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## DESIGN METHODOLOGIES FOR PRODUCT ORIENTED MANUFACTURING SYSTEMS

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### ABSTRACT

This paper presents a review of design methodologies for production systems, with focus on Product Oriented Manufacturing Systems (POMS). POMS organization is discussed and compared against production systems concepts. The methodologies are described and grouped in three classes: generic, specific and focused, if they provide a generic solution like a product, a tool or a system; only one type of solution, e.g., a production system or guides through a implementation of a particular instance of a production system, e.g., Toyota Production System implementation. The focused class of the methodologies is also divided in two groups: methodologies for designing new production systems, referred as construction methodologies for production systems, and methodologies for reengineering existing systems, referred as improvement methodologies. A better grasp of production systems design needs is given through a brief introduction to the GCD design methodology developed by the authors. Moreover the GCD methodology is put in perspective showing differences and design suitability in relation to the reviewed methodologies.

**KEY WORDS:** Design methodologies; production systems design

### INTRODUCTION

A production system transforms inputs, also referred as production factors, which typically are grouped in materials, men, direct and indirect means of production, energy and information, into outputs, usually goods and/or services, information and waste.

Designing production systems is a process of fitting the production system configuration and operation to production needs arising from market demand. Although needing and important organizational efforts, this fitting is a requirement for high productivity and system efficiency and for improving order delivery and customer service. To reduce organizational and economical efforts from such fitting, faced with today's continuous change in market demands, a frequent and efficient match of production system configuration to such changes is required. The objective is to quickly respond to product variation demands in an effective and efficient manner. Due to complexity of manufacturing systems, their design and redesign is better achieved through suitable design methodologies.

Here it is presented a review of production systems design methodologies and compare the GCD methodology [1] against others, showing differences and the GCD focus and suitability for production systems design.

The next section discusses general organization structures of production systems. The third section describes and relates different production systems design methodologies with each other. Before presenting the paper conclusion, the paper briefly describes, the CGD methodology and highlights important differences in relation with the reviewed methodologies.

## **GENERIC CONFIGURATIONS OF PRODUCTION SYSTEMS**

The most common classification of the production systems have been based on their organizational structure or layout. Thus, production systems are usually grouped in two generic classes: the Function Oriented Manufacturing System (FOMS) and the Product Oriented Manufacturing System (POMS). Typical production arrangements, normally associated to these classes, are, respectively, Job-Shops (JS) and Flow Shops (FS). Nevertheless, the relation between these concepts is not necessarily bi-univocal, i.e. it may exist JS which are POMS and FS which are FOMS.

### **Function Oriented Manufacturing System**

Normally, Function Oriented Manufacturing System (FOMS) are production systems with flexible and universal equipments, typically organized in an independent way and in functional sections for manufacturing a company full range of products demanded by the market. Each functional section is deals with only one type of transformation process or function. Other processing functions required by a product are carried out in other functional sections or departments. Due to its apparent flexibility to deal with the full range of products FOMS, have been considered most adequate for dealing with demand changes and large product variety. However, in practice this is hardly the case. It has been largely demonstrated that, in spite of being adopted in industry for many years, FOMS do not perform well and has been considered obsolete [2],[3] for many years. They are unable to meet two essential requirements or objectives for companies' sustainability and competition ability in the global market of today, i.e. to enable good use of resources and, at the same time, quickly responding to customer demands.

