# An industrial application study of the GCD design methodology for Product Oriented Manufacturing

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## Abstract

This paper presents an application and test study, carried out in a garment company in the Minho region in the North of Portugal, of the Generic-Conceptual-Detailed (GCD) methodology for designing Product Oriented Manufacturing Systems (POMS).

The methodology is in an advanced stage of development and is now being submitted to a refining process based on findings from application tests in industry.

**Keywords:** cellular manufacturing, methodology, application study

## 1. INTRODUCTION

Cellular Manufacturing Systems (CMS) [(Gallagher, (1973), Kamrani (1995), Burbidge, (1996), Suresh (1998)] although designed for a variety of parts, grouped into families, rarely take into consideration the need for parts production coordination and synchronization for meeting customer orders of end items. Thus, the need for rapid response to customer requirements, which one recognizes as an important strategic objective, is usually not taken adequately into account. However, this limitation has already been recognized and addressed by some authors over a decade. The solution calls for the connecting of a variety of cells working co-ordinately together for the same purpose, i.e. the manufacture of the same product or family of similar products. A paradigmatic example of this is what Black (1991) calls a linked-cell manufacturing system. This may be seen as a Product Oriented Manufacturing System (POMS), as may many manufacturing systems currently referred to as JIT, lean, flexible and virtual manufacturing systems. Product Oriented Manufacturing (POM) can also be associated with concepts such as the focused factory concept advanced by Skinner (1974) and the OPIM (One-Product-Integrated-Manufacturing) system concept put forward by Putnik and Silva (1995).

A POMS is defined as a set of interconnected manufacturing resources and cells that simultaneously and in a coordinated manner address the manufacture of a product or a range of similar products, including the necessary assembly work (Silva, 2002 (a)). A product may be simple, like a part, or complex, having a product structure with several levels. A set of cells that does not work under coordination towards synchronized production of end items, does not form a POMS.

Designing POMS is a complex dynamic task. This is a consequence of today's highly competitive market with constantly varying market demands and consequently varying manufacturing requirements. Such design requires a methodology, which takes into account, both, the necessary steps in the design process, using the right methods and tools, and the constantly varying restrictions and data, for reaching good design solutions.

In section 2, we present the industrial setting for the application study of POMS design using the GCD design methodology. We briefly describe this in section 3 and extend it in the following sections. Each of the sections 4, 5 and 6 addresses the application study focussing on each of the three phases or classes of tasks of the design methodology. Finally, we draw some conclusions.

## 2. INDUSTRIAL SETTING

We study a garment manufacturing plant of a SME manufacturing company with around 140 employees, located in the region Minho in North of Portugal. The company relies heavily on outsourcing to complement capacity requirements for production with a total of around forty outsourcing suppliers. These are from the Minho region, in Portugal, and recently have included some suppliers from an eastern European country.

The company manufactures quite a wide range of baby and children garment products. For each market family of products, a great variety of sizes exists related with children ages, namely and typically from 1 month up to 5 years of age.

Competition in the region and world wide, in the garment industry, is very strong. Therefore, to be profitable manufacturing companies must be efficient. This requires them applying good manufacturing organization and operating practices.

The company under study has been operating since 1979 and, until recently, it was predominantly offering its own product models to the wholesale market. Data used in this study is, mainly, based on this manufacturing-market paradigm. Nowadays, the company is moving to a different paradigm. It develops every six months a collection of new product models, which it sells, in Europe, directly and mainly to retailers.

One of the main and most important manufacturing functions relevant to the success of the company is sewing. Because of this, the study emphasizes the sewing system in the company. Management believed that there was scope for improvement in this area.

One noticeable difficulty was to plan and control production and make good use of manufacturing resources. This was contributing for loss of manufacturing efficiency.

Some observations at the plant have shown high system idleness including operators' idleness, a lot of work handling and high levels of work in process. It was also noticed that quantities to manufacture were set well above the customer order requirements, in an attitude of "just in case", for keeping up with shortages that could occur due to high rate of defective products and poor system operation reliability including, machine malfunctions and breakdowns. Additionally, and to a large extent because of these operating deficiencies, larger than necessary stocks and storage areas were provided, high set-up times were necessary and high levels of capital tied up and long lead times were resulting.

Based on recognized weak points the company strategically decided to solve operating deficiencies and improve quality of products through improved system design and operation. Additionally, to be able to better control the flow of production and meet due dates of orders production planning and control should also be improved in the process.

