Sixth LACCEI International Latin American and Caribbean Conference for Engineering and Technology (LACCEI'2008)
"Partnering to Success: Engineering, Education, Research and Development"
June 4 – June 6 2008, Tegucigalpa, Honduras.

A Glance at Reconfigurable Manufacturing Systems (RMS): Possible Connotation on a Path To High Performance

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ABSTRACT

This paper uses the dynamic World Class Manufacturing (WCM) paradigm in order to present some current conditions set in stage for future implantation of Reconfigurable Manufacturing System (RMS), thus making a prelude of RMS in the WCM arena. RMS may indeed be essential for continuous improvement, but as market structure, demand and technologies continue to evolve unexpectedly (and even expectedly) over time, globalization has made difficult to gain a sustainable competitive advantage for long by just implementing such innovative systems. Consequently, making predictions for the possible performance impact of future RMS, from much of the related theoretical and empirical literature, may be risky business. Furthermore, evidence from empirical studies in WCM shows that the critical foundation is not creating a new tendency but continually improving by selecting manufacturing practices, which fit plant context, and establishing links among them. Finally, this paper makes suggestions of RMS in the context of WCM and identifies future research directions.
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Keywords: Reconfigurable Manufacturing Systems (RMS), World Class Manufacturing (WCM), Contingency.

1. INTRODUCTION

This age of fast information exchange and benchmarking has allowed for manufacturing academics and practitioners worldwide to be exposed at each moment of time with the latest production programs such as lean manufacturing, just in time (JIT), total quality (TQ), agile manufacturing, etc. Since the pioneers of these programs are usually World Class (WC) manufactures (companies that have excelled internationally), their successful stories create some kind of tendency when other manufacturers try to follow them in their subsequent attempts of implementing similar programs (best practice argument).

Reconfigurable manufacturing system (RMS), first proposed last decade, is not yet one of those stories since its required technology is still in various stages of development. This system seems to be very promising to the point of being one of the logical steps in manufacturing. However, some caution should be taken when generalizing this statement.

Even if all manufacturing contexts have indeed become turbulent and uncertain due to excessive production capability and economic globalization, it is still very improbable that when RMS is finally developed (once reconfigurable machine tools (RMTs) is made fully available), all plants in all industries will really be forced to reassess their manufacturing programs, so that this new technology system can be designed and operated efficiently in this ever-changing environment: it may not be feasible for all plants to just abandon many of their manufacturing programs in order to adopt this new manufacturing initiative.

On top of this, there seems to be a controversy about the definition of RMS. On the one hand, the majority insists RMS is an intermediate technological practice between Mass Production and Flexible Manufacturing System (FMS); some, on the other hand, argue that RMS is a manufacturing initiative which encircles lean manufacturing (a more holistic/systemic approach); and sometimes the literature may seem to suggest RMS is a new machine.

Despite of these confusions and controversies, as interest in RMS and its effect on competitive performance has grown, there has been a corresponding proliferation of research. However, all of the work on RMS seems to be characterized by having a limited focus, particularly with regard to viewing it mostly as a physical competitive resource. In addition, there seems to be no theoretical foundation for the proposition that RMS has a competitive value as part of a holistic structure within manufacturing plants. Studies pay little or no attention to contingencies (context) and linkages (both explained further below) involved in adopting and implementing RMS. Extant research does not pay enough attention to the wide multidimensional nature of the plant performance.

When taking into account these important research topics, and if plant contingencies (context) lead to RMS, there are still empirical issues to consider when implementing a new manufacturing program. For instance, RMS must be linked to current manufacturing practices. Thus, RMS cannot be an end in itself, since its high performance path does not only depend on the contingency of the plant, but also on the linkage to other practices and areas of the plant. Both, contingency and practice linkage are the key fundaments in WCM perspective.

Using part of the WCM perspective, this paper conducts a critical review on the RMSs in its possible relationship with some available WCM initiatives, starting with the ones already being used as comparison in the RMS literature such as lean manufacturing and flexible manufacturing systems (FMS). In section 2, WCM and some of their existing programs are briefly review to globally examine present conditions of contingency and linkage set in stage for reconfigurability. In section 3, a first approximation of RMS in the WCM stage is made. The starting point is the conceptualization of RMS, where Koren et al. (1999) define it along the same line of systems such as FMS. Therefore, since FMS is part of flexible automation[1] (Filippini et al., 1998; 2001), this part will explain "manufacturing technology program" from which the flexible automation is part of. In the last section, a summary is provided with some identified future research directions.

