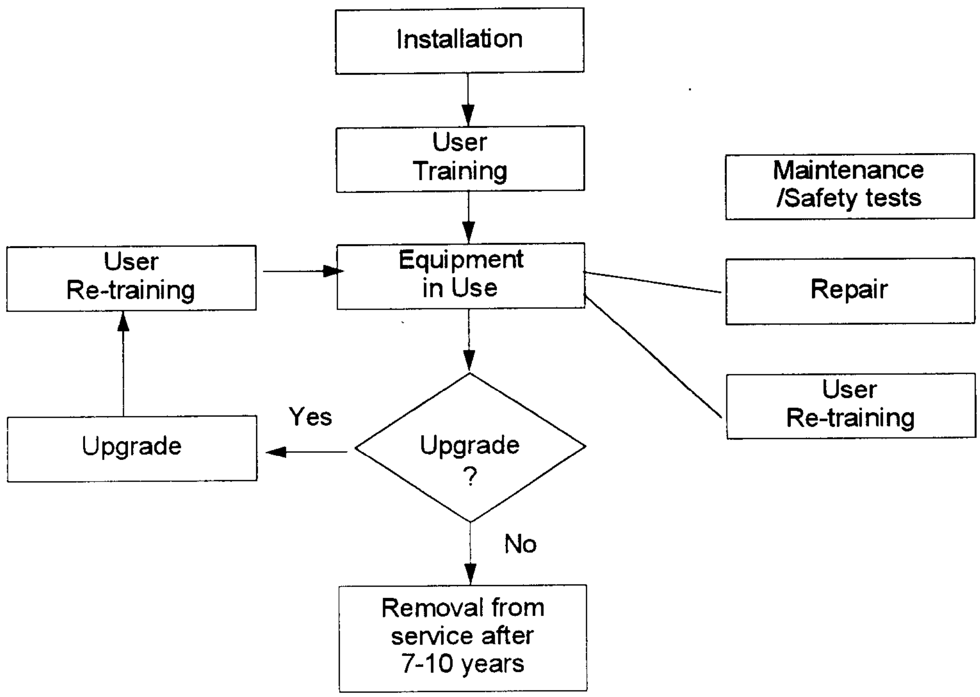
CMS is used in hospitals; a demanding environment in which product support is particularly important. Durability, product reliability and, where necessary, quick repairs are essential for obvious reasons—equipment is often used in critical care. Hospitals demand good support from manufacturers; they expect good user training, low maintenance costs and cost-effective upgrades. The medical market is increasingly cost-conscious, as governments throughout the world try to reduce healthcare costs. Consequently hospitals now look critically at the cost-of-ownership of medical equipment.

Figure 2 illustrates the main aspects of product support over the working lifetime of a CMS—medical equipment is typically used for 10 years before replacement. The product is installed by a support engineer; a complex procedure because the product requires configuration to the hospital's requirements (e.g. correct setting of alarm functions). After installation, users are normally trained by company personnel and the equipment is taken into use. The next support is usually maintenance on an annual basis, combined with safety testing which is a legal requirement for medical devices. The next aspect of support could be equipment repair (the frequency of which is determined by the failure rate). After repair, the equipment is used until further maintenance is required. Other support aspects might be the re-training of users, or training of new users. During the equipment's lifetime, it will probably be upgraded to the latest software revision 2-3 times (as indicated by company records). Therefore, upgrades are an important part of CMS support, especially since they necessitate staff re-training. From Figure 2 it can be seen that CMS product support is complex—involving various aspects which occur at different intervals over the product's lifetime. Ideally, each aspect, its relative frequency and the implications for the cost-of-ownership need to be evaluated at the design stage .

The goals of the CMS project were to develop an innovative concept, an easy to manufacture product and a fast introduction. It was developed at just the time that supportability was being recognized as a key issue by HP and suitable quantitative goals for all aspects of product support were not available (but were under investigation). This meant that CMS did not initially benefit from a full evaluation of support requirements at the design stage that would be normal for designs developed within HP today. Instead, the evaluation of support simply focused on ensuring the product was reliable and easy to repair. Consequently the only quantitative goals related to support set at the design stage were MTBF (mean-time between-failures) and MTTR (mean-time-to-repair). The importance of user training was recognized but the project goals had higher priority since development resources were constrained. Therefore, training and some other aspects of product support were not optimized by the time Rev-A was introduced. However, the product could still be supported and a high level of customer satisfaction achieved because over half the field support organization's 500 engineers were fully trained on the product within three months of first shipments.

The innovative nature of the product meant that support was significantly different to that of previous products. A manager from the project explained CMS had been optimized for easy manufacture (through DFM/A) but quantitative measures for many aspects of support were not available. He said, "We were breaking new ground and the old ways we had looked at support were invalid. CMS forced us to re-think the way we evaluated support, both at the design stage and following product introduction". Table 6 shows part of this new analysis. The main factors of CMS Rev-A support are compared to a similar product (from the preceding product generation) and the later Rev-F. Five key aspects of support are listed: installation, user training, maintenance, repair and upgrading. The third column gives data on the previous product, whereas the 4th and 5th give CMS data.

