FUNDAMENTAL CONCEPTS OF PRODUCTION MANAGEMENT SYSTEMS AND TRADITIONAL METHODS FOR THEIR INTEGRATION

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Abstract: Lack of systems integration degenerates the company's performance due to information incoherence, imprecision, outdated appointments and slow information exchange. This paper reviews some of the fundamental concepts of the most common production management systems (i.e., forecasting, planning, material requirements, scheduling and execution) and methods normally used for their integration. Integration issues are briefly illustrated by classical control theory, and main characteristics, functions, interfaces, and information of these systems are described. Three methods used by industries in the integration of such systems are quickly presented: Open Database Connectivity (ODBC), text files exchange and OLE for Process Control (OPC). Lastly, a few considerations about real-time and frequency on information exchange are presented.

Keywords: Production management, logistics, manufacturing information systems

1 INTRODUCTION

A manufacturing system aims at producing goods through the coordinate integration of people, information systems, mechanisms and activities from several sectors of the corporation, such as sales, marketing, finances, design, planning and control. A great deal of information should constantly flow among these departments, synchronously, safely and quickly, improving the company's performance and flexibility. Lack of integration of managerial systems, like forecasting, planning, inventory management, scheduling and execution, degenerate the firm's performance due to problems caused by in coherence, imprecision, outdated information and slowness in the data exchange. For this reason, this paper reviews some of the fundamental concepts of the most common production management systems and methods normally used for their integration

There exists a great variety of manufacturing information systems meeting innumerous functions in the firm's supply chain, among these, the main ones concerns sales forecasting system, planning, scheduling, control, supervision and execution. The appropriate integration of these systems allows for better resources, sectors and processes management due to the easy access to important information like strategic, tactical and operational goals, current performance measures, capacity or resources status.

Reasons to integrated manufacturing information systems are varied, but the main ones are wide originated by the need for rapid, easy and safe access to critical information usually spread through a range of people and areas. Another benefit comes from the fact that as one automates the data collection and transmission, less human errors occurs. Besides these benefits, with the large and easy use of the Internet, having information available to anyone, at any time, anywhere, is becoming an easy task. But the integration of these systems also brings other, less important, advantages, such as resources (printers, fax machines, scanners, CD recorders) sharing and cost reduction by wasting less on papers, equipment maintenance, ink cartridges, etc.

However, in practice, complete integration of production systems still do not exist, despite the technology being easily available. There are innumerous reasons for the creation of information islands in the supply chain, among them, one can mention lack of a systemic vision of the company's business, incorrect or non-use of appropriate modeling methodology, incompatibility of programming languages and platforms, and use of proprietary (dedicated) systems and communication protocols, that is, systems that were developed exclusively for the company, which often does not take into consideration international standards for systems integration, like. (There are also several reasons to motivate a company to use proprietary systems, as implementation costs and customized solutions specifically developed for the firm's operations.)

It is in the small or middle size company that the true meaning of information systems integration flourishes, since such companies cannot usually afford buying a full management software packages (suites), usually developed by big vendors like SAP, PeopleSoft and J.D.Edwards. Often, the small and mid size companies acquire their systems gradually and from several vendors, based on, costs and customization benefits.

This paper is organized as follows: next section presents, an illustration of information systems integration through the classical control theory. On section three, main production systems are individually reviewed within the context of integration. Section four shows some of the characteristics of the three most used form of integration, which are *Open Data Base Connectivity*, access (writing and reading) ASCII text files and OPC (*OLE for Process Control*). In the last part of the paper, a brief explanation about real time and frequency in data exchange in manufacturing systems integration is presented, followed by a conclusion.

2 INTEGRATION ILLUSTRATED BY CLASSICAL CONTROL THEORY

The greatest advantage on integrating manufacturing information systems relies on the hope that it will bring significant benefits to the firm such as increase in productivity, costs reduction, better management of people, processes and resources, and rapid and safe access to the company's operational, tactical and strategic objectives. To illustrate the importance of manufacturing integration and the types of information used, some basic principles can be used. Through the classical control manufacturing integration, one compares the target performance objectives with what is actually occurring in the shop floor (as one knows, productivity, capacity, inventory, among other performance related metrics, are measured in the shop-floor). The performance difference should then be used to the generation of corrective actions to be applied at the system being controlled, as illustrated at Figure 1.