## 3. THE GCD DESIGN METHODOLOGY

Silva and Alves (2002(b)) proposed the GCD methodology for POMS design. It includes three design phases or functions, namely the Generic, the Conceptual and the Detailed phase, see Figure 1. The methodology briefly illustrated with the aid of the IDEF0 modelling technique (FIPS, 1993).

In the GCD design methodology, we consider all relevant data and restrictions and seek access to a range of tools and methods through expandable and up-dated data and knowledge bases for POMS design.

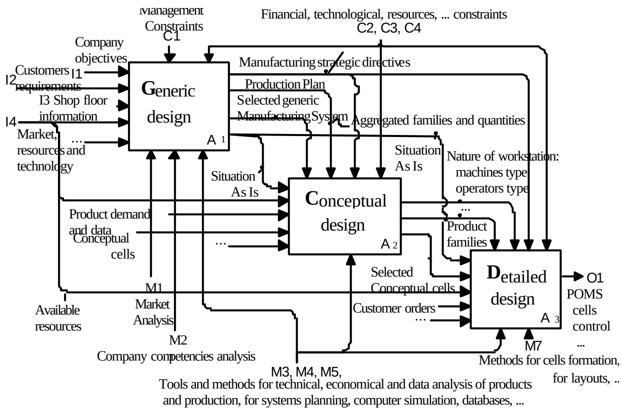


Figure 1 – Overview of the GCD design methodology

We take several decisions at strategic, tactical and operational level, successively and iteratively, in the design process, aimed at reaching good solutions for both organizational and operational configurations of POMS.

## 4. GENERIC DESIGN

At the Generic design phase, we can identify three interrelated design activities: *Strategic Production Planning* (A11), *Analysis of Company and Market Manufacturing Situation* (A12) and *Generic Manufacturing System Selection* (A13). A more detailed explanation of these is presented in Silva and Alves (2002 (b)).

The choices and decisions at this design stage depend mainly on company manufacturing strategy, existing manufacturing facilities and market environment related with product demand, services and resources. Particularly relevant are the aggregated production quantities and related product variety to manufacture in the near future. Analysis of product variety and associated processing plans lead to identifying similarities for manufacturing. A processing plan indicates the nature of manufacturing operations and type of equipment necessary.

Table 1 shows aggregated production quantities for each different market product family, which were used in the study based on a six months Autumn-Winter collection demand requirements. These quantities come from both existing customer orders and forecasted demand.

| Code | Description | Quantity |
|---|---|---|
| 01 | Baby suit | 57644 |
| 15 | Jardiniere | 22735 |
| 30 | Jogging | 16825 |
| 02 | Overalls | 11353 |
| 35 | Sweat | 5667 |
| 10 | Set of two pieces | 5068 |

Table 1 - Products and quantities

Workstations used by the company are of the multi-resource type (Silva, 2002 (a)) because, at least, we need two resources, i.e. a machine and an operator, for each one. The machines used in the sewing department are listed in Table 2.

| Identification | | Quantity |
|---|---|---|
| Overlock machine | (OM) | 47 |
| Lockstitch machine | (LM) | 13 |
| Tape binding machine | (TBM) | 7 |
| Elastic machine | (EM) | 3 |
| Lockstitch machine 2 | (LM2) | 1 |

Table 2 - List of machines available

Most of the machines used to manufacture the range of products are very simple, with one single processing function, needing full dedication of a single person when in operation. Although some operators may be able to operate different machines, when the study started they had a dedicated machine to work with.

Typically, manufacturing a product requires a number of operations grouped in three classes: pre-sewing operations, sewing operations and the finishing operations. Cutting of fabrics is not included in the study.

Pre-sewing operations have to do with the preparation of the different garment parts for the assembly into the final product. Some examples are cuffs and neckband preparation, attaching zips, labels and buttons.

Although some of the pre-sewing operations are repeated in many product types, the operations' set required from product to product is quite different. This suggests that, unless, there are enough machines and operators, it may be difficult to integrate these operations in POMS dedicated to each product family, due to dissimilarity of pre-sewing operations.

Sewing is mostly an assembly operation that joins together sleeves, backs, fronts and other parts. Sewing operations, although different have many similarities from product to product.