Figure 2: The Main Aspects of Product Support for the CMS Product



Installation is conducted only once and so the frequency over the lifetime is shown as "1" in Table 6, for all products (columns 3-5). If the complexity of the previous product's installation is shown as 100% then, compared to this, Rev-A was found to be much more complex (200%), resulting in higher installation costs. Part of this increase in installation complexity was due to hospitals utilizing the modularity in ways not envisaged by the marketing department. Recognition that installation was complex led to design changes (e.g. pre-configuration of the alarm settings) which subsequently made installation easier, as shown by the fact that the complexity is about 120% for Rev-F. (Note: HP do not use "complexity ratings"—they use individual measures such as the mean-time-to-install [MTTI]. However, the actual values are sensitive data which have been disguised in the ratings given.)

User training is conducted directly following installation and then as required (purchased) by hospitals. The demand for training is rising due to staff turnover and upgrades; consequently approximately 4-5 training sessions will be held over the working lifetime of a CMS (once post-installation, 2-3 post-upgrade and once for staff turnover). The previous generation of products, as shown in Table 6, normally required training only twice (once post-installation and once post-upgrade). The relative importance of user training is therefore much higher than for the previous product. During development ease-of-use was a priority but making user training easy, which is a slightly different factor, was not a focus—resources were already stretched. Since CMS monitors many complex physiological signals, it is inherently complicated and so training is time consuming. Compared to the previous product's rating of 100%, Rev-A rated 200%—some of this complexity being determined by fundamental design characteristics (hardware) which could not be changed. Although the hardware was fixed, software changes were made to simplify training on later revisions. This was particularly necessary as later revisions increased the number of physiological signals being monitored and therefore the time required for training could have further increased. Parallel to the software changes which enabled simpler training, non design-related improvements were also made; the training documentation was re-designed and a computer-based training (CBT) package was designed to run on a personal computer (PC). Although hardware limitations prevent this running directly on a CMS, nearly all intensive care units have PCs and so this package can be run to train staff. The changes in software, documentation and the CBT package mean that Rev-F training is rated at approximately 120%. Without the improvements between Rev-A and Rev-F, the costs associated with training users would have been unnecessarily high for both hospitals and HP.

Table 6: Analysis of 10 Year Lifetime Product Support of CMS Rev-A, Compared to a Previous Similar Product and Rev-F.

#	Support Factor with its Frequency[a] and Complexity[b]	Previous Similar Product	CMS Rev-A (1988)	CMS Rev-F (1995)
1	Installation—frequency —complexity	1 100%	1 200%	1 120%
2	User training—frequency —complexity	2 100%	4 -5 200%	4 -5 120%
3	Maintenance—frequency —complexity	10 100%	10 80%	10 75%
4	Repair— frequency[c] —complexity	f 100%	$f/3$ 95%	*lower*[d] 85%
5	Upgrade—frequency —complexity	1 100%	2-3 120%	2-3 50%

a - the frequency is expressed as a figure over the whole working lifetime (10 years)
b - the "complexity rating" is a composite of the actual measurements made by HP. It gives figures in relative and not actual terms, for illustrative purposes only
c - the actual product failure rates are confidential and so they are expressed relative to the old failure frequency (f) of the previous product
d - Rev-F has achieved a major improvement in reliability

The frequency of CMS maintenance is largely determined by legal requirements for regular maintenance, rather than the characteristics of the design. Therefore, Table 6 shows the maintenance frequency as 10 (i.e. once per year) for all three products. It is noteworthy that CMS design makes maintenance and safety checking easier, through built-in calibration and self-tests. Consequently, Rev-A is rated at 80% and Rev-F at 75% of the complexity of the previous product. The improvement in equipment maintainability from Rev-A to Rev-F has been achieved by evaluating how software changes can be used to simplify maintenance procedures. Due to the large installed base, even small reductions in complexity are important cost savers to both hospitals and the manufacturer.

The frequency with which a product must be repaired depends on the MTBF—one of the original support related design goals. From Table 6, it can be seen that CMS is three times more reliable (i.e. failure frequency is $f/3$) than the earlier product; thus reducing the frequency of support. In addition, another design goal was the mean-time-to-repair (MTTR) which resulted in the R&D group designing an easy to repair product.

A modular design makes repair easier than the previous product (Rev-A is rated 95%) despite CMS measuring more physiological parameters.

The last aspect of CMS support is upgrades. Since hospitals may have equipment upgraded 2-3 times, designing products for easier upgrades is important. No quantitative goals were set for "upgradability" at the design stage and Rev-A was complex to upgrade (120% compared to the previous product). At subsequent software releases, however, the whole issue of *Design for Upgradability* was fully evaluated, resulting in a much simplified upgrade procedure (Rev-F rated at 50%). The focus on making upgrades easier has reduced costs—and significant savings can be made when thousands of CMS monitors are being upgraded worldwide. Making upgrades easier has also made it possible for hospital engineers to undertake the task, thus reducing cost-of-ownership for hospitals.

Table 6 shows that, during the product life cycle of CMS, a number of aspects of support have been improved (e.g. installation). An important point to note is that the focus on improving support was partly achieved by a change in the financial reporting of product support. At the time CMS was introduced the field support organization's financial performance was reported totally separately to the division which developed and marketed the product. This meant that there was no direct financial incentive for the division to invest heavily in improving the supportability of the product. In 1990 this was changed and a new financial report "credited" the division which developed the product with the field support revenues, thus closing an important loop and providing direct financial incentive for development efforts to be channeled into making products more supportable.

