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Abstract

Organizing and managing dynamic networks of enterprises (or virtual enterprises) is a very complex task and many issues are still to be effectively covered. Apart from the models that can be used to create and manage virtual enterprises (VE), product data plays a central role in the VE life cycle. Virtual Enterprise composition, interaction among VE members (Autonomous Production Systems in this work), as well as its relationship with the market, is severely dependent on the product technical specifications as well as on the product process planning information. In traditional managing systems for single enterprise environment the Bill Of Materials (BOM) plays that role and at this paper its is proposed a Bill Of Materials and Movements (BOMM) as its equivalent in virtual enterprises' environments. The BOMM includes product structure, high level process planning information and some degree of virtual enterprise composition. BOMM is present during VE formation, operation, and reconfiguration, playing a central role in the material detailed planning and in the movements planning between VE members. In this article the BOMM role during the VE life cycle it is described in detail.

Keywords: Bill of materials; Production planning; Virtual enterprise;

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1 Introduction

In the last decades the world have witnessed to dramatic changes in market's behaviour. It moved from a consumer society with stable characteristics to an environment where customers make big pressure to obtain personalized products. Changes in society expectations, developments on communication and information technologies as well as the economy globalisation have generated radically different new markets requirements. This economical globalization increase competitiveness and market uncertainty, and accelerates the decrease of products life cycle (Kraemer *et al.* 2002). Market globalization is a complex experience to most enterprises. It creates new business opportunities but also new challenges motivated by a world wide competition. As result of that complexity enterprises must change its manufacturing processes and organizational relationships (Sharp *et al.* 1998). Therefore, it is imperative that enterprises react to this new environment to sustain its competitiveness and, in short, its survival. In today's highly competitive environment, it is impossible to an enterprise to sustain a high competitive level in all technical competences that belong to its capabilities. Enterprises must concentrate their efforts on those competences that they better perform i.e. its core competence (Hammer 2000). This attitude allows enterprises to participate in partnerships, where each one will contribute with its core competence to perform a global business. Coping with these requisites implies, or obligates, the definition and adoption of new organizational concepts (Putnik 2000).

Existing system and process must be simplified, optimized and updated. Enterprises internal and external fragmented processes should be exposed to integration process to eliminate wastes and optimize synergies, improving its performance. Clearly distinguish which components or services should be produced internally and which components or services should be obtained from suppliers. Coordination of participants

in new forms of organization, such as virtual enterprises, global manufacturing and logistics networks, and other company-to-company alliances, has become functionally and strategically important (Gunasekaran *et al.* 2005).

2 Concept of Virtual Enterprise

The oldest reference to the virtual enterprise (VE) concept, reports to the year of 1984 (Miles and Snow 1984). However, it is reasonable to believe that a formal definition of VE is something that does not exist (Camarinha-Matos 1997, Steil, Barcia *et al.* 1999). It is even possible to say that in bibliography exists a big profusion of meanings and terminology about this subject (Rolstadas 1998). In spite of the existing sea of relatively different concepts, basically, a Virtual Enterprise is a temporary partnership of independent geographically distributed companies connected using information and communication technologies to share costs, skills, knowledge and take advantaged of an emerging business opportunity (Davidow and Malone 1993).

It is relatively common to find the same terminology assigned to different concepts from different authors as well as the same concept assigned to different terminologies. Extended enterprise expression is virtual enterprise expression's closest rival (Camarinha-Matos *et al.* 1998, Camarinha-Matos and Afsarmanesh 1999), and some times it is possible to assist to some degree of confusion in its utilization (Rolstadas 1997). Comparatively to extended enterprise, virtual enterprise concept has a more extensive scope, and includes the first in it. Consequently, extended enterprise is a particular case of virtual enterprise concept (Jagdev and Browne 1998, Camarinha-Matos and Afsarmanesh 1999).

In the opinion of some authors, extended enterprise is the dominant expression, and the difference between extended and virtual is resumed to a semantic question (Jagdev and Browne 1998). In a virtual enterprise the integration level is bigger and,

comparatively to extended enterprise, the partnership agreements are shorter in time (Jagdev and Browne 1998). It is possible to say that extended enterprise is better used when a dominant enterprise that extends its borders to all, or a majority, of its suppliers is present (Camarinha-Matos *et al.* 1998). This reflection about extended enterprise concept is sustained in the following references: (Corradi *et al.* 1997, Camarinha-Matos *et al.* 1998, Jagdev and Browne 1998, Boyson *et al.* 1999, Davis and O'Sullivan 1999, Mertins and Arlt 1999, Zhou and Besant 2000, Camarinha-Matos 2001).

Alternatives in terminology on this subject can easily be found in literature. Some examples are virtual corporation (Davidow and Malone 1993, Franke and Hickmann 1999); virtual networks (Franke and Hickmann 1999); virtual organization (Sandhof 1999, Steil *et al.* 1999); variable production networks (Wiendahl and Helms 1997); multi-Site production facilities (Roux *et al.* 1999, Zhou and Besant 2000), virtual production networks (Tuma 1998), logistic networks (Schonsleben 2000), supply chain management, electronic commerce, cross border enterprise, network of enterprises (Camarinha-Matos *et al.* 1998) and virtual manufacturing system (Davidrajuh and Deng 2000).

Virtual enterprise concept seems to be a paradigm with a big evolutionary gap. It may also contribute to increase the competitive capacity of enterprises that decide to adopt it. Nevertheless, adopting this paradigm brings not only benefits and advantages. There are some limitations that enterprises must be aware of. Most relevant disadvantages are related to trust and legislation, as well as more difficult people relationships (Moreira *et al.* 2003). The problem of trust between virtual enterprise partners is quite a popular issue (Chiles and McMackin 1996, Meer-Kooistra and Vosselman 2000) (Ishaya and Macaulay 1999) (Brutsch 1998).

Virtual Enterprises bring more dynamic, more flexibility, higher agility and responsiveness, but all that also brings more complexity to planning and control and therefore more potential source of problems (Martinez *et al.* 2001). Another problem arising with virtual enterprises is products guarantee and after selling assistance, since they are temporary by nature. Virtual enterprises must consider mechanism that assures assistance even after its dissolution. Virtual enterprises must also deal with the juridical problem. Countries (a big majority) have not yet adapted their laws to cope with the real meaning of virtual enterprise.