Finishing operations, which are common to most products, have to do with the trimming and inspection, snapping fasteners and pressing.

The study, as mentioned before, concentrates mainly on the sewing tasks required by the different products and some finishing operations.

At company, sewing was carried out with machines arranged in lines. A closer observation of these led us to conclude that, although they were oriented to do a set of specific operations, only in some cases they were completely autonomous to carry out the full set of sewing operations required by the products. In fact two of the lines had 19 machines each, 18 of which were identical overlock machines. In a certain sense, we could say that these were function-oriented groups. We can therefore understand the comments of management, namely that it was very difficult to manage production because task allocation was complex and they had, in many cases, to start sewing a product in one line and finish it in another. Considering the situation "as is" we realize that the company is apparently using a hybrid product-function oriented system at sewing. Due to differences in sewing requirements of each product model, considerable operating adaptations were required and loss of manufacturing efficiency happened.

With the information available at this stage we were able to answer the fundamental question of the Generic design, i.e. if a Function Oriented Manufacturing System, system, a POMS or some hybrid form of these should be adopted.

Although we think that efforts must always be made to reach pure POMS whenever possible, the hybrid configuration should be considered in the design and decision process. In some cases, we cannot achieve pure POMS and, therefore, hybrid systems may have to be adopted.

If we look into the full manufacturing operations cycle, we see big differences in pre-sewing operations among products. Therefore, a separated section for these process functions should be adopted. Nevertheless, we did not see any strong reason why we should not integrate sewing and some finishing operations in the same POMS.

By analysing manufacturing requirements by market product families, it was not difficult to reach the conclusion that some products had almost identical qualitative or technological sewing requirements while others had quite different ones. This suggests that product families for sewing may be identified. This, ultimately, leads to POMS.

## 5. CONCEPTUAL DESIGN

The main and fundamental purpose of this design is selecting conceptual cell configurations that, once implemented in practice, will lead to real detailed POMS configurations. Additionally, in this step, we develop a first approximation to formation of part and product families, based on both planned and settled customer orders. It is also important to specify the nature and characteristics of workstations such as functions/flexibility, and skills of operators that are going to be required. Based on such data and purposes two main activities must be carried out: *Conceptual Cell Configurations Selection (*A21) and *Workstation Selection (*A22).

There are two fundamental classes of Conceptual cells: the basic ones and their shared cell counterparts, called non-basic (Silva, 2002 (a)). The former are completely autonomous cells; the latter are cells need to do work on products or parts initially allocated to other cells, or need work to be done in other cells, or both. The adoption of non-basic cells leads to intercellular workflows.

A typical analysis to be done, at this design stage, includes job operation plan and workflow analysis, which are essential for choosing system configuration based on conceptual cells. This helps us to ultimately identify product families at manufacturing for the available market product families. Additionally, the process routing for each product model expressed as a function of the types of machines required for each operation to be processed, are identified.

Table 3 clearly shows the workflow patterns for each product model. The number of different operations, following each other, requiring the same type of machine, is shown in parenthesis. Machines within {} are alternative to each other.

