A REVIEW OF SUCCESSFUL E-MANUFACTURING STRATEGIES

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TRACK: INTERNET-ENABLED OPERATIONS

ABSTRACT: This paper will review some of the strategies that are being successfully deployed in the field, allowing those who are implementing them to take advantage of the Internet as a powerful manufacturing integration channel between suppliers and customers. Some of the issues that will be discussed are the virtualization of the design process, product modularization, mass customization and postponement. Although some of these concepts have been around for quite a while, their implementation makes much more sense now that the Internet is a common platform for companies, their suppliers and customers to interact.

KEY WORDS: design and manufacturing strategy, virtualization, Internet.

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INTRODUCTION

Businesses that are solely based on information products that are completely digitizable can have practically all of their activities virtualized and carried out over the Web. And that should be their goal.

On the other hand, businesses that are based on physical products will still require traditional manufacturing, warehousing and transportation activities to be performed, among other more physical tasks. Sometimes, those activities become even more complex than in the past, due to changes in demand behavior and the logistics involved in producing personalized items that have to be diligently delivered directly to the end customer.

But even in the case of physical products, there is a range of activities that can make good use of the Internet's connectivity and access to the right information when it's needed, in order to create more value for the customers or simply reduce costs.

Table 1 was proposed by GRAEML, GRAEML AND EHRLICH (2002) to summarize the value-adding activities that companies have to carry out. Some of them can be virtualized, depending on the product, the production process, the degree of verticalization of the supply chain and the business model being adopted.

For many of those activities, better information may result in leaner operations, allowing for increased flexibility and time to market.

Although manufacturing it-self cannot be virtualized for physical products, as highlighted in Table 1, there is a lot that can be done, using the Internet infrastructure, to improve the value proposition for the customers or to make the operation more cost-effective.

Table 1

	product and process design	product manufacturing	materials ordering (procurement)	brand and product advertisement	customer order taking	delivery to customer	collection of payment	feedback from customer	provision of after-sales support
pure information product	Y	?	Y	Y	Y	Y	Y	Y	Y
hybrid product	?	?	Y	Y	Y	?	Y	Y	?
pure physical product	?	N	Y	Y	Y	N	Y	Y	?

Y = can be virtualized; N = cannot be virtualized; ? = sometimes can be virtualized.

INTERNET STRATEGIES FOR PRODUCT DESIGN

Agile product development has become a critical success factor in many industries. Concurrent engineering techniques, first introduced in the 80's, allow for shorter cycle times based on time overlapping of different design activities, which are executed in parallel, whenever possible (FORD AND STERMAN, 1999). But physical restrictions make it difficult for several design activities to be carried out simultaneously, as required by concurrent engineering.

In most cases, a prototype needs to be built so that the product can be tested and experimented with. Traditionally, the product has to be completely designed before it can be built.

The virtualization of design activities, which will be discussed in the following paragraphs, represents the possibility of implementing concurrent engineering and allowing for as much rehearsal with product features as possible, before a real physical prototype is built.

Virtual environments that allow for the virtualization of design activities are the result of the convergence of developments in computer digital electronic technology and visual presentation technologies (JONS, 1997).

It is becoming easier to generate realistic graphic images, with photographic quality, that can be quickly presented to other people in the team or to other teams involved in a design project.

Simulation based design

There are many benefits associated to the use of concurrent engineering, but the techniques involved require an enormous human engineering effort and have limited capability for full life-cycle cost analysis, multidisciplinary integration and optimization and for the collaboration of geographically dispersed teams (GOLDIN, VENNERI AND NOOR, 1998).

In an attempt to compensate for the shortcomings of concurrent engineering, many companies develop simulation-based-design (SBD) approaches, which simulate the entire life-cycle of the project before physical prototyping takes place. Simulations may include detailed design, prototyping, operations, maintenance and disposal of the product. They postpone the need of a physical prototype or make it completely irrelevant.

GOLDIN, VENNERI AND NOOR (1998) argue that, when engineers are immersed in a virtual design environment, they are able to create or modify their contribution to the overall project, in real time, observing the effects of their actions on the whole, immediately.