3 Autonomous Production System (APS)

Two centuries ago Adam Smith tried to explain on his book 'Wealth of Nations' the mechanisms that drive the societies. He explained that the market system is a self organized social system, controlled, regulated and directed by it self. Up to a certain extend such 'invisible hand' is still today managing the global economies. The market system strongly influences the enterprises behaviour as a whole but, according to its closed organizational structure, only affects the elements that are in direct contact with the market. The other structural elements under the hierarchy are little or not at all influenced by the market system. If the enterprise opens its structure in order to allow its elements to be directly exposed to the market, letting the market principles in, then the enterprise, as a whole would benefit. A similar line of thought is presented by other authors (Sluga and Butala 2001). This type of approach to the market would naturally redesign the enterprise to more competitive and profitable shape since a clearer view of core and non-core competencies would appear.

3.1 APS Concept

Companies are traditionally organized in hierarchical structures where the communication is established from top management to bottom levels and from bottom

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3 levels to top management through several levels of responsibility. In this type of
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5 organizations each department or section can only communicate with the outside world
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7 through the top management channel [see figure 1 (a)]. Especially in medium/large size
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9 companies, top management does not recognize precisely the market potentialities of its
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11 individual departments, wasting potential businesses.
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15 [Insert figure 1a and b about here]
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18 Any organizational unit (department, section, etc.) in a company can be seen as a
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20 production system, but that is not commonly understood. Most people identify a
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22 production system as long as its output is a tangible product such as computers, shoes or
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24 desks. A production line is clearly understood by anyone as a production system, but
25
26 other organizational units are not. All sub-systems within an enterprise can be seen as
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28 production systems. The department of production planning and control (PPC), the
29
30 accounting systems, or any other sub-system within the enterprise can be easily looked
31
32 at as production systems. The PPC system has inputs, processing, entities flowing
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34 through the system, resources, information and outputs like any other production
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36 system. The outputs (products) of a PPC system are order releases, schedules, resource
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38 allocations, etc. In this way a company may be looked as a network of cooperating
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40 production systems related to each other in a 'supplier-client' or 'partner-partner' basis.
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42 The PPC system provides schedules to other departments, the warehouse holds parts for
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44 several production sections and the department of computing maintains and upgrades all
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46 the computer systems existing in all other departments. If it is possible to introduce
47
48 enough autonomy to departments, groups of departments or parts of departments, then
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50 the entire enterprise could be looked at as a network of independent units exchanging
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52 services with each other. Once a company is organized in that way, each one of its
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54 production systems could look for business opportunities outside the company's
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boundaries without involving the top management channel [see figure 1 (b)]. This is the main idea behind the concept of Autonomous Production System (APS). Although each APS is responsible for its own market visibility and management, the idea that it must follow the business strategy defined by its mother enterprise, must keep clear. Up to a certain extend an APS can be looked at as a small enterprise that follows the strategic plan defined and supervised by a group of enterprises with which it has close ties and owned by the same group of people.

An APS is therefore the whole or a part of a company, which can establish relationships with other APS, part of the same or part of other companies, to create a Virtual Enterprise when business opportunities are identified. The dynamics and flexibility that will be obtained from a global network of APS is enormous. A Virtual Enterprise, created from the right combination of APS, can be more competitive than any existing companies. It is reasonably to consider that no existing company can naturally collect the right combination of APSs to respond always efficiently to changes in demand. A similar concept, although more radical, is the concept of OPIM (One-Product-Integrated-Manufacturing) (Putnik and Silva 1995).

Most of the people may agree on Virtual Enterprises coping with the presented concept, but other considerations must be kept in mind. The overall performance of a company is not only related to the right selection of resources (APS). In a VE environment based on APSs the efficiency of the communication between APSs, the efficiency of the VE management and the efficiency of the transportation of physical goods between APSs also play an important role in the overall performance of the VE. Virtual Enterprises can only be competitive if they can be organized in a way that they can be easily created, can be easily managed and the cost of transportation is not prohibitive. But there are other issues, intangible issues normally forgotten by most

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3 authors that will be referred here in this article. As an example there are the synergies
4 existing in traditional enterprises which make them more than the sum of their
5 resources. This is a concrete reference to the human factor, the team spirit and the
6 positive effect of people relationships and bounds in affecting overall performance. One
7 example of such aspects can be seen when comparing the performance of manufacturing
8 cells with the performance of virtual manufacturing cells (Carvalho *et al.* 2001). It is
9 quite difficult to predict how these factors would influence the VE efficiency in
10 competing with existing enterprises. Existing enterprises have been creating knowledge
11 and experience in their business that can actually make the difference. In this way these
12 enterprises are more than a group of organized resources. At this movement no answer
13 exists on how VEs would manage to overcome this handicap.

30
31 **3.2 APS Generation**

32 How can a company go from a hierarchical structure into an APS distributed structure?
33 This question does not have a simple answer. The way companies can identify their own
34 set of APSs is not easy to define and no standard procedure is necessary. Each company
35 must identify its own set of APS as well as establish its necessary interfaces to
36 communicate with the other APS. Each company can identify its own set of APSs
37 according to its own culture, knowledge, strategy, type of products and position in the
38 market. Nevertheless, it is possible to establish some basic guidelines for its generation.
39 In the limit, the biggest size for an APS is the size of the mother company itself. A
40 company can act as a single APS and that is exactly what is happening right now when
41 companies get together for cooperation to take advantage of business opportunities. On
42 the other hand, the minimum size for an APS is the minimum set of resources that can
43 still process entities and manage itself both in terms of processing and in terms of
44 communication to outside.

As far as the minimum size for an APS is concerned further details are needed. Many authors assume that a resource is the smallest entity that can be used as part of a VE. They assume that if a resource is needed for a certain VE and that resource is found and exists in a company, then that resource can be part of that VE. Some doubts persist on this subject. The VE coordinator (which is an APS specialized on that type of function) can only use that resource as part of the VE if the company that owns it is prepared and organized to provide the use of it. In different words, the company that owns it must sell that service. It is not expected that every company is ready to sell the services of all its resources. If a company is willing to sell the services of a certain resource, it needs to calculate its cost, to know the prices established in the market, to know other conditions of the market, to establish connections to suppliers and clients, to project its PPC system, etc. That is the main reason why the concept of APS is introduced.

Structuring a company in terms of APS is not a straight forwards process. It depends on many aspects, going from the company's policies to the level of understanding of its capabilities. The way a company organizes itself in terms of APS dictates its efficiency both in the traditional and in the VE environments. There are a number of considerations that must to be taken into account when organizing a company in terms of APS: (1) each APS has to be autonomous in terms of management, economic viability, as well as external visibility, (2) each APS must do its own search for partners in the global APS network when a business opportunities is identified, (3) The other APS in the same company are equally available for business opportunities as any others APS from other companies. As an example, the production planning and control (PPC) department can become an APS specialized in that function offering its services in the global APS network. In this context it is possible to assume that a

particular APS of the same company (ex. painting department) can require the service of PPC from outside as long as it represents more attractive solution.