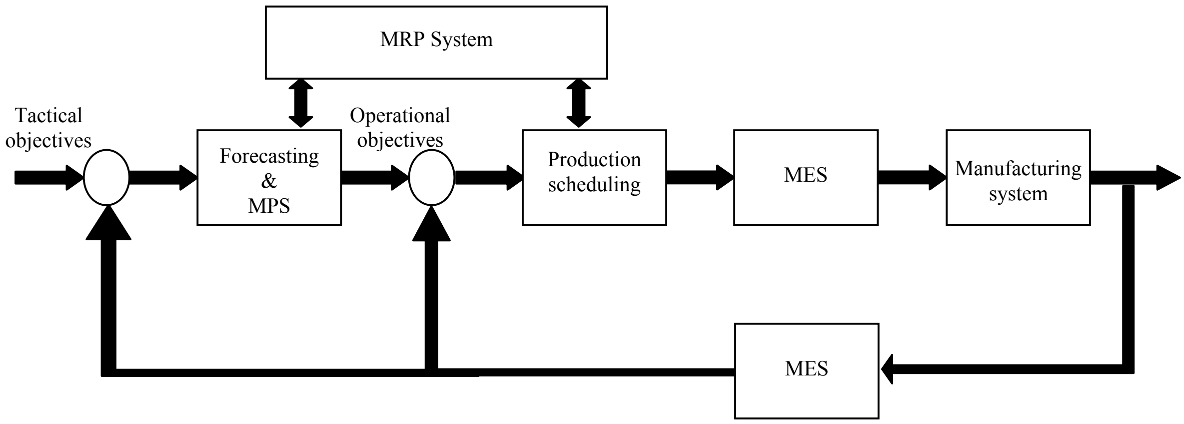

Figure 1 – Classical control illustrating manufacturing systems integration

In management, planning, control or production scheduling, performance objectives are innumerous, like minimizing delays in order delivery, improving product quality, minimizing productive costs (mainly inventory levels), and balancing resources utilization. These objectives require information that needs to be constantly stores, monitored and exchanged among several systems and areas. Based on the control theory mentioned, for the integration of manufacturing systems to be implemented efficiently, five considerations should be taken:

- Target goals must be doable;
- Decision making should contribute to the optimization of the whole system under control;
- Faithful application of commands and actions defined by the controller;
- Dependable and precise system performance measurement;
- Operational cycle (frequency) should be appropriate, that is, too fast monitoring will incur in resources wastes, and too slow monitoring is not enough to implement successful control actions.

One can therefore, foresee, that the amount of stored, exchanged, maintained and available information in (or among) the information systems in a corporation is very large. In this work, integration of manufacturing information systems is divided in two parts containing: (a) a brief description of each system and main transactions among them, and, (b) a quick explanation about their physical integration, which deals with the way and mechanisms used in exchange of information.

3 COMMON PRODUCTION MANAGEMENT SYSTEMS

This section presents some of the very basic ideas behind commonly used manufacturing systems, information they require in order to operate, and how logical integration should be performed.

3.1 Production forecasting systems

Sales history is the crucial information to estimate what should be produced in the coming future. Therefore, it is mandatory that such information be current, precise and readily available. (For new products, which do not have sales history, the difficulty in the forecasting is greater. In such case, one can use sales information of a product which behavior is expected to be similar to the new product's behavior, adjusted by some coefficients if needed.)

Sales or production forecasting (not differentiated in this work) can be made in different approaches and by several methods. For the managers, forecasting and sales history are normally treated in product families (classes or groups) and in monetary values. For the production scheduler, however, planning is done quantitatively (units, boxes, pallets, liters, tons) and refers to final products. A forecasting system must allow for the use of these different approaches, besides allowing for the transformation among them.

Several methods can be used to implement a forecasting system; amongst the most common ones time series is probably the most used. But researchers have proposed new methods; some of them seem to present better results than traditional forecasting methods. Like, methods based on artificial neural networks and fuzzy logic, for instance.

Forecasting Information should be passed to the production planning system, usually a master production system (MPS), for it to create realistic production plans based on resource capacities and other productivity parameters, as explain in the next section. On the reverse direction, that is, integration with higher hierarchical levels, forecasting should be transformed (aggregated and in monetary values) and passed to the decision makers. (More on forecasting systems and their role in the supply chain. Please, refer to VOLLMANN *et al*. (1992), LEWIS (1998), and VIALE (1997) for more about this type of system.)