| Product model | Seq. type | Process routing and required operations | Quant. |
|---|---|---|---|
| 1550,1662,1695, 1610,16 00,1694, 1596,1656 | S01.1 | OM (7) | 29898 |
| 1510 | S01.2 | OM (6) →TBM (1) →LM (2) | 5780 |
| 1648 | S01.3 | OM (6) →{OM, LM2 (1)} | 5087 |
| 1651 | S01.4 | OM (7) →TBM (1)→LM (2)→OM (1) | 5059 |
| 1535, 1528 | S01.5 | OM (7) →TBM (1)→LM (1) | 5546 |
| 1543 | S01.6 | OM (6) →{OM, LM2 (1)} | 3000 |
| 1547 | S01.7 | OM (6) | 1599 |
| 1625 | S01.8 | OM (6) | 1675 |
| 16 Product models: Market Product Family 01 - Baby suits | | | Total 57644 |
| 1647,1537,1518, 1549, 1663,1617 | S15.1 | OM (3) | 19184 |
| 1525, 1532 | S15.2 | OM (4) →LM (1) | 3551 |
| 8 Product models: Market Product Family 15 –Jardinieres | | | Total 22735 |
| 1598s, 9376s | S30.1 | OM (2) →LM (1)→OM (2) | 6480 |
| 1513s | S30.2 | OM (5) →TBM (1)→LM (1) | 3117 |
| 1627s | S30.3 | OM (3) →LM (2)→{OM, LM2 (1)}→OM (2) | 2000 |
| 1527s | S30.4 | OM (5) →LM (1) | 1771 |
| 1676s | S30.5 | OM (4) →{OM, LM2 (1)} | 1740 |
| 1670s | S30.6 | OM (6) →{OM, LM2 (1)} | 1717 |
| 7 Product models: Market Product Family 30 –Jogging (Sweats) | | | Total 16825 |
| 1598t,9376t,1627t 1676t, 1670t | S30.7 | OM (2) →LM (1)→EM (1)→OM (1) | 11937 |
| 1513t | S30.8 | OM (3) →EM (1)→OM (1) | 3117 |
| 1527t | S30.9 | OM (4) →EM (1)→OM (1) | 1771 |
| 7 Product models: Market Product Family 30 –Jogging (Trousers) | | | Total 16825 |
| 1666, 1597, 1619, 1697, 1542 | S02.1 | OM (7) →LM (1) | 9852 |
| 1624 | S02.2 | OM (7) →{OM, LM2 (1)} | 1501 |
| 6 Product models: Market Product Family 02 - Overalls | | | Total 11353 |
| 1523 | S35.1 | OM (3) →LM (1) → {OM, LM2 (1)}→OM(2) | 3620 |
| 1530 | S35.2 | OM (4) →TBM(1) →LM(2)→{OM, LM2(1)} | 2047 |
| 2 Product models: Market Product Family 35 - Sweats | | | Total 5667 |
| 1653s | S10.1 | OM (4) →TBM(1) →LM(2)→{OM, LM2(1)} | 5068 |
| 1653i | S10.2 | OM (4) | 5068 |
| 1 Product model: Market Product Family 10 - Set of two pieces | | | Total 10136 |

Table 3 - Sewing processes routing

We can see that several similarities exist between processing, either within market product families or among them. This allows us to identify manufacturing product families that are different from market families, see Table 4.

The workflow pattern and manufacturing families suggest basic conceptual cell configurations as candidates for real cell instances. Non-basic cells seem not to be required.

By analysing data, at least, two types of basic cells may be required, namely single workstation cells and pure flow cells (Silva, 2002(a)). The former may have several duplicate machines, according the workload and balancing required. An example is the workstation for sequences S01.1, which might require several OM machines. This is to be analysed at detailed design. The latter cells configuration has two or more workstations, which may themselves have duplicate machines, with direct or in-sequence flow.

Additionally basic cells with bypassing flow and, to a less extent, with inverse or backtracking flow, may have to be considered in the detailed design. This may be required due to the need for mixing manufacturing of different product models in the same cell due to load requirements and manufacturing resources availability. An advantage of this is the reduction on reconfiguration of cells, due to the manufacture of a larger variety of products in the same cell. This has a positive effect on task learning and utilization of equipment. Nevertheless, some minor adjustments may be necessary when changing products, which, after all, are very similar.