There are several advantages in structuring traditional companies into a group of APSs and some examples are: (1) Helping the identification of the strong and weak points of the enterprise, as well as its core competencies; (2) Preparing the enterprise to quickly react to the market changes on demand; (3) The efficiency of each part of the company can be easily quantified, helping the company in reaching the higher efficiency.

One possible first attempt in defining the set of APSs inside a company is to look at the existing organizational units such as departments and seek for ways to make them autonomous. If a department can supply a product (service or good) with reasonable performance and that department has the necessary set of resources to be self-managed, that department could become an APS. When a company decides to move from a hierarchical structure into a network of APSs, it allows each APS to specialize and clarify its core competences, to define its boundaries, and to evaluate its performances in comparison to other competitors. It must be pointed out that nothing stops a single department to be divided into two APSs or two departments to be organized into a single APS. The global network of APSs of companies from all around the world is believed to result in a much more flexible, efficient, and agile global production.

4 Virtual Enterprise Dynamics

In this work a Virtual Enterprise is considered to be a group of Autonomous Production Systems appearing in the market as a single enterprise. This organized group of APSs is created as business opportunities are identified and during its life cycle can adapt its configuration to changes in demand. In order to simplify all the bureaucratic issues

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3 during VE creation, it is assumed the existence of a Market of APSs which is
4 responsible to assure trust between all VE participants, organization, formalization and
5 consequently increasing the speed in all VE life cycle phases, allowing the VE to be an
6 adequate answer to effective business opportunities in a specific time window. Based on
7 those assumptions Virtual Enterprises dynamics may be seen in several different ways:
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12 (i) Considering the capability to produce specific products, VEs are structures that
13 change dynamically to cope with market needs, combining specific core capabilities of
14 its members in order to exploit a business opportunity (Cao and Dowlatshahi 2004).
15 VEs have a dynamic organizational structure with adaptable rules, allowing participant
16 organizations to join or leave the network at any time (Pires *et al.* 2001). Considering
17 the particular case of VE APS based, the dynamics and flexibility that is expected to be
18 obtained from a global network of APS is enormous. As business opportunities arise,
19 VEs may be easily created from the right combination of APSs allowing virtual
20 enterprises to be a good response to rapid changes in the market (Carvalho *et al.* 2001).
21 VE efficiency depends on a large number of factors, some of them already referred in
22 this article, but an important one is directly related to the performance of its production
23 planning and control system. This system must be feed constantly, with accurate and
24 precise information about the distributed process steps, capacity and performance of the
25 involved APS. Therefore these dynamics must be controlled in order to achieve a
26 competitive and optimal VE performance.
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31 (ii) It is generally assumed that VE life cycle is short in time. However, virtual
32 enterprise life cycle may be extended in time if entry orders justify it. In this process, in
33 order to meet customer's needs, VE available capacity must be adjusted. At this
34 moment attention isn't focus in VE adequate capabilities, but in VE adequate capacity.
35 Capacity must be adjusted due to several factors, such as an increase or decrease in
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demand at a particular moment; troubles to fulfill accorded capacity by one or more of VE participants due internal problems (machine breakdowns or others); exit (voluntary or not) of one or more VE participants, just to indicate some examples. These situations may be solved recurring to fine tuning of the existing VE structure, or by a deeply VE reconfiguration process. It seems to be clear that an efficient management of all these situations will decisively influence VE success, as VEs must give a proper answer to customers needs in time, quality and quantities.

(iii) Another factor that seems to be important to control, concerns to virtual enterprise dissolution. VE must guarantee that even after its dissolution all its products are covered by after sale services. Inclusively, during its life cycle, it is possible that some VE participants may leave the VE structure after having actively participated in its mission. Services or parts produced by those who had left the organization must be covered by guarantees. It is critical that some kind of structure stores information about which VE member was responsible for each task in a particular moment in time (traceability). This is even more critical if the One-Order-Enterprise concept is introduced, which represents the major manifestation of VE dynamics. This concept materializes the idea that the VE APS set could naturally change several times during the operation process. If one specific order implies the reconfiguration of the VE in a large scale, nearly all the members, then this is the One-Order-Enterprise idea. This is a sensible matter, namely in what concerns to after sell services, like product guarantee or maintenance operations.

5 The Bill of Materials and Movements

Bill Of Materials play a central role in the production planning and control process since it is based on that piece of information that all process explodes creating all time-phased material and capacity requirements. The most common production planning and control

model widely assumed to be the heart of ERP systems is presented in figure 2. In this model (Vollmann *et al.* 1992), orders coming from the market are feed into the master production scheduler where they are arranged in order to create a time-phased master production schedule. This schedule is no more than the quantities of each final product the company intends to have for delivery in the near future.

The bills of materials for all final products together with the inventory status data contain the information that is needed to transform the master production schedule into detailed time-phased material requirements. All of that is performed checking existing capacity in an interactive way.

Production flow control is a complex industrial problem while scheduling production throughout available capacities. The problem becomes especially complicated when dealing with multi-level product structures, geographically distributed all over the world. As seen before, Bill Of Materials is closely related with production control. Several works show that legacy systems are not suitable to be applied on those new environments (Frederix 1996; Makatsoris *et al.* 1996; Dudenhausen *et al.* 1997; Tu 1997; Wiendahl and Helms 1997; Gunasekaran 1999; Rupp and Ristic 2000; Dickerhof *et al.* 2001). The solution is building new approaches or introducing reengineering to existents.

The extra complexity brought by virtual enterprises is that the complete production system is no longer concentrated in a single factory but instead distributed in many different production sites. This characteristic of virtual enterprises brings a new type of operations that can not be ignored: transport operation between production sites. The overall production performance depends on the way those transport operations are integrated with the manufacturing operations to be performed in each autonomous production system.

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[Insert figure 2 about here]

It is also important to stress that another type of information becomes necessary in VE environment which was not necessary in traditional enterprises: information on which APS is responsible to perform each operation. An example of this type of information is presented on the BOMM in figure 3. In a certain way, as you can see, this BOMM includes also high level process planning information.

From operations management perspective, it is critical to have a plan that allows coordination of manufacturing a product in a geographically worldwide distributed environment. To perform an adequate coordination of all stages of the distributed production process, coordinator must be constantly feed with accurate information concerning capacity, performance, tasks assignments and information about movements between nodes. Considering that virtual enterprise life cycle includes the possibility of structural reconfiguration actions, it is also critical the existence of a structure or tool that allows an efficient coordination of all VE integrators and by other side that allows an adequate management of VE structural instability.

To solve the problems presented above a new tool which includes the transport requirements, the APS responsible for each task and accurately reflects the actual VE structure allowing strictness and consistency in management activities it is proposed (see an example in figure 3). This is the Bill Of Materials and Movements (BOMM) and it becomes the central piece of data in the production planning and control system proposed for virtual enterprises (Carvalho *et al.* 2005).