Discussion of the Case

Although the case covered a hospital product—which might be perceived as an extreme case—its relevance is wider as a previous author has noted that support is critical in any industry sector where the equipment downtime (malfunction) can lead to loss of revenues [32]. Therefore, the case demonstrates some important aspects including:

- An analysis of all aspects of support over the working lifetime of a product can help to ensure that a comprehensive understanding of support costs is obtained.
- Support may have to "compete" for resources with issues such as product features during NPD. Therefore, a clear understanding of the cost implications of support is essential and a change in financial reporting may be necessary to highlight these.
- With a large installed base of products, any improvement in reducing support complexity can bring large savings.
- If aspects of support, such as training, are neglected at the design stage it may be difficult to improve them at a later date due to design constraints.

CONCLUSIONS

The research provided the first empirical evidence on how support is evaluated during high-tech NPD. Within the limitations of the exploratory sample it showed that some companies:

- Do not evaluate support requirements until well into the development cycle.
- Do not cover all areas of support in their planning and do not systematically set quantitative design goals for all aspects of product support.

The results have implications for all managers responsible for high-tech NPD. Companies in the sample (and possibly many others in high-technology industry) could do more to evaluate product support at the design stage. Just as manufacturing requirements are rigorously evaluated using DFM, supportability could be evaluated better at the design stage. The survey identified a range of measures for evaluating support (Table 4) which, if used in combination, offer a means for making a more comprehensive evaluation of support at the design stage than is current practice (no single company currently used more than half of these measures). As a consequence, the quality of product support provided by companies could be improved and potentially costs could be reduced and customer satisfaction levels improved [18].

There is wide scope for further research into product support. The current study provides researchers with an indication of where further research is necessary and gives a baseline from which this research could be developed. The three main areas where further research is necessary are:

1) The findings of the current exploratory study—the limited scope of the evaluation and the late stage at which this often takes place—need to be verified with a larger, more representative sample. The design of this survey could be based upon the research described in this article, with similar questions on the quantitative goals set at the design stage matched with cross-checks on the importance of various aspects of support. Further research could, in addition, test two hypotheses which emerged from the current study:
   a) Many high-tech companies do not evaluate support requirements until half way through the new product development cycle.
   b) The most frequently used quantitative goals focus on service aspects as opposed to broader support issues.
2) Further case studies are required to investigate the importance of support and better understand the complexity of evaluating it during NPD. One study needs to cover a sample of companies within one industry, to identify if there are significant differences in the approaches used. This would identify both typical and best practices within a sector and identify the role support plays in companies' marketing strategies. For instance, do those companies which market their support capabilities heavily make a more comprehensive evaluation of support at the design stage? In addition, a second study needs to cover cases from a range of industries, both high and low-tech. This would provide a better understanding of the role of support in NPD; both in markets where it is an essential element of marketing and in markets where it is perhaps less important.
3) Once a better understanding of support planning has been obtained, it would be possible to investigate whether better evaluation of support issues at the design stage leads to better and more cost-effective support.

Researchers have previously concluded that suitable techniques are not available for influencing new product design to ensure that customers will be satisifed with both the product and the related services (including product support) [21]. Therefore, further research into this area is not only necessary to increase the knowledge of an important aspect of high-tech NPD but also to improve management practice.

ACKNOWLEDGMENTS
The author would like to thank the Hewlett-Packard Company for their support in preparing the case study on the Component Monitoring System—particularly Dan Barton, Technical Marketing Manager at HP Andover, Mass.

APPENDIX A: Example Question from the Survey

10) How is your equipment installed ?
(Tick the most appropriate box)

[ ] By the customer himself

[ ] By one of your service personnel

[ ] No installation necessary

[ ] Other - Please specify ....

22) Which of the following measurements do you use to set **quantitative goals** for new products **during the design stage** ?

Installation time [ ] Yes [ ] No

└──── What is the typical goal for a new product? How do you measure it?
....
....

APPENDIX B: Sample Profile

Details of the respondents to the survey of the UK Association for Services Management International (AFSMI): their industry sectors, positions and characteristics of their products.

a) Replies by Industry

Computers and Personal Computers	23	(35%)
Telecommunications	13	(20%)
Medical Electronics	8	(12%)
Manufacturing Equipment	4	(6%)
Vending Machines / Systems	4	(6%)
Software	2	
Security Systems	2	
Analytical Equipment	2	
Printing Equipment	2	
Other	6	
Total	*66*	

b) Replies by Respondent's Position

Field Service Manager	42	(64%)
Technical Support Manager (Marketing)	11	(17%)
R&D Manager	2	
Quality Manager	2	
Managing Director	3	
Other	6	
Total	*66*	

c) Characteristics of Respondents' Products

Product Development Time	0.5 to 5 years (average 2 years)
Product Working Lifetimes	2.5 to 20 years (average 6 years)
Preventive Maintenance (PM) required	0 to 12 PMs per year (average 2)
Product Failures	0.5 to 40 per year (average 3)
Installation Required by Engineer?	Yes: 91% of respondents' products
Repair Performed by Service Engineer?	Yes: 89% of respondents' products

REFERENCES

[1] Anderson A. and Co. with AFSM International. Linking Service Strategy to the Bottom Line. Special report from the Association For Service Management International, Fort Myers 1988.