2. LITERATURE REVIEW

Improving manufacturing and design to reach world class standards has been a central theme of operations management (OM) since the term "World Class Manufacturing'' was introduced by Hayes and Wheelwright (1984). They used it to refer to Japanese, US and German manufacturers' capabilities to compete in world markets. The concept was subsequently popularized by Schonberger (1986). World-class manufacturing (WCM) was initially agreed to refer to companies that have achieved the highest level of performance in one or more strategically important areas through adopting established processes to improve how operations are managed (Hayes and Wheelwright, 1984; Voss and Blackmon, 1996; Flynn et al., 1997). These processes are constantly varying, due to worldwide changes taken place in business contexts and an operation, which causes that the conceptualization of WCM to have a dynamic and open frame reference.

Most recent WCM literature has been expanded in an empirical form. For instance, Schonberger (2001) published a book about his empirical findings in the USA. Many other empirical studios were made as part of an ongoing international research of High Performance Manufacturing (HPM). The first 150 or so articles and results from this research have been published in a book titled "High Performance Manufacturing: Global Perspectives", edited by Schroeder and Flynn in 2001. This book argues that the methods of WCM are not general purpose but rather they should be adapted to the industry and the environment for each plant. It also finds that the paths to reach WC may be different in Germany, Great Britain, Italy, Japan and United States.

An important contribution of the HPM research is the notion of the contingency approach, instead of only imitating the best practices from global competitors (Ketokivi and Schroeder, 2004). The contingency approach argues that high performing practices should be adapted and fitted to plants in their particular situations. Another

[1] The term Advance Manufacturing Technology (AMT) is used as a manufacturing subset of information technology, comprising specific technologies such as FMS.

distinctive feature of HPM is the emphasis placed on linkages among practices. It is argued that linking one practice to another is what leads to WC, and it is an ongoing need that must be continually renewed. It is not that success follows just from the number of practices that are implemented or from the latest practices, but from how they are related to each other and how they cumulatively build on one another. Linkages of practices provide the basis for binding new programs into what the plant is heading to. Another major message of the HPM research is that WC itself is an elusive target and with an elevated level of variation in plant performance. In conclusion, it is necessary that a plant carefully diagnose its situation and then set out on a deliberate path of continuous improvement. This is, of course, easier said than done, leading to an explanation of why World Class is so difficult to achieve and sustain in actual practice.

Therefore, updating the initial WCM paradigm, it can be said that it is an integrated group of processes designed to reach world competitive advantage sustained by means of continuous improvement of manufacturing capacity (Schroeder and Flynn, 2001). As a dynamic manufacturing paradigm, WCM examines, at each moment of time, manufacturing initiatives for their possible inclusion as part of manufacturing processes, depending on the contingency (context) of the plant and on the possible integration of the new initiative to what the plant is already doing, or is going to do. This dynamic view allows its particular model to be quite broad based and ever changing as it can be seen in next section.

Before continuing, it would be necessary to define the meaning of “manufacturing initiative, practice and program”. In this study, manufacturing initiative or practice is considered to be an innovative action that modifies the managerial practices and the technological and organizational systems of a company with the aim of achieving the improvement of multiple performance types, and in particular, those of time (speed), service, quality, dependability (delivery), cost, etc.. In operation management literature, there is no one single definition of “initiative”, since it is sometimes termed as “best practice” or “innovation”. Nevertheless, despite the variety of terms used, manufacturing initiatives show considerable homogeneity, to the point of being able to categorize them into three main typologies (Filippini et al., 1998): initiatives of a prevalently technological character (e.g. CAD, FMS, RMS, etc.), initiatives of a prevalently organizational character (e.g. human resource management, relationships with suppliers, total quality management), and initiatives of both technological and organizational character (e.g. lean manufacturing, agile manufacturing, concurrent engineering, JIT, etc.).

