COMPONENT RECONFIGURATION STRATEGIES IN A MULTI-PROJECT ENVIRONMENT: THE CASE OF MADE-TO-ORDER MARKETS

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ABSTRACT

Component reconfiguration is the process through which project-specific knowledge and technological platforms are transferred and reused within organizations. Thus far the literature failed to distinguish between two possible scenarios for component reconfiguration and reuse. One is for companies operating under the mass-production paradigm and the second is for companies operating under the made-to-order paradigm. Exploring the literature reveals that very little attention was given to reusability strategies under the made-to-order paradigm. To highlight the differences in the organization of the innovation system for component reconfiguration, four propositions are offered that examine the strategy, organizational form, management style, knowledge transfer mechanisms, and technology management practices associated with the made-to-order paradigm.

The empirical core of this study is the evidence from an in-depth study of three aerospace companies operating under the made-to-order paradigm.

The findings of this study suggest that indeed the made-to-order paradigm offers new insight into the mode of organization for component reconfiguration. Furthermore, two generic component reconfiguration strategies; *design to reuse* and *exploit product success*, were observed. The paper closes by assessing the implications for R & D managers and highlighting future research directions.

INTRODUCTION

The idea that existing designs can be exploited through reuse and reconfiguration is not new (e.g. Henderson and Clark, 1990). Recent studies have emphasized the organizational structure, project management and technology management practices, and motivational factors involved in setting up the innovation system for component reconfiguration (e.g. Cusomano and Nobeoka, 1998). The motivation to design components for reuse and reconfiguration was justified by short time to market, reduced R & D costs and higher responsiveness to customer needs (Datar et al., 1997; Nayak et al., 2000). Yet past studies have by and large focused on companies operating under the mass-production paradigm. This includes but is not limited to the white good industry, hardware and software computer sectors, and more recently the automobile industry (Nobeoka, 1995).

This paper argues that the body of knowledge on component reconfiguration may benefit from exploring similar processes in companies operating under the made-to-order paradigm. In particular, this paper raises the question: Does the organization of the innovation system for component reconfiguration in companies operating under the made-to-order paradigm differ from that in companies operating under the mass-production paradigm?

To address the above question, this paper will first outline the case for the differences between mass-production and made-to-order paradigms. Following this, four propositions will be offered stressing the case for possible differences in organizing the innovation system to component reconfiguration.

A cross-industry study of the aerospace industry in Israel will be then presented. The findings of this study suggest that the organization of the innovation system in companies operating under the made-to-order paradigm differ from that in companies operating under the mass-production paradigm.

The paper goes on to suggest R & D managers two generic component reconfiguration strategies. Finally implications for intensive R & D companies are offered and suggestions for future research are made.

INNOVATION SYSTEMS: MADE-TO ORDER AND MASS-PRODUCTION PARADIGMS

The made-to-order paradigm is unique because of contractual arrangements between the firm and the client that define the production time interval, the design, and the number of units to be produced (Dorroh et al, 1994). On the other hand, under the mass-production paradigm such decisions are almost always taken by the firm based on an assessment of future market demand. Indeed, the boundaries between these two design and production paradigms are getting blurred. More and more companies operating under the mass-production paradigm apply product development practices associated with made-to-order practices. Recent studies indicate the widening use of those practices such as, (i) close client relationships, (ii) rapid translation of customer needs into product designs, and (iii) continuous learning through rapid product modification (Datar et. al., 1997). The shift towards the management of product families has also contributed to cross-product learning in mass-production settings (Meyer et al., 1997; Meyer and Utterback, 1993) whereas driving toward mass customization capabilities through modular configuration is another "made to order" practice that may provide market domination to companies operating under the mass-production paradigm (Victor and Boynton, 1997). These product development practices assist companies operating under the mass-production paradigm to shorten product lead time (Datar et al., 1997), reduce R & D costs (Nobeoka, 1995) and be responsive to clients (Nayak et al., 2000).

It has also been suggested that companies are shifting from mass-production to mass customization approach (e.g. Kotler, 1989). In this paradigm shift companies are required to introduce different organizational structures, management styles, and learning methods (Kotha, 1995).

Nevertheless, some companies still operate under the made-to-order paradigm. Operating under this paradigm would mean some inherent limitations. Firstly, companies operating under the made-to-order paradigm cannot enjoy the efficiencies associated with the economies of scale commonly found in the mass-production paradigm. Consider an aerospace company that specializes in airborne systems as an example. Such a company may need to produce only a dozen of systems per project. Thus, companies operating under the made-to-order paradigm hardly enjoy the economies of learning associated with either the mass-production or mass-customization paradigm. Secondly, differences in functionality, features and physical dimensions between various airborne systems induced by unique client's needs and deviation in avionic platforms may also add to the limited opportunity to capitalize on economies of scale. Thirdly, the hard to predict project scheduling of new product development projects, often dictated by the rules of the tendering contractual system, may present additional challenges to management attempting to coordinate concurrent projects for cross-project learning and knowledge transfer.