3.2 Master production scheduling systems

In few words, the master production scheduling (MPS) system defines what, when and how much should be made in middle to long time horizon, based on the forecast defined. It will conciliate resources capacities, productivity, desirable inventory levels and current inventory levels in the development of finite capacity a production plan.

Besides considering shop floor capacities, an MPS system also considers unproductive times in order to create realistic plans, like setup and transfer/transportation times. Regarding integration, such information may be obtained from data collected and stored by a manufacturing execution system (MES) or a supervisory control and data acquisition system (SCADA) – (both of them are treated indistinctively as MES in this work). From the higher hierarchical level, capacities and productivities can be gathered from an ERP (*Enterprise Resource Planning*) system.

Several objectives can be used in the elaboration of the master production plan, among the main ones, maximizing (or balancing) resource usage, minimizing changeover times, production of urgent orders, and just-in-time production, which means to produce just when needed and with the minimum possible waste. Again, integration of MPS and MES will allow the continuous update of these metrics.

Another important characteristic present in a master production scheduling system is the "*(ATP)* method". Which allows the company to state how much is available for delivery. ATD has gotten increased attention by the advent of the Internet as an important communication media, since customers now want to know instantly if and when their orders will be available. This shows that information systems integration goes beyond the integration of traditional manufacturing systems.

Use of MPS systems brings significant advantages that cannot be obtained with other systems like, for instance (see Section 3.3). Some of these advantages are: (a) use of actual finite capacity on the shop floor; (b) setup and transfer times can be considered; (c) optimization; and (d) available-to-promise.

These benefits, however, can only be completely achieved when the involved information systems are integrated. The reader can refer to VOLLMANN *et al*. (1992), LEWIS (1998), VIALE (1997), SLACK *et al*. (2001), SILVER *et al*. (1998), PROUD (1999), and SCHONSLEBEN (2000) for detailed explanation on MPS systems.

3.3 Material requirements planning systems

The main goal of a material requirements planning (MRP) system is to estimate the correct material (items or parts) needs at the right time in order to meet production plans or schedules. For this, the MRP creates a replenishment (or purchase) plan for each material type based on the *bill-of-material* (BOM) and manufactured production plans (Note the obvious need for MPS, schedule and MRP integration).

Many firms incorrectly use the MRP as a production planning system, although it does not consider the real finite availability of resources and production capacities. This will not incur significant problems when the firm has sufficient capacity to attend any planned values, however, usually resources are scarce, which will end up with production goals not being met.

The BOM works as a cake recipe, associating material quantities for each final product, with or without including supplier lead-times. Based on the lead-times, production plans and forecasts can be made more precisely, since the time when suppliers intend to deliver materials is known. In case a supplier cannot supply the firm's the required order, the firm can reorganize its strategy to deal with this problem and minimize possible losses. This also illustrates the need for integration in the whole supply chain, and not only within an organization.

The MRP, acting as an inventory control system, can also inform the production planning and scheduling systems about current inventory levels, work-in-progress (WIP) and expected material receivables. It is, therefore, important that such information be constantly updated, since if incorrect inventory levels are used, in excess inventory might be build or customers order will not be fulfilled. More on material requirement systems can be found at VOLLMANN *et al.* (1992), SLACK *et al.* (2001), PTAK (1996), and LUNN *et al.* (1992).

3.4 Shop floor scheduling systems

One can define a production schedule as a plan with reference to the sequence of and time allocated for each item necessary to complete the item. This definition lets us think of a schedule that has a series of sequential steps, or a routing. The entire sequence of operations, the necessary sequential constraints, the time estimates for each operation, and the required resource capacities for each operation are inputs to developing the detailed pan or schedule (VOLLMANN *et al.*, 1992).

Therefore, some of the information that should to be considered in production scheduling is:

- Resources and needed capacities;
- Changeover (setup) times;
- Transfer times;
- Product priorities;
- Order types and sizes;
- Logical operators, like optimization objectives or favorite dispatching rule.

It obvious that innumerous operation sequences can be created. In each sequence, operation times can differ based on which resource is used. Setup times, on the other hand, depend on the sequence itself (or routing chosen). Therefore, the search for an optimal schedule is usually a hard and lengthy task. For this reason, dispatching rules have been used in the creation of good (not optimal) production schedules. Rules commonly used are earliest due date, weighted shortest processing time, longest processing time, shortest setup time and critical path (PINEDO & SESHADRI 2001). But independently of how or which method is used in the schedule elaboration, the large number of information that needs to be gathered from the corporation is quite clear. The integration is, once again, crucial for the efficient performance of the company.