Through the implementation of manufacturing initiatives, plants can deal with the changing market environment. The manufacturing concepts within these initiatives have in common the fact that they interact with many plant functions simultaneously and cause significant change. Ultimately, the aim is to improve overall performance. There are a number of manufacturing initiatives documented in the literature that aim for such improved competitiveness. It is the responsibility of management to choose and implement those concepts that are potentially capable of achieving manufacturing objectives. Many of these manufacturing initiatives may be made out of “bundles” of inter-related and internally consistent practices, making up a practice area which may be called manufacturing program (e.g. HR program has initiatives/practices such as cooperation, training, turnover, etc.). Also, some of these initiatives may be characterized as being a subset of other or others manufacturing programs (e.g. FMS as part of Manufacturing Technology). Depending on the particular requirements of the plant, there are different multi-dimensional approaches available that encompass a wide variety of these manufacturing practices, which may be from many programs, in integrated systems such as lean production, mass customization, agile manufacturing, etc. These systems could be distinguished from each other in various ways like, for instance, the number of initiatives undertaken, a propensity towards certain types of initiatives (e.g., hard, soft, or mix).

3. RMS FOR WCM

Historically, the idea most companies are familiar with is recommending manufacturing managers to adopt each and every manufacturing initiative which appears as a tendency. This work, on the contrary, marks away from such idea, by associating to the company the concept whose focus is linking only the manufacturing practices (with or without adaptations) which jointly achieve a WC organization. But before such linkage between practices, there must be a strategic plan of contingency based in the particular situation of the company, in order to select, adapt (when needed) and implement practices, or the efforts of design will not have the desired effect (a more successful business). This process of contingence and linkage must be united with a deliberated path of continuous improvement. This approach, called World Class Manufacturing (WCM)[2], will subsequently be used to study current conditions set in stage for future implantation of RMS.

3.1. RMS: BEYOND FMS AND LEAN

The search to develop the technology for Reconfigurable Manufacturing System (RMS) started in the mid-nineties as a cost-effective response to market demands for responsiveness and customization. According to Koren et al. (1999), RMS is being designed for rapid change in structure, including both hardware and software components, in order to quickly adjust production capacity and functionality, within a part family, in response to sudden changes in market. Koren and company assess that for a manufacturing system to be readily reconfigurable, it must possess certain key characteristics which includes: i) modularity of component design, ii) integrability for both ready integration and future introduction of new technology, iii) convertibility to allow quick changeover between products and quick system adaptability for future products, iv) diagnosability to identify quickly the sources of quality and reliability problems, v) customization to match designed system capability and flexibility to applications, and vi) scalability to incrementally change capacity rapidly and economically.

NGM (1997) has made claims that new generation manufacturing systems will need new and effective tools to adapt to possibly frequent changes, new product introduction, and short runs without seriously impairing production. Thus, the motivation for introducing reconfigurable manufacturing systems is based on the belief that some economic benefits may be obtained by increasing reusability and reducing the excess capacity and/or excess functionality present in other types of manufacturing systems (ElMaraghy, 2006).

Many studies (e.g., NRC, 1998; Pham et al., 2004) have predicted that in order to stay competitive, companies must possess reconfigurable engineering technology, which promises to make future RMS cost-effective and very responsive to all market changes. Furthermore, even when RMS still is not fully operational (least yet implemented in any company) the specialized literature seems to indicate that it will certainly become a "best practice" as soon as RMS is made available. As matter of fact, proponents of this approach (e.g. Koren et al., 1999) believe that future RMS has the potential to offer a more economic solution than present flexible automation (e.g. flexible manufacturing system (FMS)) by increasing the life and utility of a manufacturing system. Some authors, such as Stecke (2005), even go further by also predicting more flexibility in future RMS.

We could go on and on about reconfigurable technology potentials, but cautious should be taken when calling RMS the newest and surest initiative or manufacturing technology to get high performance for the near future, even if it is the subject of major research efforts around the world. Although technology may be available today to achieve a useful and affordable RMS, its cost effective responsiveness argument still needs to be verified. In practical terms, this means that, when taking into account the total life cycle of the whole system needed, RMS is more cost effective responsive over time than present flexible automation technology (see Amico et al., 2003). In addition, there are at least 15 several fundamental and practical challenges remaining as open questions, which ElMaraghy (2006) lists as areas of research to complete the development of RMS.

