# The Relationship between Planning and Production Activities in Process Industries

Vladimir Jovan[1]
Jozef Stefan Institute
Department of Computer Automation and Control
Jamova 39, 1001 Ljubljana, Slovenia

**Abstract**

In contrast to assembly industries, the CIM concept has not yet gained full acceptance in process industries. One of the reasons for this is that in process industries functional relations between the different management levels are sometimes difficult to define. This article deals with the problem of the strict realisation of a short-term plan on the production line of a process-oriented factory. This problem, caused by the complexity and uncertainty of process industries, can sometimes be overcomed. The case study in the second part of this article briefly describes the solution of this problem during the implementation of a brick production control system.

## 1 Introduction

Efficient factory management nowadays requires the integration of process, plant and business operations (from order entry and scheduling through production, quality control, maintenance, shipping and accounting), made possible using contemporary IT products which successfully support the concept of CIM (*Computer Integrated Manufacturing*). The emphasis here is on the automation of information flows between engineering, business and other processes within a company. In the following discussion, CIM will stand for *a concept of co-ordinated and sensible application of computer technology*, to be applied in a company with the aim of improving business success (Hales, 1989).

## 2 Industrial management system

As defined in Thomas and Lamouri (1998), an industrial management system is "the integration of computer-assisted production operations and processes to manage the functions required for the productive use and optimum development of the management and manufacturing resources required to reach strategic targets." In general, it helps to optimise production and to improve the flexibility and reaction capability by acting on all the resources of the factory.

[1] E-mail*: vladimir.jovan@ijs.si*

## 2.1 Structure of an industrial management system

The organisational model of factory management is often split into three levels (Eckelmann and Geibig, 1989; Jovan and Dolanc, 1998): the process, production and business levels, which interact to a great extent with each other in order to satisfy both customers' demands and company goals. Such management organisation demands an adequate computer-based management system capable of optimising production and of improving flexibility and reaction capability by acting on all the resources of the factory. Physically, a factory management system is realised as a multi-level distributed computer system (*Figure 1*).