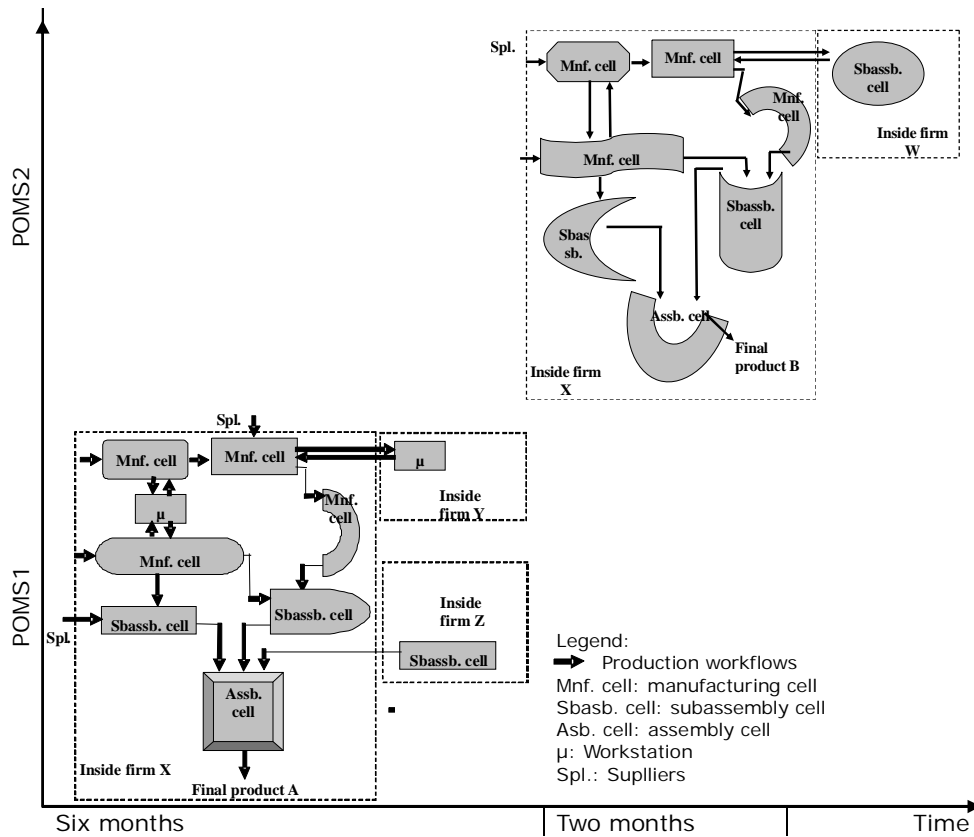
There are, at least, two important reasons for the inability of FOMS attaining these objectives. The first is the lack of manufacturing organization focus on products. The other is the highly intermittent nature of the flow of work during

manufacturing cycle due to batch production. The first reason has a severe impact on utilization of manufacturing resources and facilities and the second highly hinders the manufacturing systems ability for quickly satisfying customer orders.

### **Product Oriented Manufacturing System**

A Product Oriented Manufacturing System (POMS) is a manufacturing system configured as a set of interconnected manufacturing units, i.e. typically workstations and cells or operational configurations [1][4], which simultaneously and in a coordinated manner, addresses the manufacture of a single product model or a family of similar products. Manufacturing units of POMS may include collaborating external production partners or resources. In POMS a product may be simple, like a part, or complex, like an assembly having a multilevel product structure with several components, and may include one or both parts manufacturing and their assembly. The POM concept aims at implementing both the concepts of Simultaneous Manufacturing [5] and One-Product-Integrated-Manufacturing (OPIM) system [6], centred on the linkage and coordination of production for specific customer orders. POMS is an instance of what Skinner [7] called a focused factory. Skinner says that company manufactures better and becomes more competitive if dedicated or focused in one specific task, process or product, improving with this its productive competences and response capacity to the market demands.

According to production requirements, POMS may simply take a form of a manufacturing or assembly cell or be a more complex system. A schematic representation of two POMS is shown in FIGURE 1. This figure also shows the need to reconfigure the system after some time due to the changing market of today and to the product-customer order oriented nature of POMS, for ensuring the high levels of system operational performance. For example, in the figure the POMS1 was installed and stay unchangeable six months but the POMS2 was maintained during two months because the demand of product B changes after this time period. POMS reconfiguration can be achieved by exploring processing alternatives of products, manufacturing flexibility of machines, standardization of operating procedures, enlarged skills of operators. Processing alternatives are easily represented in processing plans [8].



**FIGURE 1. A schematic representation of a POM system**

This reconfiguration process must have in consideration or apply strategies, techniques and tools associated with Lean Manufacturing (LM) [9][10], Quick Response Manufacturing (QRM) [11] and Agile Manufacturing (AM) [12]. Both LM and QRM favour production systems organization in autonomous units or cells working under integrated coordination. AM emphasizes the importance of rapidly changing system configuration for matching processing requirements to product demand changes. AM is also highly dependent on modular production [13], which has been considered essential to product customisation [14]. Other requirements for easing POMS reconfiguration have been referred in Alves [15] and Alves and Carmo-Silva [16].