Furthermore, even after RMS is fully operational (delivering the features it promises) there is still a fundamental question to answer: will RMS be a universal practice for all plants? The contingency argument, mentioned in this paper, has something to say about this question: it depends on the plant. Of course, this should not be an excuse for doing nothing. Therefore, as general literature suggests that global economic competition and rapid social and technological changes have forced the industry in general to face manufacturing responsiveness, what are WC manufacturers doing now globally to meet the requirements of responsiveness performance with available manufacturing practices? Will RMS help improving processes in any plant anywhere? Are all plants ready for RMS? These questions will serve as a guide for the rest of this section and this paper.

Even if all industries were to experience ever-changing environments, it is very unlikely that all plants be forced, in the short term, to reassess their manufacturing programs, so that a new technology system such as RMS can be designed and operated efficiently. It will just not be feasible for all plants to just abandon many of their

[2] Schroeder and Flynn (2001) also call it High Performance Manufacturing (HPM).

manufacturing programs in order to adopt this new manufacturing initiative. Moreover, as this paper has pointed out, there seems to be an unsolved controversy about the definition of RMS.

On the other hand, there are still other key issues to consider when implementing a new manufacturing program. For instance, Cua et al. (2006) assess that a new manufacturing program such as lean manufacturing, TQ, TPM, etc., is introduced every five to ten years as the panacea for getting high performance; and even when these programs fail in practice, the two main reasons given by many academics and practitioners are partial implementation of the programs and incompatible systems within the plant. Taking into account that most of past research primarily considers manufacturing programs in isolation, Cua and company have proposed to also consider the linkage of manufacturing programs by implementing practices common to all existing programs and linking new programs with currently practices.

Therefore, as it has been said above, reconfigurable technology cannot be an end in itself since it has to be linked to other practices and areas of a plant in the path toward high performance. For starters, the pursuit of better performance and competitive advantage force manufacturing plants not to just obtain the latest equipment but to also develop resources and capabilities that cannot be easily duplicated, and for which ready substitutes are not available. From previous work, Schroeder et al. (2002) have concluded that, in the context of the resource-based view (RBV) of the plant, WCM is more likely from: 1) internal learning such as cross-training and suggestion systems; 2) external learning such as customers and suppliers; and 3) proprietary processes and equipment; they are all developed by the plant to form such resources and capabilities. Two implications of Schroeder and his colleagues' empirical findings are that resources such as standard equipment and employees with generic skills obtainable in factor markets are not as effective in achieving high levels of plant performance, since they are freely available to competitors, and that internal and external learning play an important role in developing resources which are imperfectly imitable and difficult to duplicate.

From some of the existing programs, this paper explores the literature of world class manufacturing to globally examine present conditions of plant contingency and practice linkages set in stage for reconfigurability. Thus, the starting point for this is the conceptualization itself of RMS with two of its key issues: 1) Several authors (e.g. Koren et al., 1999) have formulated RMS as a system that revolutionizes or at least evolves from FMS, and as such it has been studied empirically as part of WCM. 2) RMS literature goes further by explicitly saying that this new system has the means of improving the performance multidimensionality of not only FMS, but also lean manufacturing and mass production. So, taking into account the fact that lean manufacturing encompasses many of the WCM programs such as JIT, TPM, HR, TQ, technology, and manufacturing strategy, this is also another key issue to consider in the present paper.

Flexible automation is an attempt to combine the advantages of fixed automation with those offered by programmed automation. Using this method, plants are able to obtain simultaneously low costs per unit and a high degree of flexibility. Flexible automation is defined as an advanced integrated system of hardware and software that makes it possible to design and produce automatically a predefined variety of products. There are various types of flexible automation besides FMS, such as automated transport and warehousing, production cells and numerical production, computer numerically controlled (CNC)/direct numerically controlled (DNC) production, etc. Due to its characteristics RMS is considered the next step of FMS, and as such it must be considered as part of flexible automation as well.

According to Goldman et al (1995), lean manufacturing is a management philosophy focusing on getting the product right the first time, continuous improvement efforts, quality in products and processes, flexible production, and minimizing waste from different sources such as in transportation, inventory, motion, waiting time, over-production, processing Itself, defective product (scrap in manufactured products or any type of business.). They also suggest that lean manufacturing has three underlying components: 1) delivering value to the customer; 2) being ready for change; 3) valuing human knowledge and skills. Since the literature relates RMS and lean manufacturing, there is a door open to regard the former as much more than hard technology.