Virtual Prototyping

Virtual prototyping involves the development and experimentation with a product that doesn't yet physically exist, in a digital environment, totally based on computer usage.

The ideal virtual prototype should release design of the restrictions imposed by the requirement of a physical prototype. According to JONS (1997), a virtual prototype should allow for:

- the **design** of the product, with good visualization of its appearance and good representation of its functionality;
- the **construction** of the product (virtual prototype) without the restrictions and costs incurred when a physical prototype is created;
- product **testing** (using the virtual prototype), in order to check the performance of the real product;
- the **operation** of the product (virtual prototype), in a realistic environment and having humans in control;

Another issue that has not been mentioned by Jons, but which is also very important is:

- the possibility of **electronic distribution** of virtual prototypes, allowing for separate development teams to work together, even when they are geographically disperse.

BOSWELL (1998) considers that digital prototyping, among other new technologies, is revolutionizing the way products are designed, providing for unprecedented flexibility, through the efficient integration of data and a concurrent engineering approach. Traditional design, as reminded by Boswell, depends on the construction of several physical prototypes to be used to test and evaluate design concepts that are independent from one another. That may take a long time and increase costs to such an extent that the project may become prohibitive.

Virtual prototypes developed using 3D CAD tools can be easily virtually assembled and disassembled, allowing for more detailed studies, which can be repeated as many times as required.

The speed with which changes can be performed to virtual prototypes and the low cost of such alterations stimulate more rehearsals and tests to be carried out, with alternative part configurations. Better quality products can therefore be developed and quickly made available to the market.

For all those reasons, digital prototyping is being adopted at a fast pace by companies in the most diverse industries, especially when perfectly fitting parts are needed that are created by different development teams, working in different locations.

Virtual reality

BOSWELL (1998) believes that the study of virtual environments through a sensorial experience in which a person is immersed in a computer simulation providing him/her with visual, acoustic and tactile stimuli, may represent powerful support in design projects that involve digital prototyping. Up to now, most practical applications of virtual reality are restricted to the entertainment industry. But it may soon become an important design tool and even an efficient marketing resource, to accelerate buy-in by potential customers of products that haven't yet left the designers' desktop.

Distance collaborative design (workflow systems)

Digital prototyping and the use of simulations based on virtual prototypes allow geographically disperse design teams to work together and simultaneously on the same project. But tools are required to manage the collaborative work of different people or teams, regardless of them being in the same room or thousands of miles apart.

Work flow software can be used to integrate and aggregate the contribution of all project participants in a master model that becomes available to the whole group. That can be accomplished through visual representations and sharing of whatever data is necessary for the good flow of collaborative work.

KROO (1996) stresses that good collaborative work tools and tools for seamless communication among those involved in a design project are still difficult to find, though. There is a lot to be done in that field, from the creation of methods for managing conflicting objectives among different design teams, to the development of tools to support conceptual decisions, which have to be taken very early in the design cycle, but which dramatically impact future course of action.

Design for dynamically customizable manufacturing

There is a trend towards the customer being able to customize the functionality and the appearance of products he/she buys on-line, accessing an e-commerce site on the Web. But the design considerations involved are usually not trivial. The product and the production process have to be conceived so that customization is possible at the manufacturing or assembly stage. Production process and product design need to focus on allowing for as much flexibility as possible, during the manufacturing stage, if one intends to permit customization. The Internet empowers end customers, who are becoming able to control and configure product features prior to or during production, from the comfort of their homes.

Modularization

Modularization helps the introduction of dynamic customization and other strategies that can make operations more flexible. The concept isn't really anything new. In the 1960's STARR (1965) already argued that products should be made of pre-assembled modules in order to optimize final assembly and also contribute to diversified output, without significant impact in costs. The simplification of the assembly process, resulting from fewer modules (as compared to single parts) allows for faster assembly. Modularization also makes postponement feasible, i.e. final production/assembly can be delayed until there is demand for a specific item. That results in inventory savings. Modules can be conceived to allow for different versions of the product, which can be assembled according to the customers' diversified needs. There is more value for the customer, who can get faster delivery of more customized products. The more recent concept of mass customization becomes a powerful business proposition, when the potential of modularity is leveraged by the use of the Internet as a channel for direct communication with consumers.