POMS can be seen as a concept suitable, not only for the repetitive production [17], but also for “Make-to-Order” (MTO) and “Engineer-to-Order” (ETO) environments. This suitability could be ensured by exploring strategies, techniques and tools associated with the already referred LM, QRM and AM paradigms.

### Advantages of POMS

Well known advantages of product focused manufacturing systems, like POMS, are their better and more efficient use of manufacturing resources, speed of production and ability to deliver products faster and of comparatively higher quality than FOMS. This is mainly due to their configuration for dealing with specific manufacturing requirements of each product or family of similar products. Moreover, POMS provide a much better environment to respond to demand changes. This is because, a clearer view of each product and related manufacturing process is offered with this organization. Due to this, when demand changes, the system provides a much better understanding of what, accordingly, has to be changed in manufacturing. Therefore POM constitutes a better environment for quickly respond to product demand changes.

The suitability of manufacturing systems for high product variety environments is linked to the quickness how they can be adapted to manufacture different products. This, essentially means, quick system reset-up or reconfiguration. Under POM systems a close relationship between manufacturing requirements of products and manufacturing system organization is established

having in mind the need for frequent reconfiguration.

### **POMS as an evolution from CM concept**

Cellular Manufacturing (CM) has been traditionally identified with the manufacture of similar parts or the assembly of similar products, i.e. having similar processing and handling requirements. Because of this, CM has been developed with basis on Group Technology (GT) theory [18][19][20][21][22]. Normally, each CM system is designed for a family of parts and rarely have been designed having into consideration the need for coordinating and synchronizing production of customer orders of specific products, from raw materials to assembly. CM usually is mostly used for repetitive manufacturing based on repetitive schemes of parts and assemblies inventory replenishment. Thus the direct and agile response to varying manufacturing requirements of customer orders under MTO and ETO has been rarely addressed.

To effectively respond to the market demand challenges of today, CM System (CMS) need to evolve further to full system integration, coordination and frequent reconfiguration for fitting and efficiently responding to the varying customer order requirements and achieving good customer service. Moreover, being able to economically manufacture a single product, not only groups of similar ones, is a goal to respond to the demand paradigms of today's global market and competition. Moving in these directions means an evolution from CMS towards POMS with a consequent reduction of the use of GT. Contributions to this evolution have been given by Black [23], with the Linked-Cell Manufacturing System concept based on the Toyota Production System [24], and also by Suri [11] with the Quick Response Manufacturing concept where manufacturing functional units coexist with manufacturing cells.

### **DESIGN METHODOLOGIES FOR SYSTEM DESIGN**

There are several approaches to the design, some more formal, others less formal. For example, the Suh's Axiomatic Theory of Design (ATD) defines design based on concepts and formal definitions [25]. According with Suh:

*"Design may be formally defined as the creation of synthesized solutions in the form of products, processes or systems that satisfy perceived needs through the mapping between the Functional Requirements (FR) in the functional domain and the Design Parameters*

*(DP) of the physical domain, through the proper selection of DPs that satisfy FRs" [25]*

Beyond this, other approaches of generic application include the Extended General Design Theory by Tomiyama and Yoshikawa [26], Robust Design of Taguchi [27], Theory of Inventive Problem Solving (TRIZ) by Altshuller [28], Workshop Design Konstruktion school (WDK) by Hubka and Eder [29] and Total Quality Development (TQD) by Clausing [30].

These last three and the ATD were synthesized and compared in Tate e Nordlund [31]. These authors present the different motivations behind these methodologies. These, in some cases referred as theories, guide the designer and reduce the complexity and effort of the design process [32]. Essentially they structure the design process in a sequence of design steps leading to solutions to satisfy user requirements, i.e. design objectives. Thus functional specifications are initially determined, having into account several types of restrictions, typically of technological, economical and organizational level, and then, based on them, alternative design solutions are generated and submitted to an evaluation process.

Good design solutions are generated, at each design phase, based on data, methods and tools that a design methodology should effectively point out and guide and simplify the access to the designer. However, a methodology do not search for solutions but shows the best way to approach specific problems, searching the paths to reach solutions, including guidance in the research process and in the collection of data/information for better decisions at a specific moment in space and time [33].

A frequent criticism made to methodologies is its limited contribution to design efficiency and effectiveness. Apparently this is due to the some methodologies to be too general and to attempt to tackle broad design problems in a coupled way through complex and large number of activities and tools. This tends to be difficult and hinder flexibility to make design changes [34].