Due to the technological nature of RMS, the next section explains the manufacturing technology program, from which the flexible automation is part of. Afterwards, Section 3.3 shows a first approach of the relationship between lean manufacturing and RMS.

3.2. MANUFACTURING TECHNOLOGY IN WCM

At the present time, next generation manufacturing systems (NGMS), expected to be better equipped to survive in new competitive environments, is hitting manufacturing with future fads, such as holonic manufacturing systems (HMS), fractal companies, autonomous and distributed manufacturing systems (ADMS), human-machine coexistence systems (HUMACS), human sensory factors for total product life cycle (HUTOP), biological manufacturing systems (BMS), etc. As far as flexibility, these future fads are leading towards reconfigurability in systems being developed such as scalable flexible manufacturing systems (SFMS) and reconfigurable manufacturing systems (RMS). The focus of our study is RMS.

Current reconfigurability literature cites the technological change toward RMS as a prerequisite for competitiveness and survivability of companies and even whole economies. However, will outstanding technological performance, such as the one RMS promises, really be a critical factor for the success of manufacturing? The answer, at first glance, would seem it will, since effective implementation and use of technology is cited as a strategic weapon in a company's battles against competition so often that everybody believes in it. But when leaving the surface and going deeper into the subject, many issues arise about getting high performance such as the implications in operations management when implementing and using a remarkable and effective technology program with its different practices and dimensions (Schroeder and Flynn, 2001).

As already explained above, from the point of view of technology (FMS), this paper considers RMS best fit as part of flexible automation, which belongs to process technology, and this last itself is one of the most important parts of technology program.

Process/manufacturing technology may be defined as the equipment and the processes for making products. The WCM literature (e.g. Maier, 1997) explains some key dimensions (which are closely related to the implementation of RMS) on how manufacturing technology may influence performance: 1) the effective use of manufacturing technology may achieve the flexibility to changes in production volume, job shop schedule, and the type of product to be manufactured, 2) the application of comprehensive systems of quality management in conjunction with the technology used in manufacturing (e.g., emphasis smoothly running machines with low deviation of tolerances, scrap, and rework as well as the use of machines with automated inspections) result in high quality products, 3) manufacturing technology (e.g., through economies of scale as well as economies of scope, low down time of equipment caused by production stoppages, low set up time, and a low percentage of rework and scrap) influences low costs, 4) process technology may help ensure a plants ability to meet customers' demands (regarding delivery on-time and short delivery times manufacturing).

In order to make a great difference in attaining WC in these dimensions, manufacturing technology must include not only “hard” aspects such as flexible automation (FMS), but also "soft" aspects such as working with suppliers to develop new technology and cross-functional cooperation within the company (Maier and Schroeder, 2001).

Beyond these important dimensions, according to WCM (Maier and Schroeder, 2001), technology program comprises the aspects of not only production (process technology or manufacturing technology), but also products (product technology) and information systems (information technology). The different aspects of technology are closely interrelated so that technology becomes a competitive weapon only if all technology dimensions are linked together in the manufacturing system of a plant. Therefore, all three dimensions are assumed to be core factors with direct and indirect impact on the competitiveness and the performance of a plant. Moreover, the effective use of technology itself is influenced by several other factors.

Even with this comprehensive view, being only the technological leader in an industry is still insufficient. In WCM, technological system of a plant is not an island because all three facets of technology must fit the plan, where they all have to be embedded in and interact. Thus, technology supports the processes in the plant, and the structures of the latter support technology at all levels of the plant: products, manufacturing processes, information technology, human resources, etc. have to fit together. In addition, the effectiveness of WCM practices is closely interrelated with technology, and it influences the success of the technological system of a plant: technology and other WCM practices together affect performance. A possible missing link between technology and other areas of a plant is an important cause of failure (Maier and Schroeder, 2001).

What a plant does (and even what a plant does not do) will reflect on its outcome. Therefore, the decision to use certain technology practices, or others, or none altogether (no action taken) always has an impact on performance. This makes room for some differences that may distinguish WC manufactures from standard manufacturers. For instance, considering the different technologies that are in use, WC manufacturers are more innovative and are more likely to introduce innovations such as CAD, CNC/DNC, FMS, or soon RMS than the standard ones.