[2] Anthoney, M.T. and McKay, J. Balancing the Product Development Process: Achieving Product and Cycle-Time Excellence in High-Technology Industries. Journal of Product Innovation Management, Vol. 9, No. 2, June 1992, pp140-147.

[3] Armistead, C. and Clark, G. A Framework for Formulating After Sales Support Strategy. Proc. Operations Management Association UK Conference on Manufacturing Strategy, Warwick 25-26th June 1990.

[4] Athaide, G.A., Meyers, P.M. and Wilemon, D.L. Seller-Buyer Interactions During the Commercialization of Technological Process Innovations. Journal of Product Innovation Management, Vol. 13, No. 5, September 1996, pp406-421.

[5] Bancroft, C. Overlooked Aspects of Design for Manufacturability. IEEE Circuits and Devices Magazine, Vol. 4, No. 6, 1988, pp15-19.

[6] Berg, J. and Loeb, J. The Role of Field Service in New Product Development and Introduction. AFSM International-The Professional Journal, Vol. 14, No. 9, May 1990, pp25-30.

[7] Blaisdel, M. Support Enters the Twentieth Century. Info World, Vol. 12, No. 41, 1990, pp59-62.

[8] Blanchard, B.S. The Impact of Integrated Logistic Support on the Total Cost-Effectiveness of a System. Int. J. Physical Dist. & Logistics Management, Vol. 21, No. 5, 1991, pp23-26.

[9] Blumberg, D.F. A Strategic "Inside" evaluation of the European Service Market Opportunity in the 1990s. AFSM International—The Professional Journal, Vol. 16, No. 10, May 1992, pp33-44.

[10] Boothroyd, G. Design for Assembly - The Key to Design for Manufacture. Int. J. of Advanced Manufacturing Technology, Vol. 2, No. 3, 1987, pp3-11.

[11] Boothroyd, G. and Dewhurst, P. Product Design for Manufacture and Assembly Manufacturing Engineering, Vol. 100, No. 4, April 1988, pp42-46.

[12] Breiling, H-G. Qualitaet im Kundendienst (Quality in Customer Service). Management Circle Conf., 30-31st May 1990, Wiesbaden, Germany, Section 10b.

[13] Clark, G. After Sales Service in UK Manufacturing. Cranfield School of Management, UK, Working Paper April 1988.

[14] Clark, G. Chairman's Address. Proc. 1st Int. Conf. on After-Sales Success. London 29-30th November 1988, pp3-10 (ISBN 1-85423-0289).

[15] Conradson, S.A., Barford, L.A., Fisher, W.D. Weistein, M.J. and Wilker, J.D. Manufacturability Tools: An Engineer's Use and Needs. IEEE Transactions, 1988, pp85-91.

[16] Cooper, R.G. and Kleinschmidt, E.J. Major New Products: What Distinguishes the Winners in the Chemical Industry. Journal of Product Innovation Management, Vol. 10, No. 2, March 1993, pp90-111.

[17] Davidow, W.H. Marketing High Technology. The Free Press, New York 1986.

[18] Floyd, M. The Role of New Technology in Improving After-Sales Service. Proc. 1st Int. Conf. After Sales Success, London, 29-30th Nov. 1988, p39 (ISBN 1-85423-0289).

[19] Garvin, D.A. Managing Quality. The Free Press, New York, 1988.