There are design methodologies of wide application to design problems and others are rather focused. The wide application of a methodology could be its weakness. This is because it tends to be slow to reach good design solutions to specific design problems. This is sometimes the result of the complexity and inability of use by a wide body of designers. Only experts are likely to be able to use them. On the other hand, this general application of a methodology may be also its advantage. This is

so, particularly when such a methodology can work at a meta-methodology level, supporting the design of more specific or focused methodologies. Examples of these, based on the quite general ATD methodology of Suh, are the methodologies of production system design, developed by Carrus and Cochran [35]; Cochran et al. [36][37]; Cochran and Dobbs [38] and Suh et al. [39], the Babic's methodology [40] and the Kulak's methodology [41]. Other examples are the production systems design methodologies of Rao and Gu [42] and REALMS methodology [43].

The orientation of a methodology for the design in a specific problem area makes it more practical, quick and effective to reach viable design solutions.

It is in the design process that production systems operating performance is ensured. For this, design must be rational, structured and also detailed. This contributes to avoid errors that at design level can be costly. So, POMS design should be based on methodologies which satisfy such requirements. Moreover, the relevant elements, i.e. data, tools and methods necessary for design and the provision for generating suitable alternatives at design phases should be ensured. Eventually under this specific design area, a set of POMS alternative configurations should be put forward for analysis under the methodology. This can enhance a POMS design methodology. POMS methodologies that do not provide a view on possible arrangements for study and analysis or that are too focused on a specific physical or operational arrangement may not ensure the operating performance levels that otherwise could be achieved for a POMS. In fact, a production system should not be designed with basis on a specific system organization that has not been submitted to analysis and evaluation scrutiny. In the following section are described some methodologies that are considered of being of this type, i.e., focused methodologies.

### **Design methodologies for POMS configurations**

The design of POMS or its elements, for example, cells or operational configurations, had been, in the past, approached in a partial way, i.e., without a holistic approach to system design. Typical of these is the seminal work on Group Technology (GT) by Mitrofanov in 1959 [44]. Due to their popularity, importance and, to a great extent, their suitability for POMS design, the following methodologies deserve special reference: PFA - Production Flow Analysis (PFA) methodology [18], Toyota Production System

(TPS) [24] and Integrated Manufacturing Production System (IMPS) [23]. Some other methods techniques, procedures and approaches or frameworks, all referred here as methodologies, that can be used for production systems design and may, to some extent, be applied to POMS, are referred by name or author(s) name, and include: Ingersoll Engineers [45], Massay [46], Quick Response Manufacturing (QRM) [11], Silveira [47], Babic [40], Hyer and Wemmerlov [48], Kulak [41] and Fraser et al. [49].

The referred design methodologies have different design purposes and are supported in specific or dedicated design mechanisms. Thus, e.g. some are oriented to reengineering company processes. These include PFA, TPS, Black, Suri, Kulak and Fraser, addressing performance improvement of existing production systems. Others could be applied to the existent systems but are applicable in the construction of new systems. These methodologies are the Ingersoll Engineers, Massay and Silveira methodologies. Thus, it is possible to identify improvement methodologies and construction methodologies. The methodologies can also be grouped by industrial sector. Thus, the PFA and Ingersoll Engineers methodologies were initially thought for the metalworking sector but, according the authors they may also be applied to others industries. The TPS, Black, Massay, Suri, Silveira, Hyer and Fraser methodologies being more generic could be applied to others industries. These methodologies are briefly described below, first the improvement methodologies and then the construction methodologies.

#### **PFA methodology**

The PFA methodology developed by Burbidge in 1963 [18] is a methodology for the implementation of GT in a company. According to Burbidge, before PFA, GT was based on classification and codification of the drawings of components, and the grouping of parts of the same shape and similar functions in the same family. This was not a good method of finding families because parts of different materials and of different dimensions would be undesirably grouped in the same family. Additionally this approach was not adequate to form manufacturing cells because it could not help to find the machines groups that should process the part families.

PFA identifies, through the information analysis contained in the processes plans of each part, the part families and the machine groups.