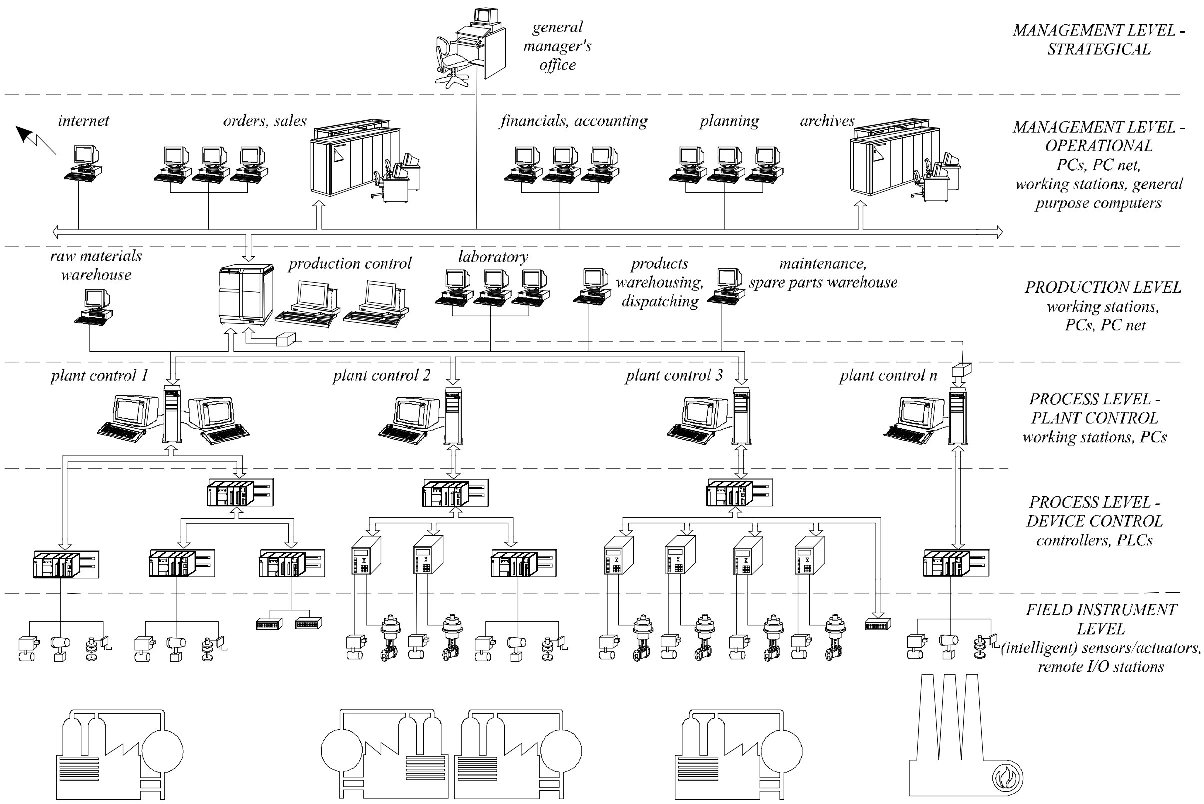


*Figure 1.* Architecture of a factory management system

This processes information and decisions which may be on-line (operational), medium-term (tactical) or long-term (strategic) (Jovan and Dolanc, 1998; Thomas and Lamouri, 1998). In general, the highest level of the factory information system performs mostly strategic management activities (long–term planning, orders, sales, financing/accounting, etc.) and sends information of a "*what-to-do*" nature to the production management system (tactical level). The production system determines the short-term plan, with regard to the delivery dates, material stocks and capacity. In this way it makes the order operational by defining "*what and how to do*", and such information is sent to the process control system/operational part of the factory management system. During the production process a lot of on-line information regarding the current state of a process, production rate, consumption of materials, energy consumption, defects, etc. is generated. Most of this information is used for efficient process control only on an operational level, but some of it is in the form of "*what and how was done*", sent to the tactical level, where, on the basis of this information, the activities of rescheduling, quality analysis, material stock management, etc. are performed. When the specific order has been realised, the production information system sends information of a "*what-was-done*" nature to the strategic part of the factory information system. In this way only the information essential for the functioning of a particular part of the factory management system is transferred between the hierarchical levels, while the majority of data has been used only autonomously to perform specific activities within a particular level. Such organisation of an information system results in its efficiency, reliability, robustness and maintainability.

During the last two decades a large number of IT products have been developed to support various activities on all levels of a factory management system. In *Table 1* one can find a typical set of IT products used within a particular level of an industrial, computer-based management system. The integration and appropriate use of an information system and the above-mentioned software products can provide efficient factory management according to basic goals and constraints on all levels of the management structure. So far it can be said that the state of the art in the field of IT products enables the full implementation of a CIM concept in production factories.

## 2.2 Industrial management systems in process industries

On the other hand there are still problems regarding the efficient use of IT products in factory management. One such problem appears mostly in process-oriented industries: in practice, *a gap currently exists between the production management and operational management levels* (process control system). In practice, in process-oriented industries it is difficult to prepare a realistic short-term plan which will result in the desired quantities of a product with a specified quality being finished by a predefined date. The reasons for this lie in the fact that, in terms of certain specific features of their production, processing industries differ from assembly production industries (Loos, 1995; Allweyer and Scheer, 1995; Thomas and Lamouri, 1998). These specific features are primarily:

- Production occurs by campaign (a set amount of time for continuous processes, a set number of batches with batch processes).
- Production is based on recipes, or focused on the maintenance of the required production parameter values.
- The inflexibility of processing plants.
- Links between various sub-processes.
- The use of raw materials of varying quality.
- The non-uniformity of product quality.
- Unstable products.
- Intermediate products and by-products.
- The recycling of raw materials or products.