[Insert figure 3 about here]

5.1 BOMM in VE formation

During the Virtual Enterprise life cycle and according to our proposal, BOMM first generation occurs in virtual enterprise formation activity. It is within this activity that all starting up processes will be performed. In figure 4 it is showed, in an IDEF0 format, how the VE formation with all its processes will works. The trigger of the all process is the idea, generated by the starter entity. The starter entity could be anyone with a business opportunity idea (must be someone with knowledge on that type of business). As it is possible to see in figure 4, the rough process plan, rough product specification and searching constrains, will be the main pieces of information that allow starting partners search and VE Project activities. From partners search will result a first set of possible APS to integrate the VE. The VE project activity will allow VE partners selection, a re-analysis of product and process specification, organizing, defining and formalize the virtual enterprise and generate the BOMM first stable version (see figure 5).

[Insert figure 4 about here]

[Insert figure 5 about here]

Defining and formalizing VE it is not a one step process. Constrains in potential participants to be assigned to tasks defined in the VE rough process plan (related to core competences and APS Market publicised capacity) and/or in the process plan will lead to the need of a new partners search based in new constrains and/or product specifications changes and/or process plan modifications. Usually, this process will be finished after few iterations and revisions. It is important to note that in BOMM generation activity will come out with a proposed version of BOMM as well as alternative combinations of APS partners and alternative BOMM that may be

considered in later stages (see figure 5). This is important since it is the first time the selection of partners is performed under the product structure point of view. This situation will increase the flexibility concerning first VE formation, but also in future actions of changing VE structure during VE operation phase. Simultaneously to the finishing of all these dynamics it will be generated a BOMM first stable version.

5.2 BOMM in VE operation

VE operation phase is responsible to transform customers' orders into production. During this process several unexpected events may occur. Some events will lead to changes in the Bill Of Material and Movements and the most important ones are:

- i) Changes in product structure due to changes in product requirements or product design;
- ii) Changes in the process plan due to changes in production methods or process technologies;
- iii) Changes in VE structure due to strategic decisions, poor APS performance or APS insufficient capacity. In cases i) and ii) the existing set of APS competences may not be suitable in dealing with the new structure requirements, so new VE configuration may be required. If customer's entry orders imply a capacity increase in a specific moment, and the existing APS are not able to satisfy new capacity requirements, then the VE reconfiguration process will be necessary.

[Insert figure 6 about here]

Figure 6 shows that VE operation will be supported by four main activities: Production Planning and Control; Financial Management; Production, Purchases and Movements; and Performance Management. All those activities are directly influenced by the BOMM but Production planning and control as well as performance management activities may led to changes in BOMM (see arrow O1 - Reconfiguring orders – on

figure 6). The production planning and control function main dynamic inputs are, as in the traditional organizations, customer's orders and demand forecast information. Reliable information from customer's orders and demand forecast will allow the generation of a consistent Master Production Schedule. In this procedure it is stressed the importance of an updated and accurate BOMM, since it is based on this structure that rough capacity checking is performed and therefore the BOMM must reflect the actual set of APSs for that particular moment. The BOMM plays a key role in the production planning and control activity since it dictates how and where the different operation will be performed.

When a new customer's order arrives in the Master Production Scheduling (MPS), three actions could be taken (see figure 7):

- The order is rejected – many reasons could be enumerated to support that decision, just to give one example: the due date required by the customer is clearly unachievable.
- The order is treated in the MPS but a VE reconfiguration is clearly required. A reconfiguration process is initiated and changes will naturally be needed for the BOMM.
- The order is accepted without any required changes in the VE structure. In this case, the master production schedule will be updated to include this new order and then the process will follow the normal procedure. This normal procedure however may require new MPS run in order to fit detailed capacity constraints.

[Insert figure 7 about here]

Traditional PPC models assume two dimensions of management: the materials management and the capacity management. Since it is assumed that main production planning and control activities take place at the VE level, another dimension must be

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3 included, which is related to managing the material movements between VE partners
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5 (see figure 8). Materials detailed planning activity is performed according to the
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7 traditional MRP (Material Requirements Planning) procedures using information from
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9 the master production scheduler, from the product structure and from existing inventory
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11 data. The result obtained is a time-phased purchasing and production plan. At this point
12
13 it is know what must buy and produced, when, were (VE partner identification), and in
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15 which quantities. According to that plan, the needs for transportation between VE
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17 partners can be determined by the movements detailed planning. At this point it is also
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19 known what and when the transportations must be performed and from whom. It is
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21 important to understand that all those plans are yet conditional to capacity checks
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23 performed on the next step. On the next module iterative capacity verification as well as
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25 lead time confirmation activity is performed. If the plans are not achievable a new MPS
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27 could be suggested or, in extreme cases, a new configuration for the VE could be
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29 suggested in order to better respond to capacity constraints.
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36 [Insert figure 8 about here]
37

38
39 During operation phase, there are other aspects that may change BOMM
40
41 structure. When manufacturing process is running, an activity is responsible for
42
43 collecting information about production progress. This activity is the production
44
45 monitoring activity (see figure 7). Basically Production monitoring uses orders
46
47 progression reports and proactive orders progression reports to generate performance
48
49 matrix, as the output of performance patterns generation activity (see figure 9).
50
51
52 The activity A213 (Production monitoring) feeds information to the activity A214
53
54 (production control and VE reconfiguring) such as Global production progress or APS
55
56 performance matrix (figure 7). The main function of activity A214 is to control the
57
58 production related to the VE products, in all partners, assuring that it stays under the
59
60

material requirements and movements plans. If deviations are detected at this activity the system perform attempts to solve the problem by sending information (re-planning suggestions at detailed level) back to the activity A212. This attempt tries to avoid major changes. If re-planning is not possible then VE reconfiguring suggestions will be generated. This suggestion naturally leads the production planning and control system into the need of changing the BOMM.

[Insert figure 9 about here]

[Insert figure 10 about here]

The way the activity A214 (Production Control and VE reconfiguring) is performed in detail is presented in see figure 10. The first activity called Production progress control is responsible to measure general production performance and suggest corrections in production orders. The second activity called Proactive Production progress control is expect to predict future problems and send warnings to activity A23 (Production, purchases and movements activity) in order to avoid potential problems from occurring in the future. The last activity named Reconfiguring and re-planning activity, has the ability to decide either to suggest attempts to solve the problems through re-planning at detailed level or generating reconfiguring orders which for sure will result in BOMM changes.