The process plans list all the operations necessary to produce each part and the machines or others workstations where each operation is processed. Beyond their own methods, the PFA has several procedures used to plan the change of a process organization, i.e. function oriented, into a product organization and process or function layout into a GT cells layout. For this it follows a 5 step procedure which essentially aims to simplify materials flow in a company, each one with a specific objective, i.e.:

1. Company Flow Analysis, CFA – to simplify the flow between plants or company divisions;
2. Factory Flow Analysis, FFA – to simplify the flow inside the departments;
3. Group Analysis, GA – to plan the division or reorganization of the departments in GT cells;
4. Line Analysis, LA – to simplify the materials flow inside each cell;
5. Tooling Analysis, TA – to simplify and reduce the frequency of the setup processes of the machines.

Usually due to the need to handle large quantities of data PFA is better implemented by means of software tools with access to product and production data bases. Some such tools have been developed by McAuley [50], King [51] and Chan and Milner [52].

PFA had been applied to many examples of reengineering batch production FOMS into cell based manufacturing systems.

### **TPS methodology**

The Toyota Production Systems (TPS) design methodology described in Monden [24] is based on the integration of four essential requirement or principles, i.e. Just in Time (JIT) production, automation, flexible workforce and creativity. This integration is requires the implementation of the:

1. Kanban system to reach the JIT production
2. levelling mix production,
3. minimization of setup time to reduce the lead-time,
4. operations standardization in order to level the production and balance the system,
5. system layout according the production flow, of work and materials, predominant,
6. multi-skilled operators to reach and facilitate the balancing process of system,
7. operators motivation and involvement in the continuous improvement of the processes,

8. visual control implementation to reach the quickly inspection,
9. implementation of communication systems between the departments to promote the total quality control systems.

AT the extreme production flow leveling means synchronized one piece flow [53].

### **Black methodology**

IMPS is the name used by the Black ([23] for systems that have production JIT. For this reason, IMSP methodology is similar TPS methodology. The Linked-Cell Manufacturing System (LCMS) is the operational configuration designed by the IMPS methodology. This design methodology intends to convert an existent factory in a "factory with a future", using the author words, and follows the following ten steps:

1. form manufacturing and assembly cells,
2. reduce or eliminate the set-up,
3. integrate the quality control,
4. integrate the preventive maintenance,
5. standardize the productive flow for the final assembly,
6. link cells (Kanban),
7. reduce the WIP,
8. spread IMPS to the suppliers,
9. automat and robotize,
10. computerize.

Essentially, the methodology guides to the JIT philosophy and TPS implementation [54]. It is applied to reengineering existing systems that and impacts all main and auxiliary production services, including accounting, procurement and sales and delivery.

### **Suri methodology**

The methodology for Quick Response Manufacturing (QRM), developed by Suri [11], is applied in fifteen steps. The first two focus the need of involvement of the top managers and the responsibility and management allocation for the QRM project. The third step consists of selecting the goods or services subject to the QRM. Normally they are the ones with long lead-times. At the same time, the objectives to be achieved are established. QRM project team is formed in steps fourth and fifth with the assignment of responsibilities to each team member. The sixth step is to analysis of the existing system. An important part of this is performance measurement. Step seven refines objectives and details project activities. The eighth step collects and analysis detailed data. The ninth step generates alternative solutions to the problems, aiming at reduction of the lead-times. These are

then discussed with top managers and CEO at the tenth step. The remaining steps are related with the formation of the implementation team (step 11) and the technical training of operators that will work on the QRM cells. These are formed on (step 12). The QRM cells implementation and the evaluation and measuring of results are carried out by steps 13 and 14, respectively. The last step (step 15) is the repeat the process for others projects.

The QRM implementation is about the reorganization of production systems, extended to procurement planning, capacity planning, lot sizing strategy, and other functions. QRM methodology is applied to existing systems.

### **Hyer methodology**

Hyer methodology, according Hyer and Wemmerlov [48] is a framework for planning and implementing cellular manufacturing. This methodology has 13 steps. The first five have to do with the problem awareness, strategic position, manufacturing capability studies, vision and goals formulation decisions to continue the project. The next three steps deal with the initial cell planning and calculus of cost/benefits for the cells. In the ninth and tenth step the detailed design is carried out, followed by the implementation of the cells (step 11). The last two steps are related with the improvement and evolution of the cells and the final evaluation of the planning process design.