For a make-to-stock firm, use of a master production scheduling system fits quite well, mainly due to the existence of a production forecast. On the other hand, if the firm is a make-to-order, a scheduling system seems to fit better (although a company using an MPS can also benefit from using a shop-floor scheduling system). Time horizon and product time are also treated differently by these systems, as shown in Table 1.

Table 1. Differences between MPS and shop floor scheduling

MPS	Shop-floor scheduling
• Tactical plan, middle time horizon.	• Operational plan, short time horizon.
• Visibility: weeks to months, allowing the decision maker to have a broader control over the system.	• Visibility: hours, days or few weeks. Restrict control over the system.
• Plan usually based on aggregated orders/forecasts.	• Plan developed based on orders or individual operations (jobs) – disaggregated.
• Does not show production sequence within a time period (bucket).	• Detailed plan, showing the production sequence to be followed in the shop floor, with starting and ending hour/date for each operation.
• Performance measured in terms of service levels, inventory levels and resource usage.	• Performance measures in terms of delays, cycle times and resource usage.
• More easily applicable to make-to-stock environments.	• More easily applicable to make-to-order environments.

In these last forty years, a great deal of works in production scheduling has been done. More on this subject can be found at VOLLMANN *et al.* (1992), SLACK *et al.* (2001), SILVER *et al.* (1998), CORREL and EDSON (1998), PINEDO and SESHADRI (2001) and PINEDO (2001).

3.5 Manufacturing execution systems

A manufacturing execution system (MES) usually represented by or integrated to a supervisory control and data acquisition (SCADA) system, portraits the role of actuator and sensor in the control loop, as illustrated at Figure 1. As an actuator, it executes the production plan or scheduled defined by their respective systems, assuring that what has been planned gets done in the shop, by coordinating activities, resources and capacities, and monitoring information and processes status. It has an important role in putting in practice what has been planned.

As a sensor, the MES reads the system's status and performance measures. It supplies the other systems with information on current shop floor inventory levels, used and available capacity, and performance measures, like cycle times, throughput times, delays, etc. Needless to say is the importance for integration of this system in the firm's information structure.

Productivity and capacity must be updated by the MES and passed to the planning and scheduling systems. Imagine, for instance, that a certain production or assembly line will be shut down for the next three days, or that some of the machines will be off doing maintenance, or that a number of employees will be on vacation for a couple of days. Based on this information, the planning (or scheduling) system can generate a new plan (or schedule) to minimize the negative effects of this event through the reallocation (reassignment) of production orders. In fact, there are many other factors that can require replanning (rescheduling): equipment failure, lack of material, urgent order arrival or order cancellation.

Next section will consider integration from a "physical" perspective, that is, methods or technologies being used for this purpose. To present a general idea of these systems and some of the information that need to be exchanged among them, Figure 2 presents a schematic representation.