| Fam. | Quant. | Seq. type | Process routing and required operations |
|---|---|---|---|
| 1 | 29898 | S01.1 | OM (7) |
| | 1599 | S01.7 | OM (6) |
| | 1675 | S01.8 | OM (6) |
| | 19184 | S15.1 | OM (3) |
| | 5068 | S10.2 | OM (4) |
| | 57424 | Aggregate load: 132895 minutes | |
| 2 | 5780 | S01.2 | OM (6)→TBM (1) →LM (2) |
| | 5546 | S01.5 | OM (7)→TBM (1)→LM (1) |
| | 3117 | S30.2 | OM (5)→TBM (1)→LM (1) |
| | 14443 | Aggregate load: 53483 minutes | |
| 3 | 5059 | S01.4 | OM (7)→TBM (1)→LM (2)→OM (1) |
| | 5059 | Aggregate load: 28027 minutes | |
| 4 | 3000 | S01.6 | OM (6)→{OM, LM2 (1)} |
| | 5087 | S01.3 | OM (6)→{OM, LM2 (1)} |
| | 1740 | S30.5 | OM (4)→{OM, LM2 (1)} |
| | 1717 | S30.6 | OM (6)→{OM, LM2 (1)} |
| | 1501 | S02.2 | OM (7)→{OM, LM2 (1)} |
| | 13045 | Aggregate load: 36953 minutes | |
| 5 | 1771 | S30.4 | OM (5)→LM (1) |
| | 9852 | S02.1 | OM (7)→LM (1) |
| | 3551 | S15.2 | OM (4)→LM (1) |
| | 15174 | Aggregate load: 71703 minutes | |
| 6 | 6480 | S30.1 | OM (2)→LM (1)→OM (2) |
| | 6480 | Aggregate load: 20412 minutes | |
| 7 | 11937 | S30.7 | OM (2)→LM (1)→EM (1)→OM (1) |
| | 11937 | Aggregate load: 43331 minutes | |
| 8 | 3117 | S30.8 | OM (3)→EM (1)→OM (1) |
| | 1771 | S30.9 | OM (4)→EM (1)→OM (1) |
| | 4888 | Aggregate load: 9955 minutes | |
| 9 | 5068 | S10.1 | OM(4)→TBM(1)→LM(2)→ {OM, LM2(1)} |
| | 2047 | S35.2 | OM(4)→TBM(1)→LM(2)→ {OM, LM2(1)} |
| | 7115 | Aggregate load: 27108 minutes | |
| 10 | 2000 | S30.3 | OM (3)→LM (2)→{OM, LM2 (1)}→OM(2) |
| | 3620 | S35.1 | OM (3)→LM (1) →{OM, LM2 (1)}→OM(2) |
| | 5620 | Aggregate load: 18528 minutes | |

Table 4 – Manufacturing families based on workflow

## 6. DETAILED DESIGN

At the Detailed design, instantiation of conceptual cells is based on manufacturing families of product models. Thus, families of parts, subassemblies and end items, based on manufacturing product orders and due dates of customer orders, are allocated to each conceptual cell. At the same time, coordinated control of work within and among cells for POM is devised. In the end, we must reach at detailed specification of the POMS, including the design of its physical or virtual configuration.

We identify the following activities 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).*

By close observation of the sequences of operations within each manufacturing family listed in Table 4, we could notice some slight differences between some product models in relation to the number and type of operations. This suggests that it may be advantageous to split manufacturing families into smaller families with closer similarities among products. This is recommended when the workload justifies configuring several cells for the same manufacturing family. However, if workload in a cell becomes too small such is not desirable at all, because the cells would not be working long enough for achieving normal rates of production, i.e. the learning effects were lost. In this case, we may even have to aggregate manufacturing families in larger families.

In the application study, this aggregation is clearly possible due to strong similarities between some different manufacturing families as can be seen from Table 4.

Some important aspects to settle, before instantiation of conceptual cells, have to do with order release and batch sizing, which highly depend on due dates for customer orders.

Thus, for example, if a continuous flow of every product model is required to meet customer requirements then many product model changes, during manufacturing, within a cell dedicated to a family, are required. This apparently could be seen as contributing for loss of manufacturing efficiency. However, since the nature of processing does not change within a family, no significant loss would take place. Moreover, if all customer orders are due, only, at the end of the manufacturing period, as they are in the application study, we need not to change production of a product model until the whole quantity required for the period is completely manufactured.

Therefore, we can establish the configuration of cells looking solely into processing requirements of families disregarding needs for product model changes within a cell.

We start with the families identified in Table 4 for establishing cells. Since we know which conceptual cells to consider, as referred above, we have, first of all, to establish the number of machines required for each cell,

We establish machine requirements based on planned production quantities and operation times. The first trials to this have shown that only twelve, from the whole set of OM machines available, were necessary.

By studying data in Table 4, if we use OM machines to manufacture family number 4, instead of using the single LM2 machine available (Table 2), this family can be merged with family number 1. The same reasoning can be extended to families number 9 and number 3 and to families 10 and 6, leading us to seven families.

To fully carry out the iterative search towards family forming, for conceptual cell instantiation in more complex settings, we may have to draw upon analytical methods and other tool aids, i.e. simple observation of data may be insufficient.

Although pure flow cells should be sought, cells with bypassing flow can be efficient. If such a configuration is considered for analysis, then families 7 and 8 can be merged to be manufactured together in the same cell. The same can be done with family 5 and with the family 2. Family number 5 can be merged with the already merged families 6 and 10, to be all manufactured in the same cell. The same is possible with family number 2 that can be merged with the already merged families 3 and 9.