### **Kulak methodology**

The Kulak methodology [41] is based on the ATD and addresses the design of production cells. The design process involves four steps and a feedback mechanism for continuous improvement, i.e., to evaluate and improve the design based on pre-selected performance criteria. The process begins with a preliminary phase of team selection followed by analysis of the production processes. In the second step cells are formed based on the principles of ADT, followed by cell implementation. Finally, performance evaluation, based on selected criteria, is done. If the solution obtained does not respond to the expectations attempts are made to improve the solution.

### **Fraser methodology**

Fraser et al. [49] propose a methodology, involving six phases: feasibility, project team, cell design, human factors, reorganization and installation and, finally, continuous improvement. The 1<sup>st</sup> phase has to do with the strategic issues,

mainly with the identification of the reasons for the change. The 2<sup>nd</sup> deals with the team project formation and the need of involving all in this project. The 3<sup>rd</sup> phase, is concerned with cells formation. The human factors phase – phase four – focus on selection, training and rewarding operators for the cells. Reorganizing and installing new layout is carried out by 5<sup>th</sup> phase and, finally, the 6<sup>th</sup> phase focus on the continue improving procedure.

### **Ingersoll Engineers methodology**

Ingersoll Engineers methodology orients the company in the implementation of Flexible Manufacturing Cells (FMC) [45]. This involve essentially five distinct phases. In the first phase is considered the strategic position of the company in order to evaluate in which way the FMC could influence the business strategy. If this expected influence is positive and based on the objectives to reach it is made the development of FMC configuration. Such development bases on the technical and economical analysis of possible configurations. This is in the second phase that treats also of how to present and convince the top management to adopt the FMC configuration and their involvement in the process. In the third phase are approached the special considerations about cells, i.e., technology application, handling, warehousing and transport systems and the utilization of industrial robots and are discussed the quality level and the control systems if machines, cells and production. The fourth phase of this methodology deals with the detailed planning, cells implementation and results measures. The fifth and last phase tries to reach Computer Integrated Manufacturing (CIM) systems.

This is also a methodology that embraces and involve all sectors of the company but could also be applied to the conception of new systems, being necessary a careful and long planning. This has to be done in this manner because only doing this it is possible having successful cells [45].

### **Massay methodology**

Massay methodology [46] uses an approach of holistic conception of systems. This facilitates the evaluation of the total system being developed. This approach uses available tools and techniques and could, according the author, being easily adopted by production systems designers.

Also, includes three case studies that are used to evaluate the proposed methodology. This is advised in the new systems design or in the improvement of existent ones. This methodology

divides in four phases: analysis, conceptual design, integrate design and detailed design. These phases are developed sequentially existing feedback between consecutive phases.

In the analysis phase is collected and treated the parts data to produce in order to identify the families. The identified families, the production quantities, the process plans and the production schedules defines the required capacities and cells capacities and provide the inputs, such the necessary equipments, for the next phase of the conceptual phase. In the conceptual phase is defined an architecture of the system through the operations and the operations sequence represented in a flow diagram. This conceptual system is divided in cells and the cells are integrated and adjusted in a CMS. The integrate design phase is still divided in five steps which objective is the configuration of the cell and system. In the end of this phase the alternatives of configurations are evaluated against performance criteria. The best solution is selected and is an input for the next phase, detailed design. The objective of this phase is attending all the specifications and dimensional details of the selected alternative. The outputs of this phase are the design documentation consisting in detailed design drawings and specifications.

#### **Babic methodology**

As the Ingersoll Engineers methodology described early, Babic [40] proposed a methodology for Flexible Manufacturing System (FMS). This methodology is based on the ATD and divides in four phases the process design: 1) specification of the operations to be processed on the system, 2) definition of the functional requisites, 3) FMS design and, finally, 4) performance analysis using the simulation.

#### **Silveira methodology**

Silveira [47] presents a methodology for implementing production cells. This methodology has three phases: the preparation phase that includes the system analysis and preparation for the new layout, the definition phase of the new layout and the physical implementation of the new layout and management systems. In the first phase are collected the data, is formed the responsible team for the change, is defined design objectives, is selected the pilot area to implement the cells and is implemented support techniques like techniques for the setup time reduction. In the second phase is chosen methods for the cells formation, is collected data for the methods application, is formed the cells,

is defined the capacity and is designed the layout. In the installation phase is planned the cells introduction, is assigned the people and machines to the cells and is made the management and analysis of cells performance.