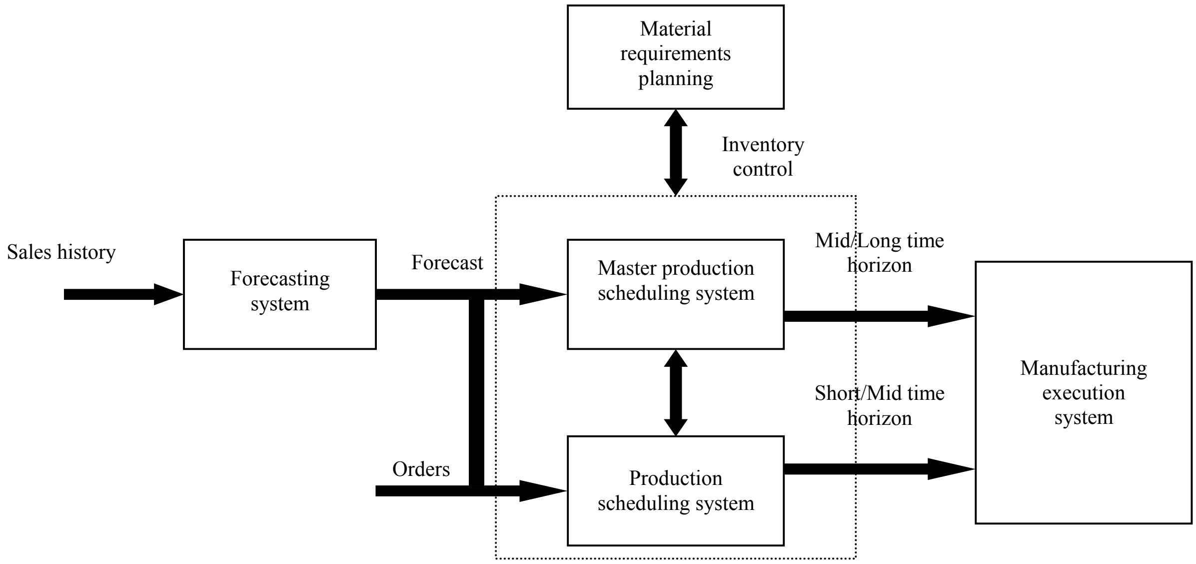

Figure 2 – Integration of common manufacturing information systems

4 PHYSICAL INTEGRATION

Physical integration deals with the approaches and mechanisms used to do data exchange among information systems. It can be seen under two approaches: communication networks and integration methods. Communication networks regard the physical media where data flows and respective communication protocols. Integration mechanisms concern the methodology used for the data exchange itself, as, for instance, ODBC, OPC and ASCII files (explained later).

This paper focuses more on reviewing the basics of manufacturing information systems and the methods for information exchange, rather than communication networks. Therefore, very briefly, one can say that communication networks allow for different devices and computers to be connected, without the need to be directly connected to one-to-one. This allows for an important reduction in the number of connections, simplify maintenance and easies expansion. Besides, it allows for devices (printers, scanner, CD burners), software and data to be shared. In this study, however, the greatest advantage of having computers, and consequently, systems, networked, is the sharing of files and databases. There are innumerous communication networks available, like Seriplex, ASI (*Actuator-sensor interface*), Interbus, SDS (*Smart Distributed System*), DeviceNET, Profibus and Fieldbus, at the shop floor level, and ControlNET and Ethernet at the corporative (or office) level. Surely, Ethernet has been the most widely used in terms of corporate integration.

Data exchange among manufacturing information systems has usually been done in three ways, depending on the hierarchical level. In higher levels (see Figure 3), it has been done through *Open Data Base Connectivity* (ODBC) and via access (writing and reading) ASCII (*American Standard Code for Information Interchange*) files. In the lowest hierarchical levels, OPC (*OLE for Process Control*) has been widely used.

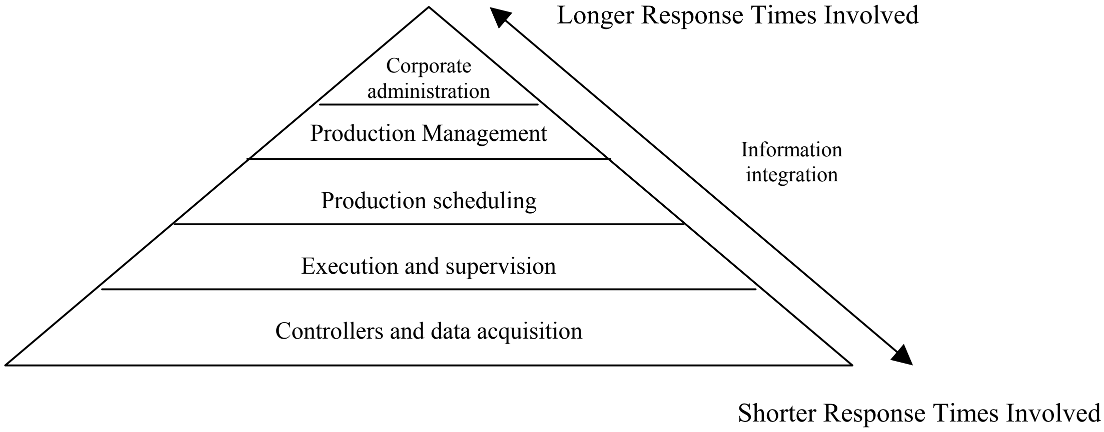

Figure 3 – A simplified view of a firm's hierarchical levels

4.1 Open Data Base Connectivity

Open Data Base Connectivity is an application-programming interface (API) used for access of databases through the structured query language (SQL) standard. Main participants in the development of ODBC are X/Open, SQL Access Group, ANSI, ISO, Microsoft, Digital, Sybase, IBM, Novell, Oracle and Lotus (SIGNORE *et al.*, 1995 and WHITING *et al.*, 1995). (Although not explained in this work, there is also a new method, very similar to ODBC called JDBC, which is used for the Java environment/application.)