WCM, through the HPM project (e.g. Maier and Schroeder, 2001), also suggests the importance of some specific technology practices which improve the competitiveness of process technology such as the effective implementation of new processes, considering producibility in the design phase of new product development, product design simplicity, a plant's ability to anticipate new technologies, and effective process.

However, these practices, or any manufacturing practice for that matter, will not work without a proper plant setting. Effort equilibrium is more important than being strong in most practices while failing in some strongly supporting practices. In principle, low product innovation (product technology) goes along with low innovation in manufacturing equipment (process technology). As far as high performance, the HPM project has indeed concluded that both product and process technology play well together by means of a balanced relationship found more among WC manufacturers.

In this manufacturing road for plants to get and maintain high performance, both newness of equipment (process technology) and percentage of sales from products introduced (product technology) also support this balancing idea. Although getting new equipment is important, some considerations should be taken. While WC plants seem to be using a significantly higher percentage of new manufacturing equipment, one has to be careful not to conclude that investment in new future equipment such as RMT will automatically improve performance. Although RMT may improve performance, a high percentage of new equipment has to be actively maintained by a plant. Eventually, equipment ages and, hence, the newness of the equipment is going to decline. It could be a dangerous business to use such WC plant as model to identify successful practices (Maier and Schroeder, 2001).

Therefore, investing in both manufacturing technology and new product introduction technology is fundamental toward WCM. Both approaches used together are more effective than either one of these investments by itself, since they tend to have a synergistic effect. Maier and Schroeder give the example that the manufacturing technology investment allows plants to gain some market share. However, a strategy that focuses only on manufacturing technology may not necessarily lead to continuous long term growth, unless the market grows by external forces. New products technology and the development of new markets are the only causes for sustainable, internally influenced growth. Therefore, these authors recommend that in order to support the growth processes from new product technology plants should improve manufacturing technology.

Based on the HPM analysis of plants, in a path where manufacturing practices lead to WC, plants must have both views simultaneously: broad and dynamic. The technology program helps defining this path, where each plant must follow according to its contingency, because it is simply not enough being the leader in one area of technology or another.

3.3. RMS AND LEAN

Although it may well be said that the reconfigurable context finds some support from some the essential elements from lean manufacturing or that some of it may somehow derived from lean, there are some clear divisions between the two.

Lean manufacturing is mostly seen as a simple improvement of mass production methods. RMS, on the other hand, tends to be breaking away from mass production, since it may allow the manufacture of highly customized products, when the customer needs them and the quantity required. In addition, while lean manufacturing has a production model capable of effectively operating when there are stable market conditions, it seems RMS is fit to face turbulent situations due to its high responsiveness characteristic.

Finally, the performance dimensions within lean manufacturing (LM), high efficiency and productivity, usually lead over the one of responsiveness (Yusuf et al., 1999); however, as seen above, both, efficiency and responsiveness, are of equal importance in RMS. Thus, LM may be good for long runs, but, when compared to

RMS, it is not as reactive and adaptable to the day to day affairs, or to the needs to industrialize a new product with short notices, or to adapting to a new demand. For this, the challenge is yet more agility, which may lead to reconfigurable processes that RMS seems prepared to deliver. Table 1 helps to illustrate some of the differences between present lean and future reconfigurable plants.

Table 1. Lean vs. reconfigurable plant

Lean plant	**Possible Reconfigurable plant**
Very stable and big market	Unstable, uncertain, unpredictable and competitive market
Fixed and optimized lay out in flows and runs	Easily reconfigurable lay out, optimized in visibility
Small size lot production	All production levels
Technology of general use with parts of automation: fewer equipment with relatively flexibility, little polyvalence and medium-high production (including FMS)	Reliable and reconfigurable technology: more equipment with high polyvalence, less level of production and more parallel lines.
Balanced and synchronized operations. Continuous improvement (Kaizen). Reduced times of setup and equipment change. Reduced cycle time. Waste elimination. Lot size flow. Work cells. JIT	Reconfigurable manufacturing processes. No permanent manufacturing automation. IT usage. Continuous and radical improvement. Reduced times of setup and equipment change. Reduced cycle time. Economies of scale and scope
Automated manipulation to avoid personnel	Designed manipulation to do reconfiguration
Vision of assemble to order	Permanent objective of manufacturing to order
Quality, productivity and flexibility	Flexibility for unexpected changes (reconfigurability). High responsiveness speed
Component standardization to be able to standardize processes	Process alternatives to have reconfigurability
Statistics process control (SPC) from products to processes	Diagnosibility from processes to variable capacity, functionality and convertibility of product family
Restrictive product design	Open-ended system for future products and product changes
Set of manageable products	Product solutions based upon value
Integration of automated processes	Integration of semi automated or flexibly automated but reconfigurable processes