5.3 In VE dissolution

Virtual enterprise dissolution, as the name may suggest, is not just an activity of closing down the virtual enterprise life cycle. During VE life cycle, several activities are performed under the umbrella of dissolution activity. VE dissolution activity has the responsibility of preparing documents and procedures in order to formalise the VE entrance and exit of APS, preparing all the procedures to close the virtual enterprise and, simultaneously, ensuring that data concerning all finished production tasks is

1
2
3 stored. On-going viability analysis; Normal or unfriendly dissolution process;
4
5 Customers service and Compiling information, are activities that sustain dissolution
6
7 functionality, guided by dissolution plan developed on formation phase (see figure 11).
8
9 Concerning BOMM, in dissolution phase, its influence is notorious at customer's
10
11 service activity. During VE activity, if a guarantee or after sell service is claimed by any
12
13 customer, VE must search inside its databases which was the set of APS responsible for
14
15 manufacture the product in question. If all the APS still in activity, the claim is sent to
16
17 the VE with the purpose of repair eventual malfunctions and be delivery to the
18
19 customer. If the set of APS is already fragmented, i.e., only some of them or al limit,
20
21 none, of them still in activity, the VE has the responsibility to start a new VE to
22
23 guarantee customer rights. If the VE is already discontinued, then satisfying customer
24
25 claims is an APSM responsibility. Here is stressed up once more the influence o
26
27 BOMM. Based on costumer claim product serial number, APSM will start a search
28
29 process in its databases to identify in a first step the BOMM that had sustained the
30
31 product manufacturing. With BOMM information, product will be sent to APS or
32
33 APS(s) required solving the problem. In extreme cases, a new VE must be created to
34
35 satisfy customer claims.
36
37
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43 [Insert figure 11 about here]
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46

47 **6 Conclusion**
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49 In this work it is introduced the innovative concept of Bill Of Materials and Movements
50
51 (BOMM). The existence of this structure is a critical success factor to allow an up to
52
53 date VE management. VE concept is characterized by several dynamic aspects that
54
55 make its management a very complex task. The set of APS than in a specific moment
56
57 work together to satisfy a specific order may not be the same that cooperate together to
58
59 satisfy another order in a different moment. Consequently, during VE life cycle it will
60

1
2
3 exist different sets of APSs responsible for the execution of different orders. This
4
5 situation results in the need of generating several BOMM during the VE life cycle.
6
7 Thus, an updated BOMM and an accurate relation with orders, allow adequate
8
9 information flow diffusion along the VE to feed critical activities of distributed
10
11 production planning and control. BOMM will also allow tracking information about
12
13 which APS were involved in manufacturing a specific product/order. This is of further
14
15 importance if the case is pharmaceutical or aeronautical industry. Hence, BOMM
16
17 appears as VE integration structure. It seems to be clear that for an adequate VE activity
18
19 a BOMM or a similar concept must exist to allow planning and control in highly
20
21 dynamic environments such as virtual enterprises.
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Figure 1. Traditional organizational structure (a) and APS organizational structure (b)

Figure 2. A popular production planning and control model

Figure 3. An example of a Bill Of Materials and Movements

Figure 4. Overall VE formation in IDEF0 format

Figure 5. BOMM Generation inside VE Project in IDEF0 format

Figure 6. BOMM in VE operation phase in IDEF0 format

Figure 7. Production Planning and Control activity in IDEF0 format

Figure 8. Materials and movements detailed planning activity in IDEF0 format

Figure 9. Production monitoring activity in IDEF0 format

Figure 10. (A214) Production control and VE reconfiguring in IDEF0 format

Figure 11. Contribution to BOMM in dissolution phase sub-activities in IDEF0 format

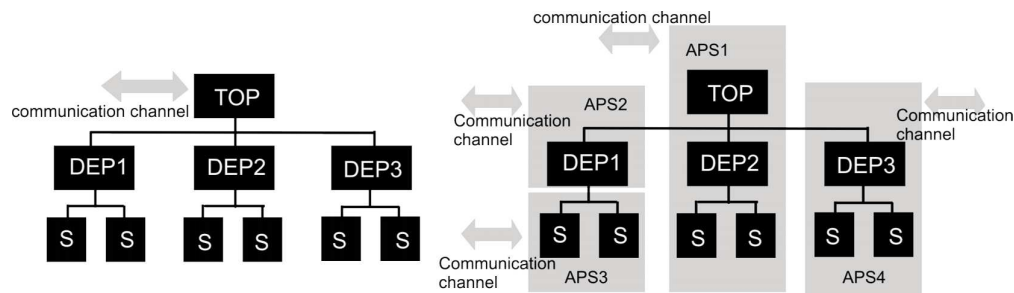


Figure 1. Traditional organizational structure (a) and APS organizational structure (b)