Thus, in many aspects the made-to-order paradigm is different than the mass-production and mass-customization paradigms. It is in this context that we further explore whether these differences also represent deviation in the organization of the innovation system. So far, research has failed to appreciate the above-described differences and thus ignored an opportunity to develop an alternative, yet complementary, perspective of the organization of the innovation system for product development. To further explore this thread, this paper focuses on one specific product development practice namely reconfiguration and reusability of hardware and software components (Henderson and Clark, 1990) applied in the context of the made-to-order paradigm.

COMPONENT RECONFIGURATION IN MADE-TO-ORDER MARKETS: THE THEORETICAL ARGUMENT

The literature that addresses the theme of component reconfiguration and reusability is wide and diverse. Reusability of components was studied from a multi-project management perspective (Cusumano and Nobeoka, 1998), as the process of designing software modules (Banker and Kauffman, 1991) or Knowledge Management Systems that capture and retrieve information (Markus, 2001). Victor and Boynton (1998) positioned the reconfiguration and reusability of components as the highest stage in their model for internal growth, suggesting that the central theme in reusability is modularity in technology, products and processes. In essence, these studies and others refer to the same thing: the process through which project-specific components are shared by a set of projects or products (Meyer and Utterback, 1993). In this process, core concepts will be reinforced whereas linkages between core concepts and components are subject to change (Henderson and Clark, 1990). The objective of this process, from a company perspective, is the same: to reduce R & D costs, accelerate product development, improve responsiveness to customers by enhancing learning in specific areas, and achieve better integration across projects in R & D environments (Cusumano and Nobeoka, 1998).

Thus far, the literature highlighted various organizational mechanisms involved in transferring project-specific technological components mainly in companies operating under either the mass-production or the mass-customization paradigm. Some of these studies considered component reconfiguration and reusability in the semiconductor industry (e.g. Kotha, 1995; Henderson and Clark, 1990), computer hardware industry (e.g. Garud and Kumaraswamy, 1993), computer software industry (e.g. Banker and Kauffman, 1991; Balda and Gustafson, 1990), automobile industry (Clark and Fujimoto, 1993; Cusumano and Nobeoka, 1998) and the electronic products industry (Sanderson and Uzumeri, 1994; Meyer and Utterback, 1993; Cusumano, 1991). These studies emphasize a number of attributes associated with reusability such as product and system modularity (Garud and Kumaraswamy, 1995; Baldwin and Clack, 1997; Victor and Boynton, 1998), organizational modularity (Sanchez and Mahoney, 1996), product families and technological platforms (Meyer and Utterback, 1993), project management practices (Cusumano and Nobeoka, 1998), product integrity and upgradability (Garud and Kumaraswamy, 1995), the knowledge/technology transfer system and mechanisms to motivate engineers to reuse components (Cusumano, 1991; Kotha, 1995; Banker et al., 1993), and organizational forms supporting reusability (Cusumano and Nobeoka, 1998). These studies provide a descriptive framework of the organizational elements involved in reusing and reconfiguring components mainly under the paradigms of either mass-production or mass-customization.

The following sections raise four propositions concerning the strategy, organizational form, management style, and knowledge/technology transfer mechanisms related to the reusability practice. By examining and comparing internal and external contexts associated with the organization of the innovation system, the differences between companies operating under the made-to-order paradigm, on the one hand, and those that operate under the mass-production/customization paradigm, on the other hand, are evident.

Component Reconfiguration and Reusability Strategies

How do companies reconfigure and reuse components? Some guiding principles about the strategic approach toward component reconfiguration and reusability were provided by several studies. Henderson and Clark (1990:16) described the strategies involved in reconfiguring components as related to the process through which the dominant design has emerged. This may involve the continuous refinement of engineer's knowledge of the product and the development of architectural knowledge through problem solving. Another approach to the strategic reuse of technological platforms is provided by Cusumano and Nobeoka (1998) who studied multi-project environments in the automobile industry. The reuse of technological platforms was one element in the management of multi-project environments. The main conclusion of their analysis indicates that *concurrent technology transfer is the better practice for companies seeking to reuse technological platforms* (ibid.:189). Clark and

Fujimoto (1991) also focus on the need to establish a cross-project learning process that provides information on specific components to project teams prior to the design stage (see also Sanderson and Uzumeri, 1994). The long term management of product families may offer companies the opportunity to exploit efficiencies embedded in technological designs before initiating new technological exploration projects (Meyer and Utterback, 1993). One aspect in the management of product families is the coordination of concurrent projects that facilitates the possibility for technology transfer between projects.