Therefore, the context and practices differences between lean and reconfigurable plants are not that big if they are managed properly. In addition to the paradigms of contingency, integration, continuous improvement and dynamism, a lean plant (with non reconfigurable equipment) may evolve to a reconfigurable plant if it has strived to do so by taking into account the following vital issues:

1. Less emphasis on high automated processes by having more polyvalent and reconfigurable equipment: RMS.
2. More quantity of lighter equipment, and more parallel than monolithic lines to reconfigure the layout more easily. Modular installations of easy access and change: RMS.
3. Flexibility from beginning to end with very short change times from head processes to obtain high responsiveness speed: RMS.
4. Creation of a culture around alternative processes and not products.

3.4. RMS: NEW PRACTICE, NEW MACHINE OR NEW MANUFACTURING PROGRAM?

RMS plays an important role in the near future from current view points, technology program and lean manufacturing. However, as it has been shown, it is very important in a WCM path to determine whether RMS really means a new manufacturing practice, program or system or just a new machine readily available to every plant. As seen above, one reason for this is that if RMS is a new initiative, a plant must likely have to possess some special skill or capability when adopting it before its competitors do. Furthermore, after the first initiative adoption, if competitors are not to fall behind on their performance, they are then force to imitate. Because initiatives are systemic, hence very complex, they cannot simply be acquired in the same way that a plant would acquire a new machine. The initiative's process of emulation is complex, and without any assurance of success, because they demand complex efforts and long time periods for their implementation. Therefore, the differences between each plant's capabilities can prove decisive in determining the success, or failure, of the intervention undertaken. It is almost impossible for most plants to sustain the costs of investing in many areas simultaneously, so they must first decide what their priorities are and then choose (Filippini et al., 2001). In addition, once RMS is at the beginning of its cycle and only just beginning to be introduced as a practice, plants must not neglect it.

Within this agenda, it is being argued that RMS focus on new ways of designing and operating production systems by which plants will achieve cost-effective responsiveness (Koren et al., 1999). Therefore, future reconfigurable practices certainly promise to develop competitive value. However, for RMS to really have competitive value as a manufacturing system, it must be supported by a foundation which it is not secluded to the resource itself (RMT), but to the manufacturing practices (reconfigurable system) as a whole fitted in the plant. Furthermore, it must take into account the multidimensional nature of performance and the plant contingencies involved in adopting and implementing this practice (i.e., beyond the best practice argument).

4. CONCLUSIONS AND FUTURE RESEARCH

Although RMS is not yet operational and carefulness should be taking when generalizing RMS as a future best practice in manufacturing, there seems to be room for RMS, in some industrial contexts, where it may play an important role in high performance.

RMS literature establishes a comparison between RMS and FMS, as well as RMS and LM. On the other hand, WCM also confirms the importance of both FMS and LM toward high performance. Thus, RMS seems to be one of the most effective initiatives to help improving performance, but there are two important issues to consider when implanting it in the right context: 1) it must be linked to other practices in a plant to be in the right path to WCM; and 2) it is not the complete solution to meet all, or even most, of manufacturing performance dimensions, to simply substitute current manufacturing practices and systems.

In practical terms, it may well be said that there may be many RMS prototype systems already developed, most of them machine-level systems, but the specialized literature does not show any specific attempt made to operatively link an RMS to other manufacturing practices. Therfore, based on our investigations and observations, some future directions may be identified: 1) to stablish an analytical framework, providing a WCM taxonomy of lean and technology to illustrate overlapping and differences in relation to RMS; and 2) to put an emphasis on contingency and linkage to overview current manufacturing environments and practices where RMS may fit.

Acknowledgments: This research has been partly funded by the Spanish Ministry of Education and Science, project DPI2005-09210. The authors wish to acknowledge the Spanish Government for its support.

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