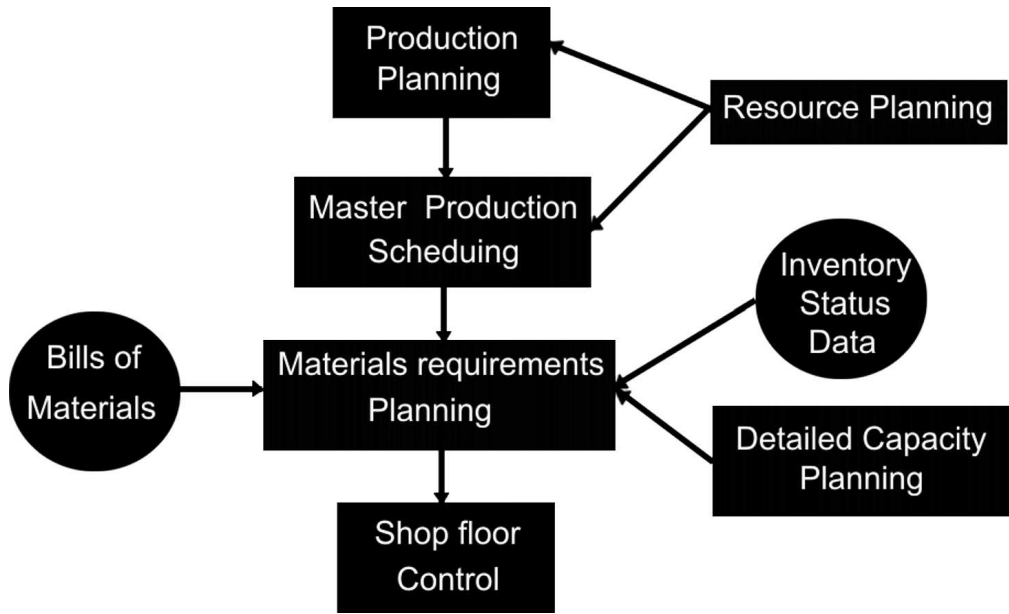


Figure 2. A popular production planning and control model

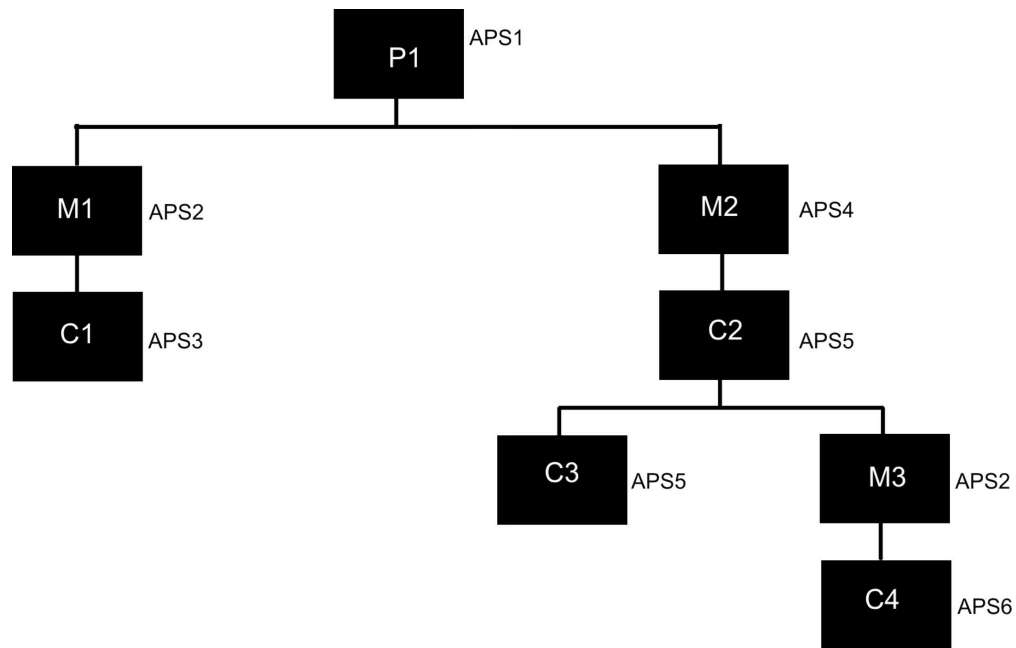


Figure 3. An example of a Bill Of Materials and Movements

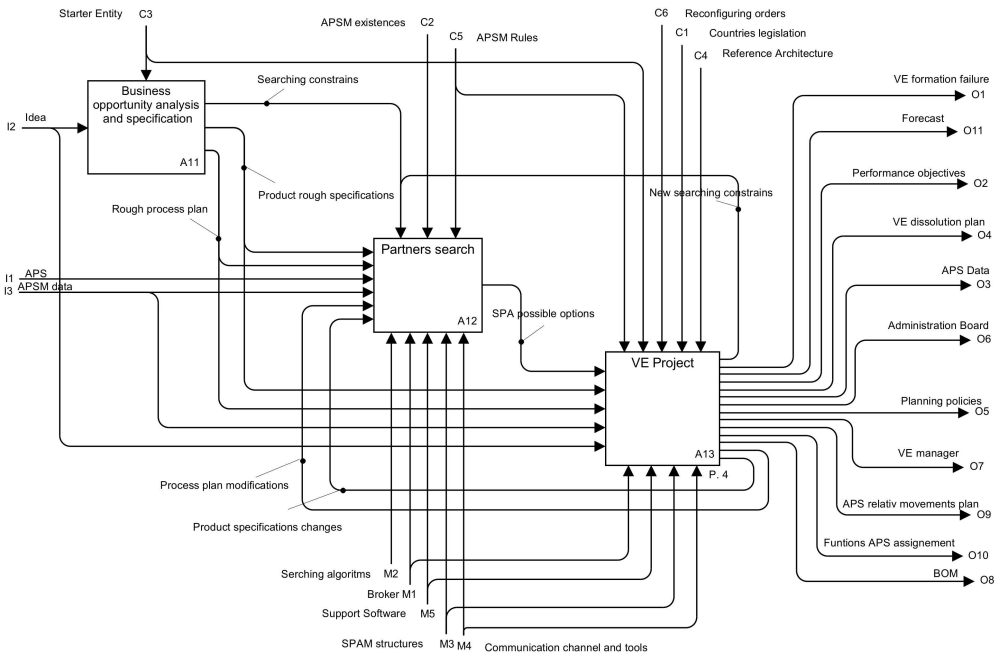


Figure 4. Overall VE formation in IDEF0 format

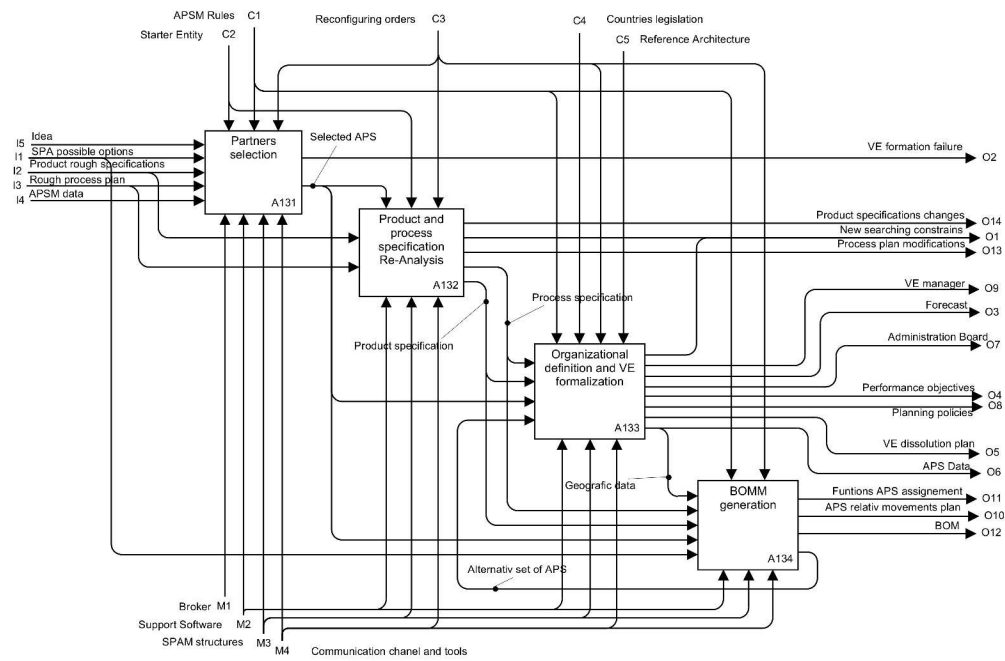