[20] Griffin, A. Metrics for Measuring Product Development Cycle Time. Journal of Product Innovation Management, Vol. 10, No. 2, March 1993, pp112-125.
[21] Griffin, A., Gleason, G., Preiss, R. and Shevenaugh, D. Best Practice for Customer Satisfaction in Manufacturing Firms. Sloan Management Review, Vol. 36, No. 2, Winter 1995, pp87-98.
[22] Heckman, R.F. Disk Drive Reliability: Increasing Product Quality is an Industry responsibility. Proc. of "Mini/Micro 82" Conference, Anaheim USA, September 14-16, 1982, Western Periodicals Co., pp1/3[1-5] (NDN 047-0015-7720-7).
[23] Hedge, G.G. and Kubat, P. Diagnostics design: A Product Support Strategy. Eur. J. Operational Research, Vol. 38, 1989, pp35-43.
[24] Holak, S.L. and Lehmann, D.R. Purchase Intentions and the Dimensions of Innovation: An Exploratory Model. Journal of Product Innovation Management, Vol. 7, No. 1, March 1990, pp59-73.
[25] Hull, D.L. and Cox, J.F. The Field Service Function in the Electronics Industry: Providing a Link between Customers and Production/ Marketing. International Journal of Production Economics, Vol. 37, No. 1, November 1994, pp115-126.
[26] Jancsurak, J. In Their Opinion. Appliance Manufacturer, April 1995, p43-48.
[27] Johne, F.A. and Snelson, P.A. Success Factors in Product Innovation: A Selective Review of the Literature. Journal of Product Innovation Management, Vol. 5, No. 2, June 1988, pp114-128.
[28] Juran, J.M. and Gryna, F.M. Juran's Quality Control Handbook. McGraw-Hill, New York, 1988.
[29] Karmarkar, U.S. and Kubat, P. Modular Product Design and Product Support. Eur. J. Operational Res., Vol. 29, No. 1, 1987, pp74-82.
[30] Kumpe, T. and Bolwijn, P.T. Manufacturing: The New Case for Vertical Integration. Harvard Business Review, Vol. 66, No. 2, March-April 1988, pp75-81.
[31] Lawless, M.W. and Fisher, R.J. Sources of Durable Competitive Advantage in New Products. Journal of Product Innovation Management, Vol. 7, No. 1, March 1990, pp35-44.
[32] Lele, M.M. How Service Needs Influence Product Strategy. Sloan Management Review, Vol. 28, No. 1, Fall 1986, pp63-70.
[33] Lele, M.M. and Karmarkar, U.S. Good Product Support is Smart Marketing, Harvard Business Review, November-December 1983, Vol. 61, No. 6, pp124-132.
[34] Lele, M.M. and Sheth, J.N. The Four Fundamentals of Customer Satisfaction. Business Marketing, June 1988, pp80-94.
[35] Livingston, I. Design for Service. Proc. 1st Int. Conf. After Sales Success, London 29-30th November 1988, pp45-71 (ISBN 1-85423-0289).
[36] Loch, C., Stein, L. and Terwiesch, C. Measuring Development Performance in the Electronics Industry, Journal of Product Innovation Management, Vol. 13, No. 1, January 1996, pp3-20.
[37] Meldrum, M. J. Marketing High-Tech Products: The Emerging Themes. European Journal of Marketing, Vol. 29, No. 10, 1995, pp45-58.
[38] Millson, M.R., Raj, S.P. and Wilemon, D. A Survey of Major Approaches for Accelerating New Product Development. Journal of Product Innovation Management, Vol. 9, No. 1, March 1992, pp53-69.
[39] Miyakawa, S. and Ohashi, T. The Hitachi Evaluation Method. Proc. 1st Int. Conf. on Production Design for Assembly, April 1986.

[40] Moriarty, R.T. and Kosnik, T.J. High-tech Marketing: Concepts, Continuity, and Change. Sloan Management Review, Vol. 30, No. 4, Summer 1989, pp7-17.
[41] Page, A.L. Assessing New Product development Practices and Performance: Establishing Crucial Norms. Journal of Product Innovation Management, Vol. 10, No. 4, September 1993, pp273-290.
[42] Parker, K. Being Green Doesn't Have to Hurt. Manufacturing Systems, Vol. 11, No. 10, October 1993, pp31-36.
[43] Perry, J.H. A Conceptual Framework for Evaluating Capital Equipment Purchases. Journal of Purchasing and Materials Management, Winter 1987, pp32-38.
[44] Pittiglio, T. and Hoole, R. Service: A Strategic Weapon in Electronics. Electronic Business, February 15th, 1987, pp123-125.
[45] Stewart, G. Market Trends. Proc. 4th European Service Management Conference, London, 27-28th February and 1st March 1990.
[46] Stoll, H.W. Design for Manufacture. Manufacturing Engineering, January 1988, pp67-73.
[47] Stoll, H.W. and Cole, J.H. DFM Aids Manufacturing Priorities in the Design Cycle. Computerworld, Vol. 19, No. 36, September 1985, pp107-113.
[48] Teresko, J. Service now a design element. Industry Week, Vol. 243, No. 3, February 1994, pp51-52.
[49] Youssef, M.A. Design for Manufacturability and Time-to-Market; Part 1: Theoretical Foundations. International Journal of Production & Operations Management, Vol. 14, No. 12, 1994, pp6-21.

CRANFIELD SCHOOL OF MANAGEMENT
WORKING PAPER SERIES
List No 6, 1992

SWP 1/92 Mike Sweeney
"How to Perform Simultaneous Process Engineering"

SWP 2/92 Paul Burns
"The Management of General Practice"

SWP 3/92 Paul Burns
"Management in General Practice: A Selection of Articles"

SWP 4/92 Simon Knox & David Walker
"Consumer Involvement with Grocery Brands"

SWP 5/92 Deborah Helman & Adrian Payne
"Internal Marketing: Myth versus Reality?"

SWP 6/92 Leslie de Chernatony & Simon Knox
"Brand Price Recall and the Implications for Pricing Research"

SWP 7/92 Shai Vyakarnam
"Social Responsibility in the UK Top 100 Companies"

SWP 8/92 Susan Baker, Simon Knox & Leslie de Chernatony
"Product Attributes and Personal Values: A Review of Means-End Theory and Consumer Behaviour"

SWP 9/92 Mark Jenkins
"Making Sense of Markets: A Proposed Research Agenda"

SWP 10/92 Mike Sweeney & Ian Oram
"Information Technology for Management Education: The Benefits and Barriers"

SWP 11/92 Keith Thompson (Silsoe College)
"International Competitiveness and British Industry post-1992. With Special Reference to the Food Industry"

SWP 12/92 Keith Thompson (Silsoe College)
"The Response of British Supermarket Companies to the Internationalisation of the Retail Grocery Industry"

SWP 13/92 Richard Kay
"The Metaphors of the Voluntary/Non-Profit Sector Organising"

SWP 14/92 Robert Brown & Philip Poh
"Aniko Jewellers Private Limited - Case Study and Teaching Notes"

SWP 15/92 Mark Jenkins & Gerry Johnson
"Representing Managerial Cognition: The Case for an Integrated Approach"

SWP 16/92 Paul Burns
"Training across Europe: A Survey of Small and Medium-Sized Companies in Five European Countries"

SWP 17/92 Chris Brewster & Henrik Holt Larsen
"Human Resource Management in Europe - Evidence from Ten Countries"

SWP 18/92 Lawrence Cummings
"Customer Demand for 'Total Logistics Management' - Myth or Reality?"