#### **Final considerations**

Generic methodologies may address production system design in spite of not being focused on this area. The result of this is that design solutions tend to be general, requiring further handling to treat detail, usually requiring further design steps outside the methodology. To reduce such efforts production systems oriented methodologies are required and have been developed as reviewed. These are more explicit and straightforward in guiding the designer to workable alternative solutions and ultimately, through a recommended evaluation process, to choose one. In particular they focus on known and tested configurations of production systems of types such as CMS, FMC and FMS and POMS, from where one is chosen and adjusted according production requirements. For this reason, they are more objective, reducing the range alternatives from where to select.

Some methodologies lead to solutions that are operational configurations of production systems, i.e. the physical and system operational configuration of is solved or designed.

Table 1 presents the summary of the methodologies described showing application areas or design solutions.

The proposed methodology in this paper is a half way between the specific methodologies and the focused methodologies. However, this methodology is more oriented than a specific methodology because after the POMS selection, it only considers the design process of this system and their conceptual [55] and operational configurations. By this way, the proposed methodology consider only the relevant aspects for the POMS design, not restricting, nevertheless the configurations alternatives of POMS. Some of the methodologies presented, namely, the Ingersoll Engineers, Suri and Fraser methodologies include a few steps related with the implementation and training of the responsible team for this implementation. Though do not neglecting the importance of these steps, they were not included in the proposed methodology since was not the objective of the work developed implement the methodology in a company.



**Table 1. Summary of design methodologies presented**

Methodology	Examples	Solutions
Generic	<ul style="list-style-type: none"> <li>- <i>Extended General Design Theory</i></li> <li>- <i>Robust Design</i></li> <li>- TIPS</li> <li>- WDK</li> <li>- Axiomatic Design Theory</li> <li>- TQD</li> <li>- ...</li> </ul>	<ul style="list-style-type: none"> <li>Product</li> <li>Process</li> <li>Tool</li> <li>Machine</li> <li>Production System</li> <li>Information System</li> <li>...</li> </ul>
Specific for production system	<ul style="list-style-type: none"> <li>- <i>Rao and Gu (1997)</i></li> <li>- <i>REALMS</i></li> <li>- <i>MSDD</i></li> <li>- ...</li> </ul>	<ul style="list-style-type: none"> <li>1 Production System</li> </ul>
Focused in a operational configuration of POMS	<ul style="list-style-type: none"> <li>- PFA</li> <li>- TPS</li> <li>- Black</li> <li>- Ingersoll Engineers</li> <li>- Massay</li> <li>- Suri</li> <li>- Babic</li> <li>- Silveira</li> <li>- Kulak</li> <li>- Hyer</li> <li>- Fraser</li> <li>- ...</li> </ul>	<ul style="list-style-type: none"> <li>1 operational configuration of POMS</li> </ul>

**GCD METHODOLOGY FOR POMS DESIGN**

Although the many methodologies presented, the authors of this paper proposed the Generic-Conceptual-Detailed (GCD) methodology that is organized around three major design phases, namely the Generic, the Conceptual and the Detailed phase. The authors are convicted that none of the methodologies presented considers in an iterative way the design process through three hierarchical analysis levels, namely, the strategic, the tactical and the operational level. Also, these methodologies did not support the production system design and reconfiguration for its easily adaptation to different market demands, allowing the adoption of POMS configuration adjusted to the market and production needs.

Even so, some of the methodologies presented, namely, PFA, TPS, Massay, Babic, Silveira and Kulak methodologies did not consider in an explicit way, and in many cases, implicit, the strategic analysis level. Additionally all the methodologies are focused in a operational configuration, did not allowing the selection of alternatives of configurations more suitable.

In the case of the PFA, Massay, Babic, Silveira, Kulak and Ingersoll Engineers methodologies the design of operational configurations is a independent design. So, they weren't oriented to the POMS design in the acceptance and broad presented in this work,

i.e., in searching coordination and synchronization of the POMS configurations necessary to the different phases of production.

In this aspect, this methodology shares some common features from the Black methodology for Integrated Manufacturing Production System (IMPS) and from the Suri methodology for QRM systems. Distinguishing features of the GCD methodology is its orientation to system reconfiguration and the spread of design functions, from strategic to operational level with exploration of conceptual manufacturing arrangements or configurations, at cell design and workstations design, instantiated at detailed design level. System adaptation or reconfiguration is needed according to customer order manufacturing requirements. Design roles, frequency and design players, were identified for each design phase in Alves and Carmo-Silva [16].