Figure 5. BOMM Generation inside VE Project in IDEF0 format

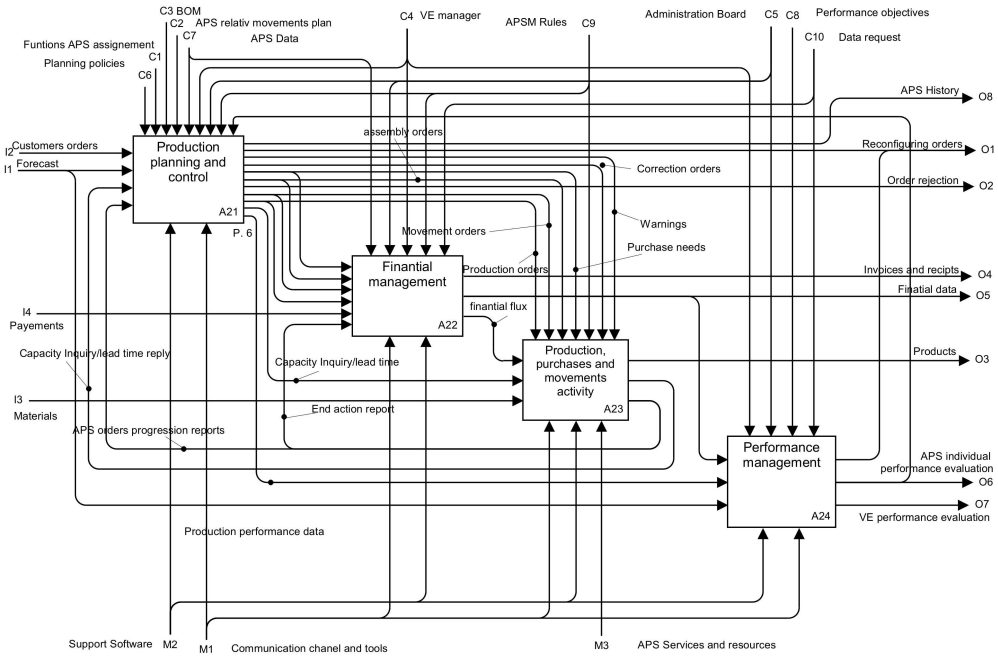


Figure 6. BOMM in VE operation phase in IDEF0 format

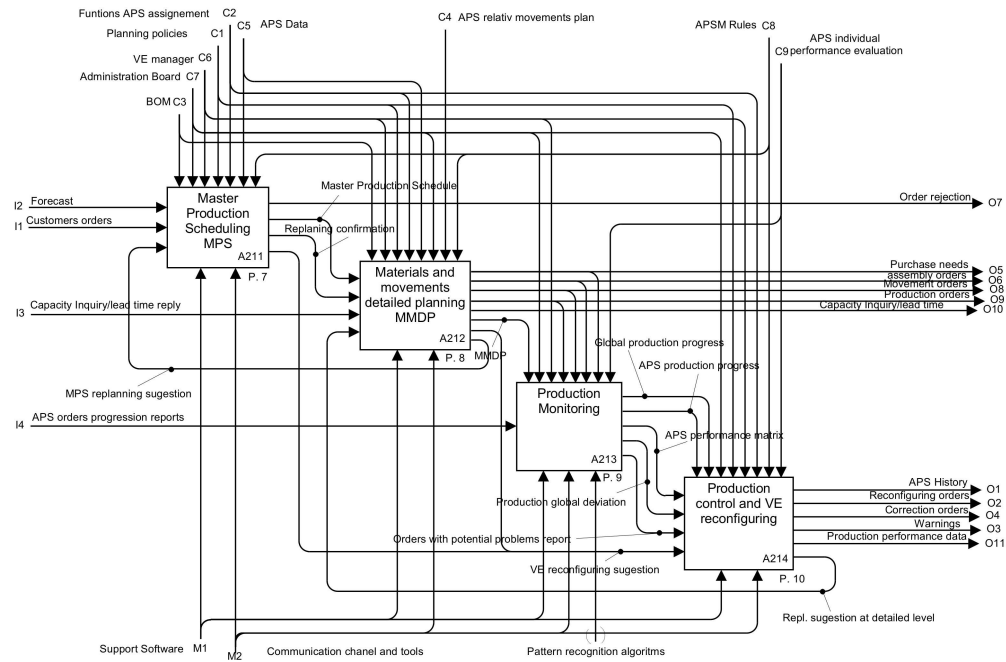


Figure 7. Production Planning and Control activity in IDEF0 format

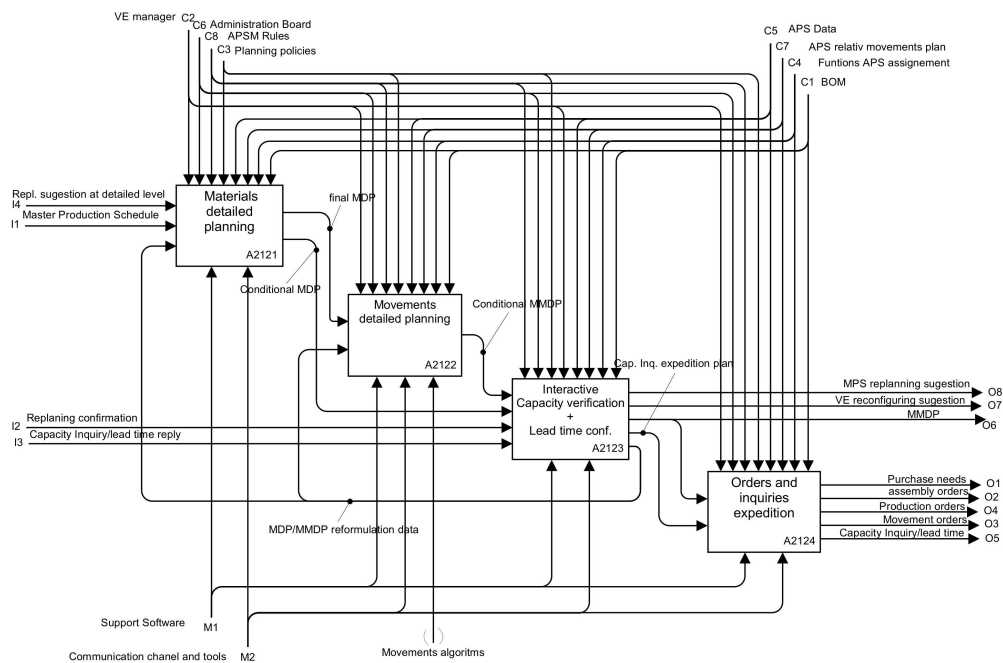


Figure 8. Materials and movements detailed planning activity in IDEF0 format