In order for reconfiguration and reusability to be effectively executed some basic planning needs to be followed. Cusumano and Nobeoka (1998) elaborate that a careful planning of two concurrent projects with an overlapping period of two years would produce a successful transfer of technology between projects, hence leading to the reuse of components and technological platforms.

Indeed, in the context of companies operating under the paradigm of mass-production this type of project planning is a necessity. The rapid introductions of new products requires project coordination in order to exploit the benefits of transferring learning and designs from one project to another (Datar et al., 1997). This is in particular relevant in companies that plan a series of new product releases, launching sequential generic R & D projects, such as in the automobile, electronic goods and semiconductor industries.

However, when examining the launch of a new product development project in an aerospace company, planning and coordinating concurrent product development projects seems beyond management control. The launch of new product development projects under the paradigm of made-to-order is dictated by the bidding “game rules”. In a complete contrast to companies operating under the mass-production paradigm such as, Toyota, Nissan and other car manufacturers, companies operating under the made-to-order paradigm respond to calls to tender, initiate projects only after the conclusion of contract negotiations and rarely in parallel to other new product development projects. Thus, the strategic approach to reusability in companies operating under the made-to-order paradigm cannot be based on a careful planning of concurrent knowledge transfer but rather on another set of strategies unique to the contextual conditions of the made-to-order paradigm.

Proposition 1: Companies operating in made-to-order markets will develop reusability strategies that overcome their inability to exploit concurrent knowledge transfer between projects.

Knowledge/Technology Transfer Mechanisms

The study of knowledge and capabilities transfer across the firm has attracted attention in recent years (Spender, 1996; Kogut and Zender, 1992). It has been acknowledged that transferring skills is a rather difficult task because of the idea that knowledge can be tacit (Polanyi, 1966; Kogut and Zander, 1992). At the same time, some studies claim that knowledge and specific designs can be transferred between projects as it was a commodity, assuming that knowledge is accessible, codifiable and context independent (e.g. Smith 1995). For example, the study of technology transfer has paid little attention to the tacit nature of knowledge (e.g. Cusumano and Nobeoka, 1998). Nonetheless, codifying tacit knowledge is rather challenging. One demonstration of this challenge is the knowledge transformation model proposed by Nonaka and Takeouchi (1995). Another way to look at the transformation of tacit into explicit knowledge is through the interactions between individuals and groups, leading to the creation of a common language or code facilitating the sharing of knowledge within the firm (Kogut and Zander, 1992). In vertical technology transfer, e.g. from development to production, the jargon used by design and production engineers is different, posing additional problems. Thus, a successful technology transfer may require mutual adaptations between these parties (Leonard-Barton, 1999). These adaptations may include a set of higher-order organizing principles that will act as mechanisms facilitating the conditions for knowledge transfer (Kogut and Zander, 1992). We argue that the same principles are relevant for horizontal technology transfer, i.e. between project teams, because of the unique contextual and provisional nature of knowledge involved in engineering work (Blackler, 2000), making the transfer of project-specific knowledge slow, costly, and uncertain (Grant, 1992). Suggestions were made with regard to the options available to companies to ensure the transfer of unique knowledge between projects. These include the use of Knowledge Systems (Markus, 2001) that are designed to capture, store and retrieve information. Others, such as Cusumano and Nobeoka (1998) suggested a careful planning of concurrent projects to ensure the flow of information while projects are still active. Thus, in addition to project planning and information systems, companies develop a shared code and language that support mutual adaptations at the transmitting and receiving ends. This is in particular significant in companies in which project planning contributes little to knowledge and technology transfer.

Proposition 2: Companies operating under the made-to-order paradigm develop knowledge transfer mechanisms supporting the continuous adaptations of the design code across project teams.

Organizational Forms Supporting Reusability

In proposing that alternative reusability strategies may exist because of different internal and external contextual factors, one has to assume that if indeed strategy and structure are interdependent (Chandler, 1962; Hall and Saias, 1980), then the organizational form may vary as strategies change.

Yet organizations have a variety of structural forms to choose from when implementing a strategy (Olson et al., 1995:51; Hax and Majluf, 1981). This is indeed the case for organizational forms that were associated with knowledge/technology transfer. For example, the differentiated structure at Toyota studied by Cusumano and Nobeoka (1998) or the matrix structure proposed by McCollum and Sherman (1993).

Yet, the matrix organizational structure is not free of problems (Peters, 1979). One area of tension associated with the matrix structure is the struggle for higher level of authority between the project manager and the functional department manager, in particular when it comes to decisions around technical problems (Cusumano and Nobeoka, 1998:160). Yet recent years have seen a shift from the traditional matrix organizational form. Some of the mutated structures propose remedies to inherited problems in the matrix structure such as, the *Differentiated Matrix* structure in which project and functional managers share authority.