These features cause process industries to be *complex* and *uncertain* (Scherer, 1995). The complexity of the production process arises primarily from the required linking of various sub-processes, each of which affects the quality of the final product. Each sub-process requires the maintenance of a certain number of process parameters (pressure, temperature, flow, viscosity, etc.), which leads to a large number of operation-level sensors, actuators, controllers and programmable controllers, which have to operate safely and reliably.

The uncertainty of a processing industry is expressed above all in product quality. It is desirable to achieve high and uniform product quality in every industrial process plant; but the non-uniformity

| level | level activities | used IT products | constraints |
|---|---|---|---|
| **planning**<br>(strategical level)<br><br>result:<br>long-term plan<br><br>*focus:*<br>*customer*<br><br>*decision location:*<br>*office*<br><br>*data flow time scale:*<br>*month-week-day* | ⇒ *Forecasting*<br>⇒ *Costing*<br>⇒ *Production Planning*<br>⇒ *Product definition*<br>⇒ *Human resources*<br>⇒ *Inventory management*<br>⇒ *Purchasing*<br>⇒ *Distribution* | • *forecast/demand management system*<br>• *manufacturing resource planning system*<br>• *material requirements planning system*<br>• *enterprise resource planning system*<br>• *electronic commerce*<br>• *financial/accounting system*<br>• *sales and service management system*<br>• *distribution & logistics planning*<br>• *supply chain management system*<br>• *material flow simulation*<br>• *computer aided design*<br>• *decision suport system*<br>• *internet* | • *orders*<br>• *utilisation of resources*<br>• *finances* |
| **execution**<br>(tactical level)<br><br>*result:*<br>*short-term plan*<br><br>*focus:*<br>*product*<br><br>*decision location:*<br>*factory*<br><br>*data flow time scale:*<br>*day-hour* | ⇒ *Resource allocation*<br>⇒ *Scheduling*<br>⇒ *Production dispatching*<br>⇒ *Document control*<br>⇒ *Labor management*<br>⇒ *Tracebility*<br>⇒ *Quality management*<br>⇒ *Maintenance management* | • *manufacturing executive system*<br>• *statistical process control/quality*<br>• *management system*<br>• *product data management system*<br>• *maintenance system*<br>• *production planning system*<br>• *planning & scheduling tools*<br>• *laboratory information management system*<br>• *warehouse management system*<br>• *internet/intranet* | • *capacity*<br>• *delivery dates*<br>• *quality*<br>• *material stocks* |
| **control**<br>(operational level)<br><br>*result:*<br>*product*<br><br>*focus:*<br>*production process*<br><br>*decision location:*<br>*operater room*<br><br>*data flow time scale:*<br>*hour-min-sec-msec* | ⇒ *Real time data acquisition*<br>⇒ *Process monitoring/ control*<br>⇒ *Alarm management*<br>⇒ *Defects management* | • *computer numerical control*<br>• *controllers/ programmable logical controllers*<br>• *distributed control system*<br>• *hard wired logic*<br>• *man machine interface*<br>• *(intelligent) sensors/actuators/displays*<br>• *supervisory control and data acquisition*<br>• *intranet* | • *quality*<br>• *safety*<br>• *energy consumption*<br>• *maintenance, defects* |

*Table 1.* Basic-level activities and corresponding IT products in the industrial management system

of the quality of basic raw materials, the poor performance of the control system, deviations in process parameters, failures of technological equipment, outages in energy supply, and often also combinations of various indeterminate reasons, render any prediction of the level of quality a risky task.

The complexity and uncertainty of process industries leave a gap in the functionality of the flow of information between the production part of the management system (short-term planning) and the operational management system (process control system). There thus remains an information gap between the production and operational management levels in a process company, which blocks efficient information integration and which is, in turn, a basic idea of the classical CIM concept.