SWP 19/92 Ariane Hegewisch & Irene Bruegel
"Flexibilisation and Part-time Work in Europe"

SWP 20/92 Kevin Daniels & Andrew Guppy
"Control, Information Seeking Preference, Occupational Stressors and Psychological Well-being"

SWP 21/92 Kevin Daniels & Andrew Guppy
"Stress and Well-Being in British University Staff"

SWP 22/92 Colin Armistead & Graham Clark
"The Value Chain in Service Operations Strategy"

SWP 23/92 David Parker
"Nationalisation, Privatisation, and Agency Status within Government: Testing for the Importance of Ownership"

SWP 24/92 John Ward
"Assessing and Managing the Risks of IS/IT Investments"

SWP 25/92 Robert Brown
"Stapleford Park: Case Study and Teaching Notes"

SWP 26/92 Paul Burns & Jean Harrison
"Management in General Practice - 2"

SWP 27/92 Paul Burns & Jean Harrison
"Management in General Practice - 3"

SWP 28/92 Kevin Daniels, Leslie de Chernatony & Gerry Johnson
"Theoretical and Methodological Issues concerning Managers' Mental Models of Competitive Industry Structures"

SWP 29/92 Malcolm Harper & Alison Rieple
"Ex-Offenders and Enterprise"

SWP 30/92 Colin Armistead & Graham Clark
"Service Quality: The Role of Capacity Management"

SWP 31/92 Kevin Daniels & Andrew Guppy
"Stress, Social Support and Psychological Well-Being in British Chartered Accountants"

SWP 32/92 Kevin Daniels & Andrew Guppy
"The Dimensionality and Well-Being Correlates of Work Locus of Control"

SWP 33/92 David Ballantyne, Martin Christopher, Adrian Payne and Moira Clark
"The Changing Face of Service Quality Management"

SWP 34/92 Chris Brewster
"Choosing to Adjust: UK and Swedish Expatriates in Sweden and the UK"

SWP 35/92 Robert Brown
"Goldsmiths Fine Foods - Case Study and Teaching Notes"

SWP 36/92 Mike Sweeney
"Strategic Manufacturing Management: Restructuring Wasteful Production to World Class"

SWP 37/92 Andy Bailey & Gerry Johnson
"An Integrated Exploration of Strategic Decision-Making"

SWP 38/92 Chris Brewster
"European Human Resource Management: Reflection of, or Challenge to, the American Concept"

SWP 39/92 Ute Hanel, Kurt Volker, Ariane Hegewisch & Chris Brewster
"Personnel Management in East Germany"

SWP 40/92 Lawrence Cummings
"Logistics goes Global - The Role of Providers and Users"

SWP 41/92 Roger Seaton & Martin Cordey-Hayes
"Interactive Models of Industrial Technology Transfer: A Process Approach"

SWP 42/92 Susan Segal-Horn
"The Logic of International Growth for Service Firms"

SWP 43/92 Mike Sweeney
"Benchmarking for Strategic Manufacturing Management"

SWP 44/92 Paul Burns
"Financing SMEs in Europe: A Five Country Study"

SWP 45/92 Robert Brown
"The Graduate Enterprise Programme - Has it been Worthwhile?"

CRANFIELD WORKING PAPERS
List No 7, 1993

SWP 1/93 John Mapes
"The Effect of Limited Production Capacity on Safety Stock Requirements for Periodic Review Inventory Systems"

SWP 2/93 Shai Vyakarnam & Alison Rieple
"Corporate Entrepreneurship: A Review"

SWP 3/93 Cliff Bowman & David Faulkner
"Pushing on a String: Uncertain Outcomes from Intended Competitive Strategies"

SWP 4/93 Susan Baker & Mark Jenkins
"The Role of Values in the Design and Conduct of Management Research: Perspectives on Managerial and Consumer Cognition"

SWP 5/93 Kevin Daniels, Leslie de Chernatony & Gerry Johnson
"Validating a Method for Mapping Managers' Mental Models of Competitive Industry Structures"

SWP 6/93 Kevin Daniels & Andrew Guppy
"Occupational Stress, Social Support, Job Control and Psychological Well-Being"

SWP 7/93 Colin Fletcher, Ruth Higginbotham & Peter Norris
"The Inter-Relationships of Managers' Work Time and Personal Time"

SWP 8/93 Mike Sweeney
"A Framework for the Strategic Management of both Service and Manufacturing Operations"

SWP 9/93 Colin Armistead & Graham Clark
"The 'Coping' Capacity Management Strategy in Services and the Influence on Quality Performance"