Customer's involvement in design activities

Customers can be involved in the design of products in several different ways. They can be invited to tell what features and functionalities they consider important in the "product-to-be". A company may create an area in its Web site, specially dedicated to collecting customers' opinions about features included in new products being designed. They can also send electronic messages to customers of previous products, or to potential customers of new products, asking for their collaboration.

Customers may also be invited to experiment with virtual prototypes and express their impressions, in a stage when adjustments can still be performed at lower costs.

It is possible for a company to create or stimulate the creation of virtual communities of users. Virtual communities are a precious resource for information gathering and idea generation (ARMSTRONG AND HAGEL III, 1996; VENKATRAMAN AND HENDERSON, 1998).

In general, people feel happy about expressing their opinion and ideas and contributing to the design of something new. They even feel as if they were part of the development team, which makes product buy-in faster and customers more committed and loyal to the company's brand.

Customers' buy-in after contact/participation in the product's design

Exposing the customer to the product during development stages, showing its new features and the reasons why customers should be interested on it, avoids customers being lost to the competition, even when other players already have their products in the market.

Embraer, the Brazilian aircraft manufacturer, used that kind of strategy to secure orders from some European customers on a product that still didn't exist. Customers were presented to the new ERJ-170 through the use of sophisticated simulation and virtual reality tools that provided them with a good picture of what the airplane would be like. The company also used virtual reality to confirm design solutions for the installation of structural components, equipment, hydraulic plumbing and wiring. All of this helps to reduce costs and development cycles, as well as design changes later in the process, according to ERA (2002).

INTERNET STRATEGIES FOR MANUFACTURING

The Internet gives new momentum to a trend, which has been around since much before the Web became part of the business environment: the automation of production processes, particularly in the case of manufacturing companies.

Information systems allowed for more flexible automation, even with some degree of manufacturing customization, based on information made available to the manufacturing process from databases. But the Internet went much beyond that and became a common platform, shared by vendors and buyers. Customers can interact with their suppliers' data bases, and even their production processes, providing manufacturing with an astonishing new dynamic.

Dynamic customization

Some companies were already attempting to use manufacturing systems capable of customizing products to customers' specific needs as early as the beginning of the 1990's. Levi's, for example, even conceived a business model for which the customer would go to a department store, get measurements taken, choose the fabric and color for a pair of jeans and then go home and wait for the delivery of a made-to-order purchase (MCKENNA, 1995). The department store would transmit the required information to the factory from a computer terminal in the store's premises and manufacturing would happen in an absolutely demand-driven pull manner. The business model described above ended up being abandoned by Levi's, not due to market acceptance, but rather due to a conflict of interests experienced by retailers.

The Internet is providing dynamic customization initiatives with an extra push. There are many Web-sites today that allow customers to configure the product the way they want and to trigger a production order, regardless of where the customer is physically located at the moment. Auto-makers (e.g. GM's Celta, in Brazil, see CSILLAG AND SAMPAIO (2002)), bicycle manufacturers (e.g. sevencycles.com) and shirt makers (e.g. closet.com.br) are just a few examples.

There are several advantages related to the adoption of a business model based on dynamic customization, when one sees things from the supplier's angle:

- there is no requirement for finished goods inventory, as the customer buys a made-to-order product;

- as it is the customer himself/herself who defines the features and configuration of the product, there is better alignment between what s/he wants and what is made available;
- when the product that the customer gets is closer to what one wants, s/he will be willing to pay a higher price for it (there is more value for the customer);
- customers who ask for personalized orders help the supplier to achieve better understanding of market demands and, therefore, better plan for the mass market, as well.

From the customer's point of view, the main advantage is to be able to buy something that is better suited to one's specific wishes and needs. That advantage is counter-balanced by the additional effort (time and patience) required to configure the product to one's particular interest. Such effort should be kept as low as possible, so that customers are not scared away. The perception of increased value caused by the possibility of customization must be greater than the additional effort required from the customer.

For the product to be customizable to a greater extent during manufacturing time, though, it is important that product and process be designed with that purpose in mind. That's why we emphasized design considerations in the previous session.