The ODBC architecture has four main components: Application module, drivers manager, drivers and data source. The application module conducts the processing and calls ODBC functions to submit SQL commands and receive results. The drivers manager loads and unloads drivers for an application; it processes ODBC function calls or transfers them to a driver. The driver processes ODBC functions; submit SQL requests to specific data sources and returns results to the application. If needed, the driver modifies an application request to the DBMS (Database Management System) format. The data source consists of information that the user wants to access, the operational system associated, the DBMS and the network platform used to access the DBMS (WHITING *et al.*, 1995).

An example of ODBC application in the integration of manufacturing systems is shown at Figure 4. In this application, the production plan will be updated at the *MAINT_REPORTS* database according to the defined instructions.

```
COMMENT=Export Planned Schedule into MAINT_REPORTS
COMMENT=1) Remove Previous Report
COMMENT=2) Add New Report
COMMENT=3) Remove "TOTAL" at end of report

ODBC=
'OPPI'; 'UserID' '*'; 'Password' '*'

VARIABLE=
:PRODUCT ;ROW; 1;20
:BEGINDT ;FIRSTDAY
:ENDDATE ;LASTDAY
:VALUE   ;DATA;F[I]
ENDVARIABLE=

ODBCSQL=
  LOCK TABLE MAINT_REPORTS IN SHARE ROW EXCLUSIVE MODE
  delete from MAINT_REPORTS where DATASET_NAME='$DATADIR$' and USERNAME='$USERNAME$' and
ATTRIBUTE='DP'
  insert into MAINT_REPORTS
(DATASET_NAME,USERNAME,AS_OF_DATE,ATTRIBUTE,PRODUCT_CODE,BEGIN_DATE,END_DATE,VALUE) values
(rtrim('$DATADIR$'),rtrim('$USERNAME$'),SYSDATE,'DP',rtrim(:PRODUCT),rtrim(:BEGIN),rtrim(:
END),rtrim(:VALUE))
  delete from MAINT_SCHEDULE where PRODUCT_CODE IN (' ','TOTAL')
  commit
ODBCEND=
```

Figure 4 – Production plan update via ODBC

4.2 ASCII files integration

The ASCII (flat) file integration is easier to be implemented, however it is not as fast, efficient and reliable as the ODBC method. Through ODBC, the application program accesses the data directly from the source (database), along with a synchronization procedure that manages simultaneous access. ASCII file integration is quite different from this. If an application wants to pass information to another one, it creates or updates a file, which will be read by the application to receive the information. Some of the disadvantages of this method are:

(a) The fact that application programs have to be constantly and synchronously reading and writing files to keep themselves and other application programs updated;

(b) This method usually requires some form of customization in, at least, one of the application program exchanging information; and

(c) If alteration occurs in the format or type of the data exchanged between application programs, reprogramming the read and write procedures will probably be necessary.

An example of this integration mechanism is the transfer of the current inventory levels, kept by the MRP, to the master production scheduling system and, after the master plan is ready, transfer it back to the MRP for material requirements calculations. Another application is exemplified by Figure 5, which contains a production plan created on May 29th 2000. In this example, the first field in *DATA* is the product code, the second is the day to be produced and the last field is the quantity to be made.

```
COMMENT=MPS
CREATE=May 29, 2000
FILE=NETDMD
INIT=3-0
TYPE=1-1
STRUCTURE=
COMMENT;ROW;COL;DATA
DATA=
00224   ;07/19/00;00000243
00224   ;08/24/00;00000268
00321   ;03/02/01;00002092
00321   ;03/09/01;00002174
00321   ;03/30/01;00002297
02570   ;03/08/01;00000801
10601   ;02/21/01;00000147
10601   ;02/28/01;00000110
10601   ;03/14/01;00000182
10630   ;01/30/01;00001016
10630   ;02/06/01;00001082
10630   ;02/13/01;00001142
10634   ;02/02/01;00000272
10634   ;02/09/01;00000482
10634   ;02/16/01;00000421
10659   ;02/20/01;00000001
10659   ;03/05/01;00000001
10667   ;09/27/00;00000150
10667   ;10/11/00;00000150
10750   ;01/02/01;00001870
10750   ;01/09/01;00002954
10751   ;09/22/00;00000176
10753   ;04/24/01;00002595
10753   ;05/01/01;00002328
10756   ;06/23/00;00001717
10756   ;07/04/00;00003470
DATAEND= 26
```