In the design process several decisions at strategic, tactical and operational levels, are made and used successively and iteratively in each POMS design phase. The complexity of this decision process is better dealt with computer aid. This is a strong reason for the authors had been proposed a decision support system to implement the GCD methodology, already referred.

**Generic Design**

At this phase of design a fundamental evaluation must be made which is essential to proceed with all the subsequent POMS design activities. This evaluation aims at ensuring that the POM organization is suitable for responding to market requirements having into account competences, manufacturing processes and resources and company and market restrictions.

For this, at a first stage, the POM and the FOM organizations are compared against each other. This starts by identifying a selected range of products whose production wanted to evaluate under these concepts. An inconclusive decision about this, leads us to consider the hybrid concept of POM and FOM. Essentially this tends to result in a mix of FOM organization, usually at parts production, with cellular manufacturing. Although the GCD methodology can help in this system design the true POM concept tend to be partially lost. The strategy behind it may however be taken as farther as it is advantageous, in economical terms and customer service. If such a hybrid situation is proven unsuitable the FOM concept may have to be adopted. It is important to point out at this stage that the POM concept,

although mainly exploring CMS it may share different combinations of organizational concepts.

Three main interrelated design activities at the Generic design phase can be identified: Strategic Production Planning (A11), Analysis of Company and Market Manufacturing Situation (A12) and Generic Manufacturing System Selection (A13). The choices at this design phase are determined by many factors relevant to the company manufacturing strategy, being particularly relevant: 1) the production requirements resultant from product forecasted demand spectrum and behaviour, 2) the market available resources and services, and 3) the company present manufacturing position and situation mainly related with resources, processes and organization. It is also necessary that product variety and volumes of production be identified.

### **Conceptual Design**

The main and fundamental purpose of conceptual design is selecting, from sets of predefined possibilities, conceptual cells and workstations to be instantiated later, at detailed design phase, into the real POM system. Thus, two main activities need to be carried out at conceptual design: Conceptual Cells Selection (A21) and Conceptual Workstations Selection (A22). The set of possible conceptual cells that can be chosen includes the basic ones and their shared cell counterparts, non-basic, described in Silva and Alves [4][55].

### **Detailed Design**

It is at the Detailed Design level that frequency of design is large. In fact, in theory, system reconfiguration should be carried out every time a new product order needs to be released for production or, in the least, by short planned periods of undisturbed production. This may aggregate a few customer orders of the same product or of similar products. The following activities are defined at Detailed Design phase: Formation of Families of Parts, Subassemblies and End Items (A31), Instantiation of the Conceptual Cells (A32), Instantiation of Workstations (A33), Intracellular Organization and Control (A34) and POM System Organization and Intercellular workflow Coordination and Control (A35). A detailed explanation of these is presented in Carmo-Silva and Alves [4], showing the operational cells evaluated at the second design activity of this phase, namely, the instantiation of conceptual cells. A case study showing the application of

GCD to a company is presented in Silva and Alves [56].

### **The GCD methodology Computer Aided Design System**

Due to the complexity of design and need for massive data handling in POMS design a Computer Aided Design System is being developed to implement the methodology. At the moment a prototype of such system was developed [8][15][16][57]. This prototype includes a database, updateable on a continuous basis, a knowledge base for design methods and tools and some interfaces and aids needed for easing the design process. However, the prototype is not yet in a state capable of being applied in practice. Further refinement is required mainly to enlarge the design and evaluation methods base and interfacing with information systems.

### **CONCLUDING REMARKS**

Designing production systems is a complex task. Its design involves many activities, data, information, restrictions and decisions. Many academics and practitioners have recognized the importance of design methodologies. Having a suitable methodology for helping in this process can be of great benefit for quickly generating good design solutions.

A number of methodologies were briefly presented and described in this paper emphasizing aspects and issues and comparing them with the authors proposed GCD. For this to be implemented in practice as required a software prototype application is being built integrating an extendable knowledge base on design and evaluation methods. The authors are working on these aspects together with the gathering of industrial data for validating and adjusting the methodology and the prototype.

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