SWP 10/93 Ariane Hegewisch
"Equal Opportunities Policies and Developments in Human Resource Management: A Comparative European Analysis"

SWP 11/93 Paula Stanley
"Service to the Courts: The Offender's Perspective"

SWP 12/93 Mark Jenkins
"Thinking about Growth: A Cognitive Mapping Approach to Understanding Small Business Development"

SWP 13/93 Mike Clarke
"Metro-Freight: The Automation of Freight Transportation"

SWP 14/93 John Hailey
"Growing Competitiveness of Corporations from the Developing World: Evidence from the South"

SWP 15/93 Noeleen Doherty, Shaun Tyson & Claire Viney
"A Positive Policy? Corporate Perspectives on Redundancy and Outplacement"

SWP 16/93 Shai Vyakarnam
"Business Plans or Plans for Business"

SWP 17/93 Mark Jenkins, Eric le Cerf & Thomas Cole
"Defining the Market: An Exploration of Marketing Managers' Cognitive Frameworks"

SWP 18/93 John Hailey
"Localisation and Expatriation: The Continuing Role of Expatriates in Developing Countries"

SWP 19/93 Kevin Daniels & Andrew Guppy
"Reversing the Occupational Stress Process: Some Consequences of Employee Psychological Well-Being"

SWP 20/93 Paul Burns, Andrew Myers & Andy Bailey
"Cultural Stereotypes and Barriers to the Single Market"

SWP 21/93 Terry Lockhart & Andrew Myers
"The Social Charter: Implications for Personnel Managers"

SWP 22/93 Kevin Daniels, Gerry Johnson & Leslie de Chernatony
"Differences in Cognitive Models of Buyers and Sellers"

SWP 23/93 Peter Boey & Richard Saw
"Evaluation of Automated Warehousing Policies: Total Systems Approach"

SWP 24/93 John Hailey
"Training for Entrepreneurs: International Perspectives on the Design of Enterprise Development Programmes"

SWP 25/93 Tim Denison & Simon Knox
"Pocketing the Change from Loyal Shoppers: The Double Indemnity Effect"

SWP 26/93 Simon Knox
"Consumers and Grocery Brands: Searching for Attitudes - Behaviour Correspondence at the Category Level"

SWP 27/93 Simon Knox
"Processing Ideas for Innovation: The Benefits of a Market-Facing Approach"

SWP 28/93 Joe Nellis
"The Changing Structure and Role of Building Societies in the UK Financial Services Sector"

SWP 29/93 Kevin Daniels, Gerry Johnson & Leslie de Chernatony
"Similarity or Understanding: Differences in the Cognitive Models of Buyers and Sellers. A Paper outlining Issues in Mapping and Homogeneity"

SWP 30/93 Habte Selassie & Roy Hill
"The Joint Venture Formation Environment in a Sub-Saharan African Country: A Case Study of Government Policy and Host Partner Capability"

SWP 31/93 Colin Armistead, Graham Clark and Paula Stanley
"Managing Service Recovery"

SWP 32/93 Mike Sweeney
"The Strategic Management of International Manufacturing and Sourcing"

SWP 33/93 Julia Newton
"An Integrated Perspective on Strategic Change"

SWP 34/93 Robert Brown
"The Graduate Enterprise Programme: Attempting to Measure the Effectiveness of Small Business Training"

CRANFIELD WORKING PAPERS
List No 8, 1994

SWP 1/94 Keith Goffin
"Repertory Grids in Market Research: An Example

SWP 2/94 Mark Jenkins
"A Methodology for Creating and Comparing Strategic Causal Maps"

SWP 3/94 Simon Knox
"Re-engineering the Brand"

SWP 4/94 Robert Brown
Encouraging Rural Enterprise in Great Britain - Britain's "Venturecash" Competition

SWP 5/94 Andy Bytheway, Bernard Dyer & Ashley Braganza
"Beyond the Value Chain: A New Framework for Business Modelling"

SWP 6/94 Joe Nellis
"Challenges and Prospects for the European Financial Services Industry"

SWP 7/94 Keith Thompson, Panagiotis Alekos & Nikolaos Haziris
"Reasoned Action Theory applied to the Prediction of Olive Oil Usage"

SWP 8/94 Sanjoy Mukherjee & Ashley Braganza
"Core Process Redesign in the Public Sector"

SWP 9/94 Mike Sweeney
"A Methodology for the Strategic Management of International Manufacturing and Sourcing"

SWP 10/94 Ariane Hegewisch & Henrik Holt Larsen
"European Developments in Public Sector Human Resource Management"

SWP 11/94 Valerie Bence
"Telepoint: Lessons in High Technology Product Marketing"

SWP 12/94 Andy Bytheway
"Seeking Business Improvement: A Systematic Approach"

SWP 13/94 Chris Edwards & Ashley Braganza
"Classifying and Planning BPR Initiatives: The BPR Web"

SWP 14/94 Mark Jenkins & Malcolm McDonald
"Defining and Segmenting Markets: Archetypes and Research Agendas"

SWP 15/94 Chris Edwards & Joe Peppard
"Forging a Link between Business Strategy and Business Re-engineering"

SWP 16/94 Andrew Myers, Andrew Kakabadse, Colin Gordon & Siobhan Alderson
"Effectiveness of French Management: Analysis of the Behaviour, Attitudes and Business Impact of Top Managers"