Figure 5 - ASCII file containing an MPS created on May 29th 2000

4.3 OLE for Process Control

The third integration method is commonly used in the lower hierarchical levels, that is, in supervision, control and execution activities in automated production systems; it is called OLE (Objects Link Embedded) for Process Control, or simply, OPC. It is based on Microsoft's technology and is an industrial standard which offers a common communication interface that allows different application to interact and exchange information. OPC communication is implemented through client/server architecture. The OPC server acts like data source (as a hardware device in the shop) and any OPC-based application can access information regarding this device by accessing variables established by the server. It is an open and flexible solution to the classical problem of proprietary driver. Almost all major application developers are including OPC in their products (BERGE, 2001 and IWANITZ AND LANGE, 2001).

ODBC and OPC currently differ in two basic points (other differences could be described but it is not part of this work's scope): ODBC deals with communication (access to) with databases, while OPC regards information exchange at the shop-floor level; and ODBC is used at the higher hierarchical levels, integrating, for instance, forecasting and planning systems to ERP and MRP systems, while OCP integrates systems like manufacturing execution, scheduling, control and supervision systems, like SCADA, for instance. For this reason, OPC is often related to the industrial automation field. Figure 6 exemplifies the integration described.

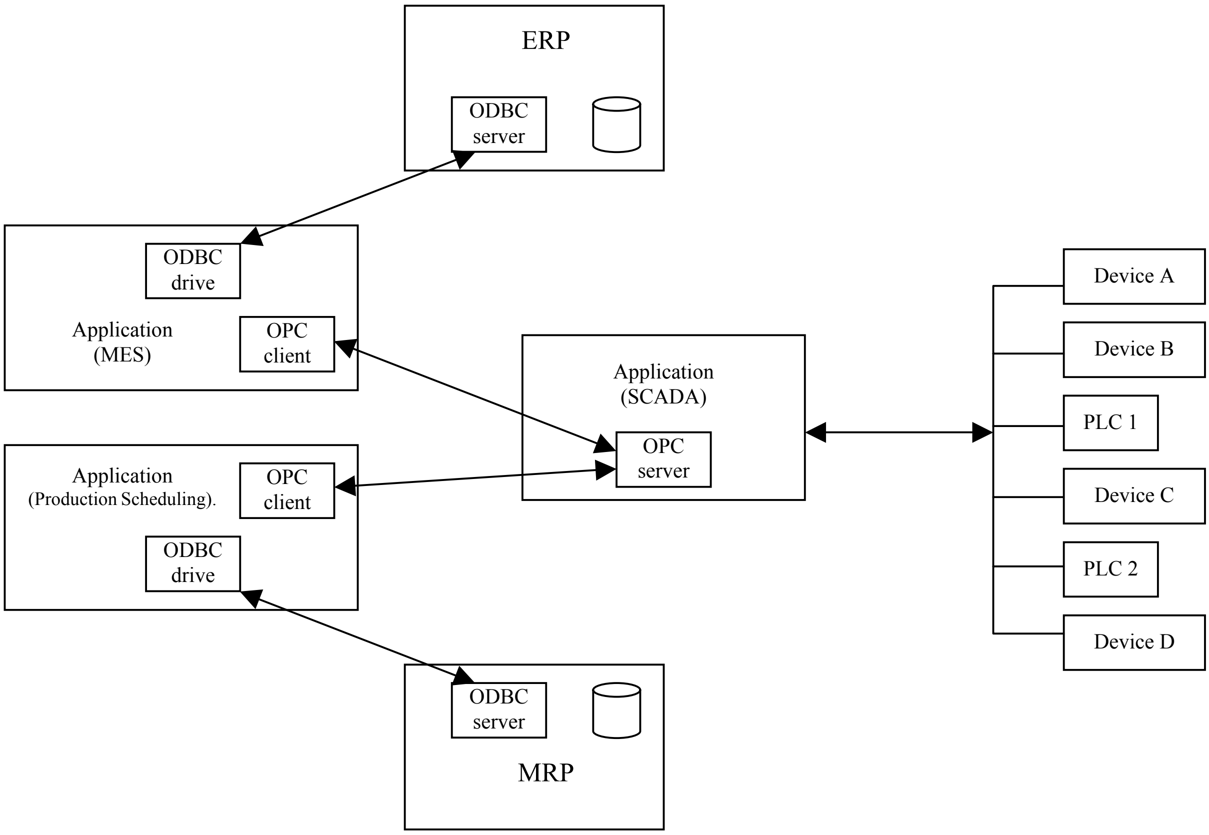

Figure 5 –Physical integration

5 FREQUENCY ISSUES ON INFORMATION EXCHANCE

The frequency how information is exchanged among production management systems should not be the same at all the hierarchical levels. Data exchange in the control and data acquisition, that is, at lower hierarchical levels, for example, is fast, usually minutes, seconds or much less than this. On higher levels, response times associated are very different; there is no need, for instance, for a production plan to be updated every minute. In summary, exchange information at these levels does not have to be too frequent; working in hours or even days is sufficient. At the highest levels, involving strategic management and administration, information is exchanged asynchronously, usually triggered by managers and operators, and data exchange frequency is not too critical.

These ideas of frequency and response time are closely related to the concept of real time. There is not precise definition for real time. In this work, real time is associated to the frequency (or response time) at each hierarchical level under consideration. Response time at the shop floor level (control, supervision and execution) must certainly be much faster than the response time at the level where production planning forecasting systems run. Something can go wrong or have to be altered in the forecasting plan; however, there is no need for corrective actions as frequent as in the shop level. As in the previously explained case, the real time for information updating in an acquisition system can be seconds or minutes (or much less), but for the production planning, a daily update is probably quick enough. It is clear, therefore, that the real time definition should concern the hierarchical level considered. Consequently, it is important to use information systems that can operate within the response time range demanded by the involved integrated systems. Too frequent updates incur losses and wastes. The same happens to lack of (or too slow) information updating. Going back to the classical control analogy (figure 1), frequency regards the data acquisition (feedback loop) and the response time concerns how quick the systems reacts to new control actions.