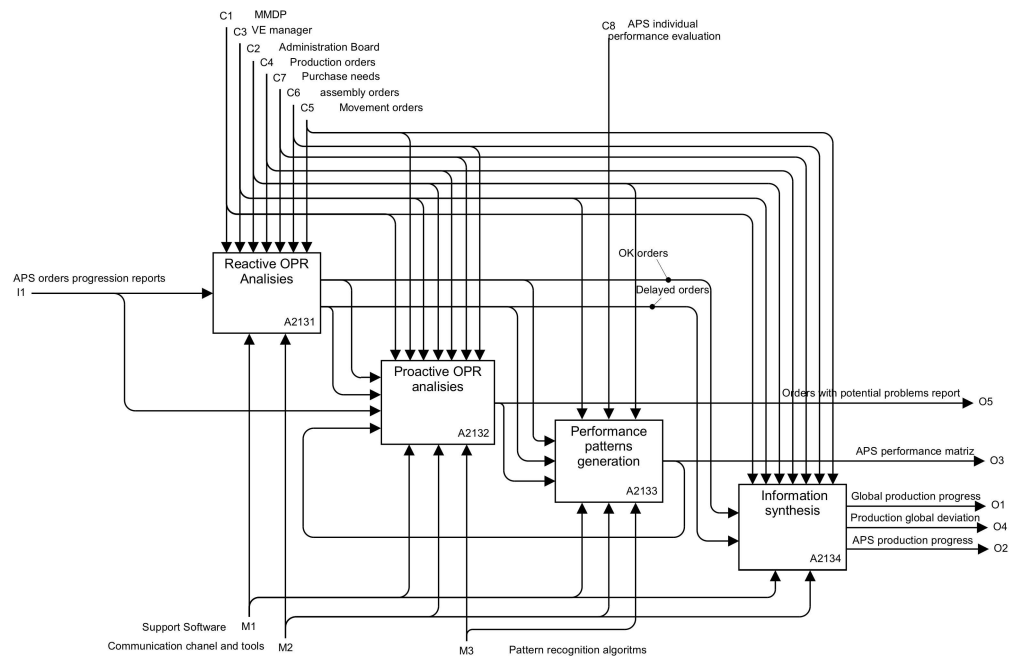


Figure 9. Production monitoring activity in IDEF0 format

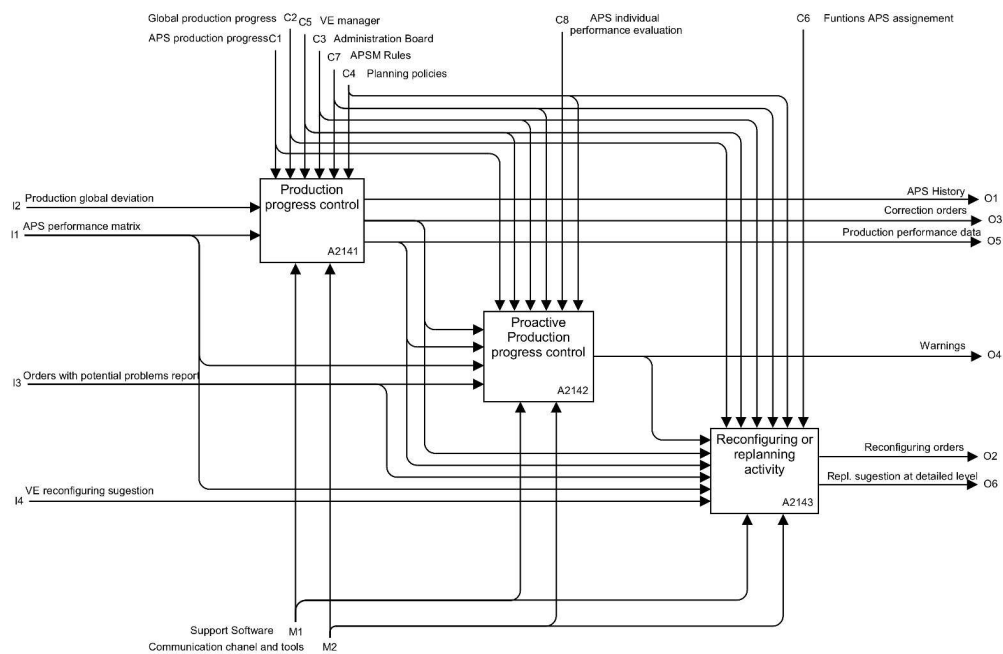


Figure 10. (A214) Production control and VE reconfiguring in IDEF0 format

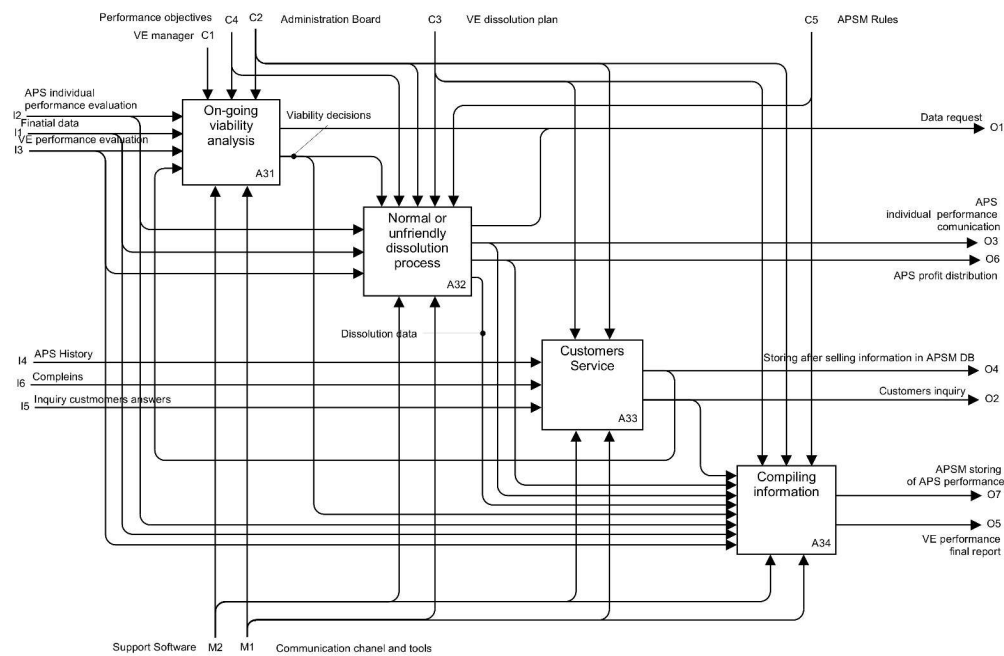


Figure 11. Contribution to BOMM in dissolution phase sub-activities in IDEF0 format