Yet the challenge for companies operating under the made-to-order paradigm is to utilize the organizational form to support the capturing, storage and retrieval of knowledge for future reconfiguration (Henderson and Clark, 1990). Research so far has paid attention to organizational forms that enhance knowledge creation, such as the 'hypertext' organizational form (Nonaka and Takeouchi, 1995:161) however little attention was given to organizational forms that facilitate the transfer of knowledge between projects. There lies a challenge to create an organizational structure that on the one hand promotes knowledge creation and on the other hand supports the transfer of knowledge. Another angle that represents the same dilemma is the investment in the build up of pool of expertise within the functional group of the matrix structure and exploring ways to disseminate these expertise across projects. Though never considered as a remedy to these challenges in past studies, some unique working structures were indeed offered. These include the role of the Chief Engineer at Toyota to oversee multiple concurrent projects thus enhancing the rapid transfer of new designs among multiple projects (Sobek et al., 1998). In addition, Toyota created a variety of working structures that operate as functional teams and support the development of design tasks across projects. Similar technology integration mechanisms were also found at Sony (Sanderson and Uzumeri, 1994). These working structures are flexible and may change according to management recognition of the degree of either inter-project or cross-functional learning required in this process. For companies operating under both paradigms, i.e. mass-production and made-to-order, these working mechanisms, as part of the organizational form, are essential for the transfer of expertise across projects. This is in particular appropriate in the case of companies operating under made-to-order markets relying on working structures to capture, store and retrieve knowledge.

Proposition 3: The organizational form in companies operating under the made-to-order (and perhaps mass-production) paradigm provides an infrastructure, through flexible technology integration structures, for the transfer of technology and knowledge across projects.

Management Style for Component Reconfiguration and Reusability

A top-down management approach is implied by past studies (e.g. Sanderson and Uzumeri, 1994; Cusumano and Nobeoka, 1998) for an effective reusability process through project planning and control.

Yet research has suggested additional approaches to management style in the context of product development. The role of networks (Tushman and Nadler, 1996; Van Aken and Weggeman, 2000) and the entrepreneur (Floyd and Wooldridge, 1999; Pfeffer and Salancik, 1978) in driving process innovations were highlighted in past research. The "organic" organization characterized as decentralized, with loosely defined roles and a high level of lateral communication was also proposed for companies needing to quickly introduce new products in changing markets (Grant, 1996). However, tension exists between maintaining the creative spirit that is needed for fostering innovations within the organization and the notion of control and efficiency. Creating conditions for creativity in products and processes requires the implementation of an "organic" organization however achieving efficiencies from the R & D and innovation process would rather promote a "mechanistic" management style. Fostering knowledge transfer between project teams relies mainly on good communication channels and strong social networks yet making the reusability process efficient and cost-effective would need a high level of management control. Consider again the aerospace company that operates under the made-to-order paradigm. Creativity indeed will require the facilitation of organizational traits associated with the organic organization. Nonetheless, project coordination, as a mean of management control, cannot be applied to this case.

Proposition 4: Companies operating under the made-to-order paradigm would tend to create a management style that encompasses characteristics fostering creativity and yet providing control over the innovation system.

Thus far, four propositions are offered suggesting that companies operating under the made-to-order paradigm face unique operational and strategic conditions, different than the contextual arrangement commonly found in companies operating under the mass-production/customization paradigm.

Three dimensions stand out as unique organizational mechanisms; management style, knowledge/transfer mechanisms, and the organizational form. These will be considered in this paper as the infrastructure of the innovation system in the context of component reconfiguration. Figure 1 illustrates the positioning of these organizational mechanisms that support the innovation infrastructure upon which component reconfiguration is achieved.