So, only four families, leading to as many cells, need to be configured to manufacture the whole production requirements for the Autumn-Winter collection (Table 5).

| Cell | Seq. type | Product models | Sequences |
|---|---|---|---|
| A | S01.1, S01.7, S01.8, S15.1, S10.2, S01.6, S01.3, S30.5, S30.6, S02.2 | 01/1550, 01/1662, 01/1695, 01/1610, 01/1600, 01/1694, 01/1596, 01/1656, 01/1547, 01/1625, 15/1647, 15/1537, 15/1518, 15/1549, 15/1663, 15/1617, 10/1653i, 01/1543, 01/1648, 30/1676s, 30/1670s, 02/1624 | OM (3 to 7) |
| B | S01.2, S01.5, S30.2, S01.4, S10.1, S35.2 | 01/1510, 01/1535, 01/1528, 30/1513s, 01/1651, 10/1653s, 35/1530 | OM (4 to 7)→TBM(1) → LM (1 to 2) →OM (1) |
| C | S30.7, S30.8, S30.9 | 30/1598t, 30/9376t, 30/1627t, 30/1676t, 30/1670t, 30/1513t, 30/1527t | OM (2 to 4) →LM (1) → EM (1)→OM (1) |
| D | S30.4, S02.1, S15.2, S30.1, S30.3, S35.1 | 30/1527s, 02/1666, 02/1597, 02/1619, 02/1697, 02/1542, 15/1525, 15/1532, 30/1598s, 30/9376s, 30/1627s, 35/1523 | OM (2 to 7) → LM (1 to 2) →OM (2 to 3) |

Table 5 – Manufacturing families to form the cells

The number of machines for this new product family arrangement, assuming 90% of operator's efficiency, is shown in Table 6.

| Cell | OM | | LM | | TBM | | EM | | Total |
|---|---|---|---|---|---|---|---|---|---|
| A | 3.2 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| B | 1.4 | 2 | 0.5 | 1 | 0.2 | 1 | 0 | 0 | 4 |
| C | 0.4 | 1 | 0.5 | 1 | 0 | 0 | 0.08 | 1 | 3 |
| D | 1.5 | 2 | 0.6 | 1 | 0 | 0 | 0 | 0 | 3 |
| Total | 9 | | 3 | | 1 | | 1 | | |

Table 6 – Number of machines for each cell

Table 6 clearly shows that, due to family aggregation, the required number of OM machines was reduced from twelve to nine. We noticed a substantial reduction in other machines types, too. This means that a better utilization of resources is achieved. This happens because of the very low utilization of machines, which would be obtained, if each cell was formed with basis on each of the ten families from Table 4. We notice that the total number of machines required is considerably less than those available. This is due to two reasons. First, other processing functions that use the remain machines, mainly in the pre-sewing operations area, were not considered. Second, an excess of machines do really exist because the company decided do outsourcing work that traditionally was manufactured indoors.

Now, machines should be allocated to workstations, together with operators in a balanced way to achieve planned production rates. This must have in consideration the skills of operators and cell operating modes and strategies. In general, we could think of operating modes such as rabbit chase, TSS and working balance (Black, 1995), and strategies such as teamwork and time-sharing resources (Suri, 1998).

As referred above we realize that some finishing operations that do not require machines, namely trimming and inspection, can be performed within the established cells. Therefore the number of operators is established taken this further workload and the 90% operators efficiency into account (Table 7).

| | Load (minutes) | N. º Operators |
|---|---|---|
| Cell A | 222938 | 4,3 ->5 |
| Cell B | 93532 | 1,8 ->2 |
| Cell C | 27710 | 0,5 -> 1 |
| Cell D | 100581 | 1,9 -> 2 |

Table 7 - Number of operators for each cell

Each cell works as a multi-model line (Ghosh, 1989). Therefore, every time a product model changes, slight adjustment to the cell configuration and/or to balancing may have to be done.

Although the conceptual configuration chosen restricts cell arrangements that can be made, there is still a need to clearly define the detailed intracellular organization and control.

Establishing how materials flow and how operators work within a cell is also required. Characteristics and quantity of production, equipment tasks, skills and and operators suggest that the TSS operating mode is the most adequate for each cell to be formed.

Flow of orders within a cell must have into account the need for coordinated work of the different separated parts of the same product model. These, preferably, should be manufactured one following the other. However, in our case such separated parts are made in different cells.