Due to the above, in this type of industry it is very difficult to establish both effective planning and a link (integration) between planning and production. The solution of the issues of planning has been approached from various directions: planning based on statistical times, on the application of models of technological processes, on the application of artificial intelligence methods, etc. In practice, however, the results have not been satisfactory, primarily due to the inevitable simplifications and assumptions, as well as a lack of accounting for production uncertainties in real-life situations.

In practice, this gap is being bridged by a specific type of production employee, named, after Scherer (1995), "*system regulators*" - system process engineers. The system engineer does not directly participate in the production process; his/her main task is to monitor the performance of the technological process and, on the basis of the current values of production parameters (the utilisation of production capacities, the situation regarding basic raw materials, stocks, available energy sources and, above all, his/her experience), to make on-the-spot adjustments to the running of the technological process in such a way as to attain the desired overall production goals. In his/her decision-making, he/she employs all available information technology, while the transformation of business-level goals into an appropriate mode of production process control is a matter of judgement and not of IT, which serves merely as a support function in the decision-making process. It remains a task for the future to reduce the impact of system process engineers, by introducing adequate concepts which will be more efficient (along with the reduction in the importance of the human factor) in carrying into effect the demands of the business component of the company in the sphere of production.

An example of a process control system designed in such a way as to bridge the gap between the demanded/desired production and the currently available capacity of the production line is presented in the next section.

# 3 Case study

## 3.1 Description of the production process

The manufacture of brick products is a technological process which starts with the preparation of clay and continues with the shaping of products in their raw state and the drying and firing of products, and finishing with the finished products being placed on pallets. Brick-firing is a continuous-type process performed in a tunnel kiln, requiring the on-line advance preparation of adequate volumes of dried raw products. In the largest Slovenian brickworks, the shaped raw bricks are dried in batches in 13 drying chambers, each 300 $m^3$ in volume, heated by blowing hot air generated by cooling the tunnel brick-firing kiln. Since this air is not sufficient for needs, additional hot air generators are switched on as required, in order to supply an adequate flow of hot air for the drying process. To reduce production costs (natural gas consumption), to improve quality, and to achieve uniformity of production, a study of the modernisation of brick production process control was carried out (Jovan et al., 1995; Jovan and Dolanc, 1998). Regarding development efforts, emphasis was placed on a search for a more efficient technological procedure, based on the options offered by computer-based control. The installation of the drying chamber control system, consisting of five networked PLCs and a supervising computer, was performed over a period of three months. The statements of operators, process engineers and other system-users of the drying chamber control system confirm our predictions: the consumption of hot air in the drying process was substantially reduced, so that the operation of additional hot air generators was no longer necessary (in fact, a new problem arose: what to do with excess hot air).

The main practical operating problems are how to ensure planned production, reduce energy consumption, improve and stabilise quality, and shorten drying time. None of these four aims can be considered in isolation, and any measures proposed to fulfil one objective will affect the other two. So-called “optimal solutions” are thus a compromise between production rate, desired quality and energy consumption.

Computer control of the drying process is based on the maintenance of the desired time profile of the relative humidity of the air inside a particular drying chamber. Due to technological limitations (permitted drying speed, shrinkage, prevention of crack formations, energy consumption, variation in clay composition, initial clay moisture, etc.), the reference profile is bounded within acceptable limits, as illustrated in *Figure 2*. For a given product, and a given type of clay, the profile and the constraints, together with all necessary further modifications, are determined by the process engineer.