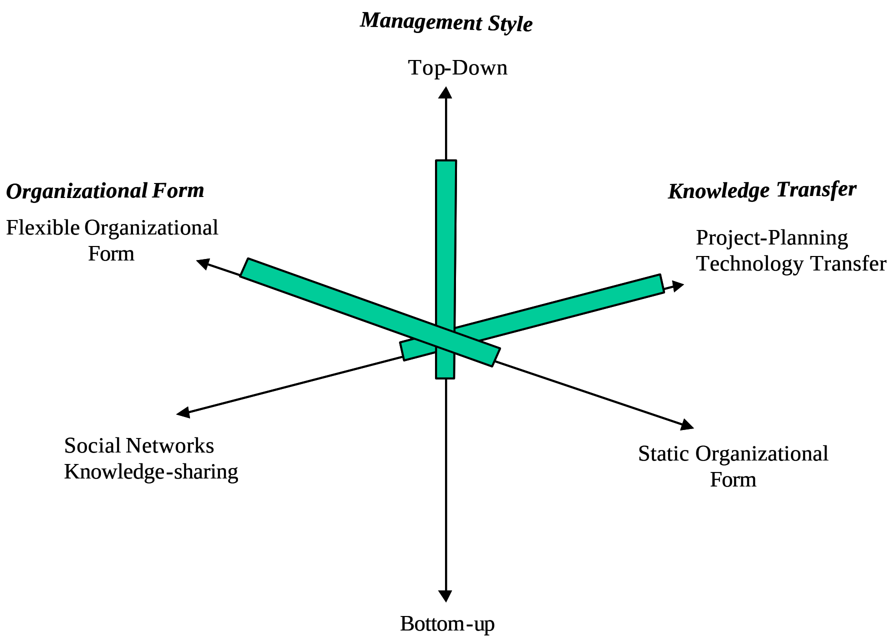

Figure 1: The Positioning of the Innovation System in Mass-Production Markets

Figure 1 suggests that companies operating under mass-production markets achieve component reconfiguration and reuse through the integration of top-down management style, well-planned project coordination, and a flexible organizational form.

With this argument, we seek to reveal the role of certain organizational mechanisms in shaping the component reconfiguration and reuse practice under the made to order paradigm.

The chief question to be addressed in the second part of this paper is: Do companies operating under the made-to-order paradigm differ from those operating in mass-production markets in the way they organize their innovation systems?

RESEARCH METHOD AND APPROACH

An in-depth study of three companies operating in the aerospace industry in Israel was carried out between 1997-2000. The aerospace industry is characterized by a line of products tailored according to the specifications of the client. In this sense, the aerospace industry operates under the made-to-order paradigm.

A two-phase study was carried out between 1997 and 2000 to examine reusability operations and strategies in companies operating under the made-to-order paradigm. Interviews were conducted with over 100 engineers, managers, and technicians involved in R & D projects.

The distinctive strength of a case study method is in its ability to deal with a variety of evidence, documents, questionnaires, interviews, and observations. In particular, in exploring an emerging field and its unknown practices, as in the example of component reconfiguration and reusability, a case study method seems highly appropriate. In other words, the study adopts Laurila's (1997: 222-223) view that "the feasibility of the case study approach is thus based mainly on the opportunities it creates for observing and describing a complicated research phenomenon in a way that allows analytical organization".

Moreover, in Yin's terminology (1989), the case study design is eminently justifiable in this particular situation because the case serves a revelatory purpose. The observation of, and insights into issues surrounding intra-firm organization of the innovation system should amount to a significant empirical contribution.

Following a pilot study with ten top managers from five leading aerospace companies in Israel, a more detailed study of the operations and strategies involved in reconfiguring and reusing technological components and platforms at three aerospace companies, Elisra, Rafael and TAMAM, was then carried out. A detailed and careful analysis made it possible to identify the organizational mechanisms involved in reconfiguring and reusing components in companies operating under the made-to-order paradigm.

CASE STUDY RESULTS: DIFFERENCES IN ORGANIZING THE INNOVATION SYSTEM FOR COMPONENT RECONFIGURATION BETWEEN MASS-PRODUCTION AND MADE-TO-ORDER PARADIGMS

Product development processes may vary from one company to another. In particular, changes in the way companies organize their innovation system, invest in particular capabilities, and develop unique competences may differ across industries providing, in some cases, a competitive edge over competitors. It is in this context that we argue that significant differences were detected between the studied companies (see Table 1). Yet, perhaps more important, significant differences were also identified between companies operating under the mass-production paradigm and those operating under the made-to-order paradigm. These differences reflect on the propositions offered above (see Figure2). The next section will reflect on propositions 2-4.

	YellowTech	TAMAM	Rafael
Organizational form	Matrix-based aligned with technology development and learning centers	Matrix-based aligned with cross-functional and vertically integrating functions	Matrix-based aligned with cross-functional teams
Knowledge/Technology transfer	Based on project planning, organizational structure and social networks	Based on the organizational structure, the System Engineer and social networks	Based on social networks and the organizational structure
Management Style toward "reconfiguration"	Top – Down	Middle - Down – Up	Bottom – Up
Technological commonality	Structured and centrally controlled	Unstructured, centrally controlled	Unstructured, loosely controlled
Modularity in design	Hardware and software, highly controlled	Software, highly controlled	Software, highly controlled
Projects organized in product families	Mixed, both project-based and program-based organization	Program-based organization	Program-based organization
Leading role in transferring technology	Chief Scientist (Leadership) Project manager (Operations)	System Engineer (Knowledge Center)	Project member (Entrepreneur)