It is possible to evaluate several layout configurations (Arvindh, 1994), such as the well-known U shaped one. This seems to be very suitable for our four cells, as shown in Figure 2. This configuration offers good functionalities including the flexibility of having the same operator controlling the input and output of the cell.

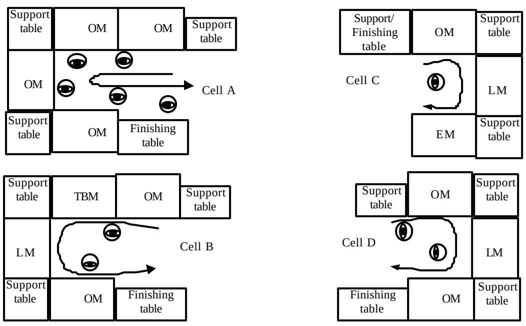


Figure 2 – Intra and intercellular layouts

Detailed design finishes with total system integration and organization. An important part of this is the selection of the intercellular coordination of production flow.

This coordination is necessary because, in our case, some garment products have one part made in a cell and the other in another.

We, finally, should refer that scheduling also plays a role in workflow coordination not only within cells but also between cells.

Generally, no single design activity can be performed in isolation. All the five activities of detailed design are closely interrelated and iterative. Moreover, depending on complexity and costs involved, in order to carry them out, a range of methods and tools may have to be used for technical and economical evaluation of alternative solutions.

## 7. CONCLUSION

An industrial application study of the GDC design methodology for POMS is presented in this paper. The methodology steps were implemented towards reaching a suitable POMS configuration.

By systematic application of the methodology we arrived to four cells only, for manufacturing the whole range of around forty product models, distributed through six market-families.

The system configuration obtained has two fundamental advantages: a clear definition of responsibilities and motivation for quality of products and high production rates of end items. These rates can be achieved due to learning effects associated with large production quantities resulting from high aggregation of production into families.

Additionally, having cells dedicated to families of product models, the production control problem is simplified in two dimensions. First, it is easy to solve the product model allocation problem to cells. Second, due to the decision of continuous production of each six-month requirements for each model, few and easy product changes, within each cell, and cell adjustments are necessary.

## REFERENCES

1. Arvindh B, Irani SA. Cell formation: the need for an integrated solution of the problems. Int. Journal of Production Research, 1994; 32; 5: 1197-218.
2. Black JT, Chen JC. The role of decouplers in JIT pull apparel cells. Int. J. of Operations & Production Management, 1995; 7, 1: 17-35.
3. Black JT. The Design of the Factory with Future. McGraw-Hill, Inc., 1991.
4. Burbidge JL. Production Flow Analysis for Planning Group Technology. Clarendon Press, 1996.
5. FIPS PUBS - Federal Information Processing Standards Publications. Draft FIPS Publication 183 Announcing the standard for Integration Definition for Function Modeling IDEF0, 1993.
6. Gallagher CC, Knight WA. Group Technology. Butterworths, 1973.
7. Ghosh S, Gagnon RJ. A comprehensive literature review and analysis of the design, balancing and scheduling of assembly systems. Int. Journal of Production Research, 1989, 27, 4: 637-670.
8. Kamrani AK, Parsaei HR, Liles, DH. Planning, Design and Analysis of Cellular Manufacturing Systems. Elsevier Science, 1995.
9. Putnik GD, Silva SC. "One Product Integrated Manufacturing". In Balanced Automation Systems, eds. L. M. Camarinha-Matos, H. Afsarmanesh, Chapman & Hall, 1995.
10. Silva SC, Alves AC. A Framework for Understanding Cellular Manufacturing, CARs&FOF Conference, Porto, Portugal, 2002 (a).
11. Silva SC, Alves AC. Design of Product Oriented Manufacturing Systems. In Knowledge and Technology in Production and Services, Eds. V. Marik, L. Camarinha-Matos and H. Afsarmanesh, Kluwer, 2002 (b).
12. Skinner W. The focused factory. Harvard Business Review 1974.
13. Suresh NC, Kay JM. Group Technology and Cellular Manufacturing – State of the Art Synthesis of Research and Practice. Kluwer Academic Publishers, 1998.
14. Suri R. Quick Response Manufacturing – A Companywide Approach to Reducing Lead Times. Productivity Press, 1998.