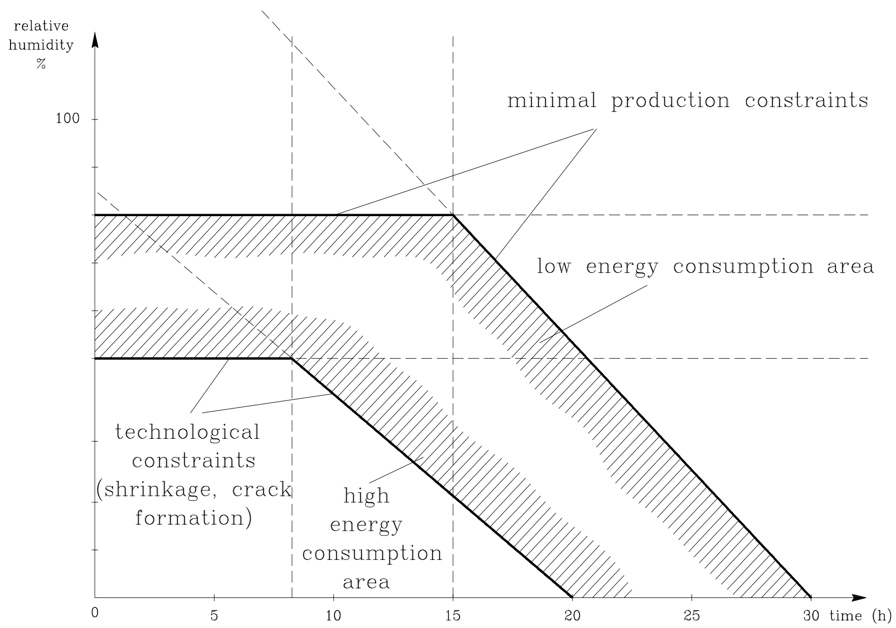


*Figure 2*. Constraints of the reference profile of the relative humidity of drying air for a particular product (tile)

Automatic maintenance of the prescribed time profile of air humidity in drying chambers guarantees the same course of drying in all drying chambers, thus making a major contribution to the uniformity of the production process and production scheduling. The drying profile, as defined by process engineers, also guarantees adequate quality, along with the lowest energy consumption.

### 3.2 The link between planning and production functions

The determination of the time profile of the amount of humidity in the drying air gives the possibility of modifying the duration of the drying of individual batches. *Figure 2* indicates that one batch of tiles can be dried in a timespan of between 20 and 30 hours, without any detrimental effect on product quality (in general, it is a rule that the acceleration of the procedure is paid for in terms of increased energy consumption - in our case, up to 20%). Thus we have an option of the on-line adjustment of actual production volume to required production volume, as specified by the planning function on the basis of short- and long-term order data. Even in instances of a lack of pre-processed clay, of a lack of dried products for input into the tunnel kiln, of the inoperability of individual drying chambers, and of other types of failures, as well as of requirements imposed by the policy of energy efficiency, the experienced process engineer can, by determining the appropriate profile, act appropriately in terms of ensuring the uninterrupted operation of the production process.

The on-line adjustment of the reference moisture profile in order to achieve a desired production rate and the optimal performance of a plant is, in this case, a correction part of the so called “flexible recipes” concept (Rijnsdorp, 1991), while the plan itself can be treated as an initialisation part of that concept. The flexible recipes concept thus serves as the basis for the real implementation of production plans regarding the current state of the production process and the demands for production rate, minimal energy consumption, high and uniform quality, and technological constraints. In this particular case it represents one of the missing links between the logistical and production functions of the company.

The role of the process engineer has been modified as the role of process control has been allocated to the computer system. Nowadays, the process engineer's role is mainly to make on-line adjustments to the production rate, according to the current state of the production process and the demanded production plan, by selecting the optimum curve for the drying process. The process engineer is therefore capable of maintaining the optimal operation of the production process at all points of its operation.

# 4 Conclusion

Discrete manufacturing production is an area in which the CIM concept has demonstrated its full range of uses, and in which the integration of modern IT software products can yield fundamental increases in productivity, improvements in product quality, and reduced production costs. In contrast to assembly industries, the CIM concept has not yet gained full acceptance in process industries. There are a number of critical reasons hindering the introduction of the classic CIM concept to the processing industry - in practice, this demonstrates that there is sometimes a gap between business management processes (sales, supply, financing, planning, etc.) and the production plant of a company. The missing link between business and production levels has yet to be found in industries of this type.

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