6 CONCLUTIONS

Lack of systems integration degenerates the company's performance due to information incoherence, imprecision, outdated appointments and slow information exchange. This paper has shown some of the complex aspects inherent to the integration of main manufacturing information systems, such as the production forecast, material requirements planning, master production scheduling, scheduling and manufacturing execution. A general overview of the proposed integration was illustrated through classical control theory with feedback loop. In this abstraction, some of the main parameters that allow an efficient integration were explained.

Each management system was quickly reviewed. The types of information that need to be exchanged among which system, along with their most important characteristics and function within the company's supply chain, were shown.

This work did not intend to make a detailed explanation of these systems, but a brief description of each one of them and to show how they interact and should be integrated.

Integration can be seen under two paradigms: logical integration, which deals with the information that should be exchanged and stored; and the physical integration, which concerns commonly used methods for data access.

In the logical integration, an analogy of classical control theory with feedback loop was used to illustrate the behavior, functions and information in the systems and how they should operate in coordination so that the enterprise can be more efficient. Clearly, the complexity involved in implementing such integration is not trivial.

The physical integration considered three methods judged to be the most currently used: interface via ODBC, flat file access and OPC. Based on the author's own experience, integration by flat file exchange is the most commonly used, mainly because of it's easy implementation and because every system has a way of reading or creating files. On the other hand, this method tends to disappear since it presents a series of limitations, such as, need for customization, lack of security, and lack of synchronization in case of users accessing the same files simultaneously. ODBC integration is used for databases access, integrating management and planning systems in the middle and high hierarchical levels systems. The OPC integration is more appropriately used in the integration of low level systems, namely, systems applied to the control, monitoring, supervision and execution of manufacturing systems, although there is a recent tendency to used it at higher hierarchical levels.

The frequency how data are exchanged among manufacturing information systems should not be the same. The integration of low-level systems will often require fast answers and decisions. The integration of high hierarchical level systems, however, does not demand critical time information exchange/update. This issue should be carefully considered during integration projects.

Lastly, there is an evident trend for information systems to be integrated through ODBC, JDBC, OPC and XML (*Extensible Markup Language* – not considered in this work) methods; and not by the simplistic ASCII files exchange method still quite used in industrial environments. Which poses slow and, sometimes, unreliable integration.

The dream of the computer-integrated manufacturing, concept known for a long time, has yet to be fully accomplished, however, this is a real tendency which became a feasible strategy supported by the new technologies, reduced equipment and software costs, and the strong push caused by the wide use of the Internet, a media that allows for enterprise integration never before imagined.

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