Table 1: Main Findings from the Studied Companies

Proposition 2-4: Findings

Proposition 2: The technology transfer mechanisms in the studied companies convey an image of building a common technological infrastructure, supported by a strong sense of community, shared language and technology management practices. Knowledge transfer mechanisms under the made-to-order paradigm have focused on promoting a shared language and technological platform for transferring knowledge between projects. This was in particular enabled through the implementation of commonality and modularity practices in the studied companies. These two product development practices support the continuous code adaptation from both the transmitting and receiving projects. In practice, projects were using similar design codes and programming languages. Designing new components followed the modularity practice that enabled the exchange of technological components between projects. Projects were also organized around product families in order to stimulate a consistent design within the product family. Social interactions have played a central role in enabling the development of a shared language that has been described by engineers as the "glue behind engineering practices".

Proposition 3: The organizational forms found at the studied companies demonstrate a high level of flexibility in which working structures and vertical knowledge integration play a role in enabling knowledge transfer between projects. The organizational form utilized by the studied companies was based on a matrix structure however with the support of unique working structures that ensured the transfer of knowledge between projects. Elisra has implemented learning centers for specific technologies. TAMAM and Rafael have relied on cross-functional teams and vertical functions to transfer knowledge. These working structures and learning centers supported the capture of knowledge from one project team and enabled the dissemination of knowledge across projects in the R & D division.

Proposition 4: The management style at the studied companies has varied significantly. Yet the different management styles applied in the studied companies demonstrate management's attempt to strike a balance between controlling over the innovation process and faclitating the conditions for creativity. Evidence suggests a high level of control over the innovation system at Elisra while Rafael demonstrates a high degree of freedom towards creativity. TAMAM has pursued a middle way approach in which a middle-bottom-up management style was implemented.

Figure 2 illustrates the differences between the organization of the innovation system for component reconfiguration between companies operating under the mass-production paradigm and those under the made-to-order paradigm. It is evident that two striking differences are in the dimensions of management style and technology transfer mechanisms. Both paradigms pursue the implementation of similar organizational forms.

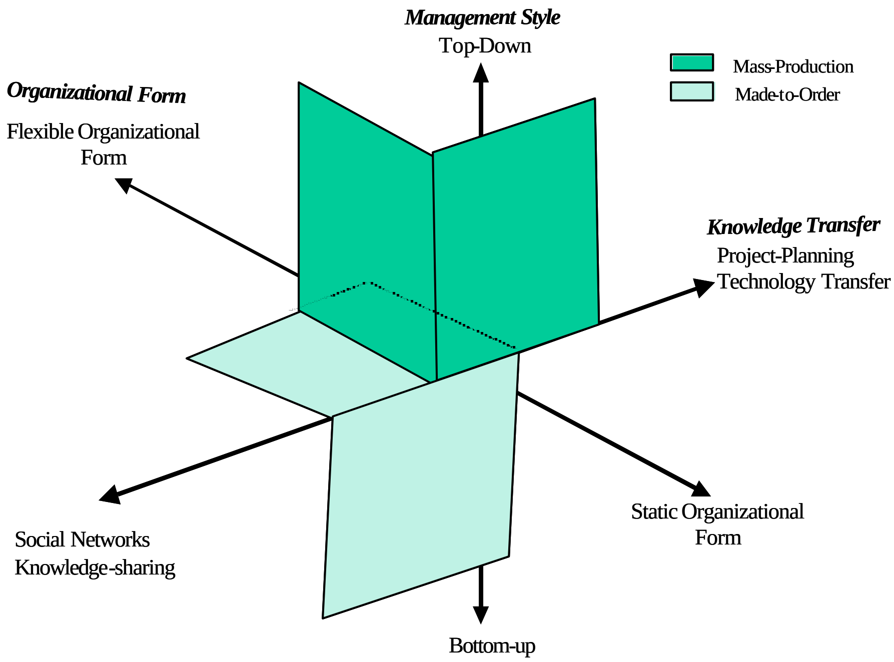

Figure 2: The Positioning of Mass-Production and Made-to-Order Innovation Systems.