Postponement

Modular design allows sub-sets to be mounted and kept aside until the customer reveals his/her needs or preferences. Only after that, final assembly takes place. To postpone some stages of production – especially those about which the customer may have something to say – can be an effective strategy, because it allows for customization. Since not everything needs to be done after the interaction with the customer, well thought postponement doesn't dramatically affect the delivery cycle of customized products, when compared to the delivery cycle of mass production items (CSILLAG AND SAMPAIO, 2002b).

The customer has been "spoiled" by the Internet. S/he not only wants to configure the product and order it to his/her specific needs, but also demands diligent delivery, regardless of the distances involved. That is understandable: It became very easy to choose the product, customize it and order it through the Web. The customer doesn't think of the manufacturing and logistics challenges companies face in order to produce, transport and deliver the product to his/her doorsteps with the level of service that is being demanded.

Postponement is a particularly suitable technique to reduce cycle times of customized products, helping companies to close the gap between customers' expectations and what is feasible, with respect to delivery times.

Customer triggered manufacturing

The integration between companies and their suppliers makes it possible, at least in theory, for the customers to directly interact with their suppliers' production systems, triggering the production of the items they want. Customers may also be able to stop production of items for which their own customers have cancelled orders or they may be able to change the supplier's manufacturing schedule, to give priority to the production of items that suddenly became more urgent than others.

Such level of interference in the internal processes of other companies will only be acceptable to suppliers that trust their customers and have strong common interests, because it involves giving away part of one's own autonomy, in order to increase the agility of the supply chain as a whole.

CONCLUSIONS

The ideas expressed in this paper are mainly a result of the authors' observation of what is happening in the field, based on their own personal experience and also on information they collected from other sources. The study was carried out in an exploratory, non-systematic way. The authors believe that it does not lack scientific relevance, though, because it brings light to some subtle and other more evident changes in organizations and their environment, many of which had not been anticipated by academia or business people.

One should not consider the Internet as the only factor responsible for the changes described here. Other IT advances preceded or happened along with the introduction of the Internet in the corporate environment, contributing to the e-volution. The fact that digital prototypes are not "physical" as their traditional counterparts, for example, provides them with those "magical qualities" that, according to GEOFFRION AND KRISHNAN (2001), make them perfect for the Internet. The Internet would be useless to that specific design task if other technologies were nor available, like CAD software, high-quality computer monitors, etc.

Physical constraints that made collective, shared and simultaneous work so difficult in the past are not a problem anymore. Design activities can become much more dynamic and inclusive, in the sense more people can contribute to them. As mentioned before, not only different design teams can work together on the same project from remote locations, but the customers, themselves, can interfere with the development and production of items they want, fine-tuning the product to specific requirements and starting the manufacturing process.

The Internet-driven transformation of the organizations, though radical in its promised effects, does not necessarily happen at as fast a pace as one might expect, because it is not just a technology shift. Processes have to be redesigned to take advantage of the new technology and its infrastructure. In many cases, whole businesses need to change. And such deep restructuring involves and affects the organizations and their people in profound ways. That is a good reason for serious consideration of the managerial implications of the e-volution, which is not going to take place in most organizations, if managers do not concentrate in handling arising issues that may prevent the desired changes to occur. MORTON (1988) alerts to the fact that changes in technology or business processes have to be well-balanced and aligned with relevant changes in the company's strategy, its organizational structure and its people's roles. Otherwise, the desired positive effects will not be accomplished and the change initiative will only waste people's time and generate frustration.

The evolution of the technique is fantastic. Business structures are also becoming more dynamic and adaptive to severe changes in the environment. One should not be surprised if science provided us with another of its sporadic miracles and turned teleportation into something feasible, disassembling matter in one place and re-assembling it somewhere else, as in Star Trek (GRAEML, GRAEML AND STEIL, 2001). If we convince ourselves of the feasibility of the ideas expressed by CRICHTON (2000) in his *serious* fiction book "Timeline", we should expect all of the "*no(s)*" and "*?*" in Table 1 to become sole "*yes(es)*", one day. Of course, we may have to wait longer than our life times or any business cycle until that ever happens, which, unfortunatelly, makes speculations about it of no use for business purposes, for now!

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