SWP 17/94 Malcolm Harper
Micro-Credit - The Benign Paradox

CRANFIELD WORKING PAPERS
List No 9, 1995

SWP 1/95 Andy Bytheway
"Information in the Supply Chain: Measuring Supply Chain Performance"

~~SWP 2/95 John Ward & Joe Peppard~~
~~"Reconciling the IT/Business Relationship: A Troubled Marriage in Need of Guidance"~~

SWP 3/95 Kevin Daniels, Gerry Johnson, & Leslie de Chernatony
"Collective Frames of Reference, Recognition, and Managers' Mental Models of Competition: A Test of Two Industries"

SWP 4/95 Alison Rieple
"Staffing as a Lever of Strategic Change - The Influence of Managerial Experience, Behaviour and Values"

SWP 5/95 Grafton Whyte & Andy Bytheway
"Factors Affecting Information Systems Success"

SWP 6/95 Andy Bailey & Gerry Johnson
"The Processes of Strategy Development"

SWP 7/95 Valerie Bence
"The Changing Market for Distribution: Implications for Exel Logistics"

SWP 8/95 Valerie Bence
"The Evolution of a Distribution Brand: The Case of Exel Logistics"

SWP 9/95 Andy Bytheway
"A Review of EDI Research"

SWP 10/95 Andy Bytheway
"A Review of Current Logistics Practice"

SWP 11/95 Joe Peppard
"Broadening Visions of BPR: The Imperative of Strategic Integration"

SWP 12/95 Simon Knox & David Walker
"Empirical Developments in the Measurement of Involvement, Brand Loyalty and their Structural Relationships in Grocery Markets"

SWP 13/95 Ashley Braganza & Andrew Myers
"Issues and Dilemmas Facing Public and Private Sector Organisations in the Effective Implementation of BPR"

SWP 14/95 John Mapes
"Compatibility and Trade-Off Between Performance: An Alternative View"

SWP 15/95 Mike Sweeney & Marek Szwejczewski
"Manufacturing Standards of Performance for Success"

SWP 16/95 Keith Thompson, Nicholas Thompson & Roy Hill
"The Role of Attitudinal, Normative and Control Beliefs in Drink Choice Behaviour"

SWP 17/95 Andy Bytheway
"Information Modelling for Management"

SWP 18/95 Mike Sweeney & Marek Szwejczewski
"Manufacturing Strategy and Performance: A Study of the UK Engineering Industry"

SWP 19/95 Valerie Bence
"St.James's Hospital and Lucas Engineering Systems Ltd - A Public/Private Sector Collaboration in BPR Project A - Elective Admissions"

SWP 20/95 Valerie Bence
"St.James's Hospital and Lucas Engineering Systems Ltd - A Public/Private Sector Collaboration in BPR Project B - The Re-Organisation of Purchasing and Supplies"

SWP 21/95 Simon Knox & David Walker
"New Empirical Perspectives on Brand Loyalty: Implications for Segmentation Strategy and Equity"

CRANFIELD WORKING PAPERS
List No 10, 1996

SWP 1/96 Andy Bailey & Gerry Johnson
"Patterns of Strategy Development"

SWP 2/96 Simon Knox & David Walker
"Understanding Consumer Decision Making in Grocery Markets: New Evidence from the Fishbein Model"

SWP 3/96 Kim James, Michael Jarrett & Donna Lucas
"Psychological Dynamics and Organisational Learning: from the Dysfunctional Organisation to the Healthy Organisation"

SWP 4/96 Mike Sweeney & Marek Szwejczewski
"The Search for Generic Manufacturing Strategies in the UK Engineering Industry"

SWP 5/96 John Baker
"Agility and Flexibility: What's the Difference"

SWP 6/96 Stephen Adamson, Noeleen Doherty & Claire Viney
"30 Years On - What Have We Learned About Careers?"

SWP 7/96 Keith Goffin, Marek Szwejczewski & Colin New
"Supplier Base Management: An Empirical Investigation"

SWP 8/96 Keith Goffin
"Operations Management Teaching on European MBA Programmes"

SWP 9/96 Janet Price, Ashley Braganza & Oscar Weiss
"The Change Initiative Diamond: A Framework to Balance Business Process Redesign with other Change Initiatives"

CRANFIELD WORKING PAPERS
List No 11, 1997

SWP 1/97 Helen Peck
"Towards A Framework of Relationship Marketing: A Research Methodology"

SWP 2/97 Helen Peck
"Towards A Framework of Relationship Marketing: An Initial Case Study"

SWP 3/97 Chris Edwards & Joe Peppard
"A Critical Issue in Business Process Re-Engineering: Focusing the Initiative"

SWP 4/97 Joe Peppard and Daniel Fitzgerald
"The Transfer of Culturally-Grounded Management Techniques: The Case of Business Re-Engineering in Germany"

SWP 5/97 Claire Viney & Shaun Tyson
"Aligning HRM with Service Delivery"

SWP 6/97 Andy Bailey & Gerry Johnson
"Logical or Processual? Defining Incrementalism"

SWP 7/97 Keith Goffin

"Evaluating Customer Support Requirements
at the Product Design Stage"