PROPOSITION 4: STRATEGIES FOR COMPONENT RECONFIGURATION

Two distinct strategies to organize the innovation system for reusability are offered to R & D managers. These strategies refer to the vertical integration of technologies, components and knowledge that resides in projects. These strategies target the build up of either long- or short-term competitive advantage but can be also integrated. The strategies proposed here are:

⇒ *Design for Reuse*. This strategy aims at designing platforms and components for potential reusability in the future. The organizational and managerial capabilities supporting this strategy are aimed at setting standards to guide engineers to design components with a thought in mind that the base design will be reused in the future. For example, modularity and commonality support product design for potential reusability in the future. Another example is a Design Center (e.g. at YellowTech), which produces ASIC solutions with a view to sharing these components between projects. These capabilities aim to improve the process of reusability by introducing technological platforms that have been designed in line with some reusability procedures, tools and metrics. These organizational mechanisms are located outside the matrix structure and tend to create an infrastructure that the entire matrix structure and its elements operate upon (see Figure 3). In contrast to Cusumano and Nobeoka's (1998) proposition, which argued that in the case of new design the potential for technology transfer is low, this strategy suggests that a new design actually paves the way for an effective reusability strategy yet this scenario does confirm that new designs, particularly for reuse, require the longest lead time (ibid.:116; Clark and Fujimoto 1991).

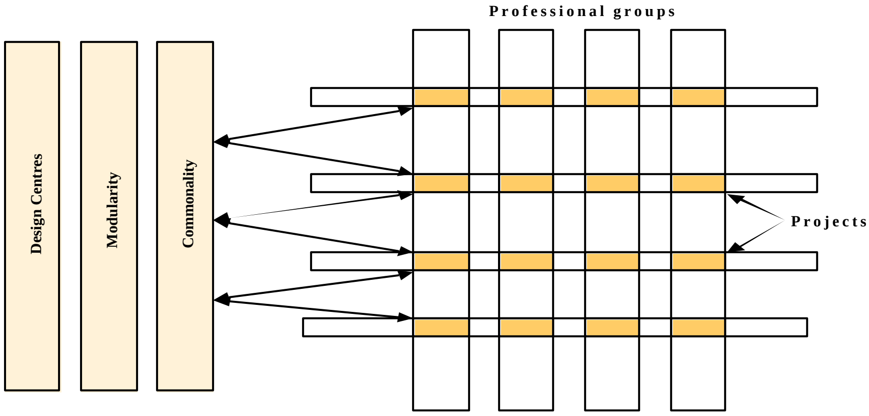

Figure 3: Mechanisms Supporting the *Design to Reuse* Strategy

⇒ *Exploit Product Success.* This strategy aims at exploiting product and technological platform success by transferring components from the base project to others. In this case, the process can be either sequential or concurrent (Cusumano and Nobeoka, 1998). The organizational capabilities that support this strategy are aimed at opening communication channels between projects, making existing solutions and technologies visible to others, and creating links between projects. Some of these capabilities are, for example, the matrix structure, knowledge transfer structure at YellowTech, interactions with clients, integration with Sales, and the horizontal coordination of concurrent engineering activities by cross-functional teams. These organizational mechanisms are within the matrix structure (see Figure 4).

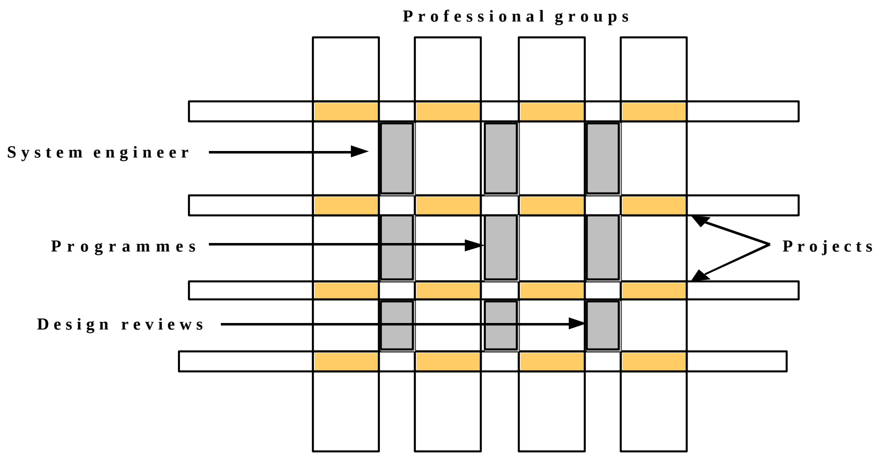

Figure 4: Mechanisms Supporting the *Exploit Product Success* Strategy

As seen above, the studied companies organized their innovation systems in three different ways. Elisra has built wide range of capabilities supporting the *exploit product success* strategy and yet introduced organizational and technological capabilities that promote the *design to reuse* strategy. Elisra has constantly perused the integration between these two strategies in order to expand reusability opportunities in new products. TAMAM has invested in developing capabilities that sustain the *exploit product success* strategy with some indications for developing capabilities that promote the *design to reuse* strategy, however lacking the integration between these two strategies (See Figure 5). Rafael invested in developing capabilities for the *exploit product success* strategy but hardly developed capabilities that support the *design to reuse* strategy (See Figure 5).

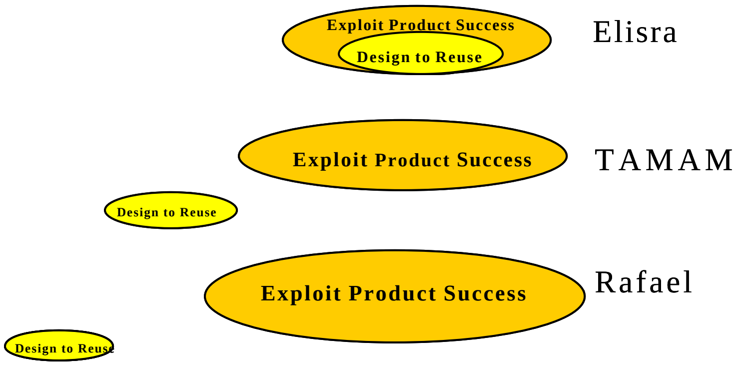

Figure 5: Reusability Strategies at Elisra, TAMAM and Rafael

COMPONENT RECONFIGURATION: FUTURE RESEARCH

The two strategies offered in this paper allow R & D managers to exploit the efficiencies that component reconfiguration and reuse may offer (Cusumano and Nobeoka, 1998). These strategies are free of any project planning considerations and neither of these strategies are tender-dependent. In a way, the proposed strategies bridge the gap between the unique contextual factors involved in designing products under either the mass-production or the made-to-order paradigm.

Yet the framework offered in this paper is induced by the in-depth study of one industry in one country. Further research in other industries and countries is needed to validate the proposed framework.

In this quest, some questions remained unresolved and thus invite further investigation and development. One fundamental question is which strategy should be core and which peripheral. In our opinion, the answer to this question is embedded in the on-going discussion about management's ability to strike a balance between exploitation and exploration activities within the firm (March, 1991).

The *design to reuse* strategy is an exploration activity in which new process innovations are introduced such as, design centers and technology management practices, changing the way the organization innovates and sustains competitiveness. The outcome of this activity, in addition to a set of reusable technological components, is also a new set of practices. On the other hand, the *exploit product success* strategy is the institution of existing practices harnessed to the effort of reusing existing solutions. As demonstrated above, most of the observed organizational capabilities associated with the *exploit product success strategy* at the studied companies were introduced well before the reusability activity has become central to the innovation system. From this perspective, the *exploit product success* strategy is an exploitation activity. Thus, the proposed reusability strategies are the two edges of the same continuum (Koza and Lewin, 1998) redirecting the discussion to the theme of striking a balance between exploitation and exploration adaptations. Yet evidence from this study suggests a tendency to invest in exploitation adaptations in order to cope with changing markets. Would this mean that the studied companies are falling into the self-destructive path in the long run in favor of immediate returns gained in a rather quick adaptation to exploitation tactics (March 1991; Levinthal and March 1993)? Such a conclusion can be drawn from a longitudinal study of reusability exploration and exploitation adaptations in the defense and other industries.

A successful application of either reusability strategy requires an appropriate organizational form, one that supports knowledge creation and yet facilitates the transfer of knowledge and technological designs to other projects. In particular, the theme of organizational form becomes crucial as competition game rules change and intensify (Volberda, 1996), as it was demonstrated in the defense industry. Thus far, the matrix organizational form has proven to be the foundation upon which new organizational forms are built such as the hypertext (Nonaka and Takeouchi, 1995), the differentiated matrix (Cusumano and Nobeoka, 1998) or perhaps the matrix/functional found at Elisra. Further research is needed to reveal additional organizational forms that support the reusability process.

Lastly, there is a need for establishing a correlation between modes of organizing for reusability and product success. Thus far, studies have attempted to establish a correlation between reusability and productivity however were mainly interested in software development projects applying Business Object practice (e.g. Banker and Kauffman, 1991). Cusumano and Nobeoka (1998), who studied the organization of the innovation system for managing multi-project environments at Toyota and other automobile manufacturers, in which reusability has played a major role, have claimed that recent years' improvement of the studied companies' competitive edge may possibly be linked to the reorganization of the innovation systems. Nevertheless, further study needs to target and identify the impact on product and market performance by specific organizational, technological, and managerial mechanisms involved in the organization of the innovation system for reusability.

CONCLUSION

In this paper we explored the concept of component reconfiguration and offered some modes of organizing innovation systems to support this practice. We also proposed R & D managers two strategies to organize the innovation system for component reconfiguration; *exploit product success* and *design to reuse*. These component reconfiguration strategies, unlike previously proposed approaches (e.g. Cusumano and Nobeoka, 1998), are generic and may be applied in both mass-production and made-to-order markets. Lastly, this paper highlights some areas stemmed from this study that are in need for further development.

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