Lean organization, management by process and performance measurement

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Introduction

Two of the major characteristics of the new production paradigm known as lean production are: the pursuit of excellence in terms of a suitable mix of performance and continuous improvement[1,2]; rethinking work organization in order to gain a flexible and effective organizational structure[3].

In this article we show that the pursuit of excellence and the organizational change required by lean production leads to a management-by-process organization, and that management by process influences the performance measurement system (PMS).

The case study presented as an example is Zanussi-Electrolux – the largest European producer of domestic appliances, which has introduced management by process into most of its plants. The article provides a detailed analysis of the organizational change and its effects on performance measurement.

Lean production and management by process

The pursuit of excellence (obtained in particular by superseding performance trade-off logic) and the changes in work organization (teamwork, job enrichment, etc.), suggested by the lean production paradigm, lead to the adoption of management by process.

In particular, management by process is selected because: there is a need to link all the activities in order to pursue a unified objective (customer satisfaction in all its aspects)[4]; and the overall performance (especially non-cost performance such as quality, timeliness, flexibility) results from an integration and co-ordination of the activities[5].

Thus the primary justification of management by process is to overcome functional organization rigidity (“the functional silos”[6]), where single functions or units often have different and contradictory performance objectives (e.g. manufacturing efficiency vs delivery punctuality). Traditionally each function or unit tries to maximize its own performance and considers good local performance as the only condition for good overall performance[7].

Part of this work was presented at the 1st International Conference of the EurOMA – European Operations Management Association, 27-29 June 1994, Cambridge, UK.

International Journal of Operations & Production Management, Vol. 16 No. 2 1996, pp. 221-236. © MCB University Press, 0144-3577

Management by process co-ordinates the efforts so several performances are achieved simultaneously.

A process – a sum of activities, each composed of operations consuming resources – can be looked on as the place where the added value develops[8]. Each process is moved and directed towards the customer and contributes, together with others, to his/her satisfaction.

The management-by-process organization is task-oriented and determined by the aggregation of competence and activities[9]; responsibility is linked to the role and not the level, the career is transversal[10], the organization becomes horizontal[11], the unified objective is a mechanism of integration which facilitates learning and permits flexibility.

So management by process is intrinsically oriented to interfunctional effectiveness instead of functional efficiency. The objective can be reached by a harmonic composition and integration of sub-tasks, with functional responsibilities but co-ordinated by the process logic: the performances are the result of the synergetic and synchronous effects of the single contributions along the operations value chain[12,13].

Management by process and performance measurement

Considering a production process as a chain of activities, each phase characterized by a customer/supplier (or internal client or customer-in) logic[4] implies that everyone has a customer – even those far from the downstream activities – and everyone is served by someone else. So a poor performance in a single link in the chain is sufficient to spoil the overall performance. Moreover, to evaluate the performance of a link in the value chain, the constraints (backward-dependent along the chain) and the opportunities (forward-dependent along the chain) in each phase must be considered.

In other words, management by process gives rise to a network of independently focused sub-factories, each with its own management criteria and responsibilities, but strictly linked together according to the customer/supplier logic. The above-mentioned sub-factories can also be related to other processes.

Emphasis is on inter-functional effectiveness (overall quality of the product offered[14]), process efficiency (productivity as a consequence of quality) and system flexibility; furthermore, using process analysis, cost drivers can be understood better.

Performance measurement itself is a process: "the process of quantifying the efficiency and effectiveness of action"[15].

The effects of management by process on the requirements of the (PMS) can be summarized as follows:

- Overall indicators must be constructed. These must be able to measure the effectiveness of the process in accomplishing the primary task of the process itself.

- The performances that measure the attainment of the sub-tasks (converging to ensure that the primary task is achieved) must be identified. They should be evaluated not only in absolute but also in relative terms, i.e. between each other, so as to have the best possible mix with the resources available.
- The single function/unit performances must be defined, measured and evaluated in relation to the process sub-tasks. This is the contribution of the sub-tasks to the single functions or units.
- Finally, the system must be able to identify, according to the customer/supplier chain logic, which performances can be ascribed to one process unit and which instead, though deriving from the activity of the unit itself, depend, above all, on the performance of the preceding unit in the process. This is the function/unit responsibility identification.

Process measures determine result measures (such as the financial indicators) and "are spoken in the language of the land that is being measured" (while financial indicators are the same everywhere)[16]. Process measures "must be owned by the group they are measuring"[17].

Main processes in a manufacturing organization

Among the processes that can be distinguished in a manufacturing organization, three can be considered fundamental: product development; manufacturing (material processing); logistics (material handling).

For each of the above three processes, Table I shows the main organizational variables and performance measurement variables.

The organizational variables include the number of people and organizational units involved in each process, as well as the frequency with which each organizational unit is involved in the process activities.

	Organizational variable			Performance measurement variable			
Process	No. of people involved	No. of units involved	Frequency of unit involvement	Critical performance	No. of objects to be measured	Total measurement costs	Average measurement frequency
Product development	Low	Medium	Low	T/Q	Low	Low	Low
Manufacturing	High	Medium	Medium	C/Q	High	High	High
Logistics	Low	High	High	T	Medium	Medium	Medium

Notes:
T = Time performance
Q = Quality performance
C = Cost performance

Table I.
Process organizational and performance measurement variables

The performance measurement variables include the most critical performance dimension (T = time performance, C = cost performance, Q = quality performance), the number of objects to be measured and the costs and frequency of measuring.

The differences in the performances to be measured and in the corresponding indicators can be seen as deriving first from the product development phase in relation to the product development process (Figure 1). The phases are respectively: concept generation and product planning; product design and product engineering; process engineering, piloting and production ramp-up. Time-to-market is defined as the time interval between the product concept generation and the market introduction. The overlapping degree or simultaneity ratio can be defined as:

$$\sum_{i=1}^{n} \frac{t_i}{\mathrm{DT}}$$

where: DT is the development time, t_i is the i-activity duration, n is the number of activities of the product development[18]. "Fitness for use" is a term coined by Juran[19]. The carry-over index is the number of old product parts included in the parts of a new product[18].

<table>
<tr><th></th><th colspan="3">Time performance</th><th colspan="2">Quality performance</th><th colspan="2">Cost performance</th></tr>
<tr><td>Concept generation and product planning</td><td rowspan="3">Time to market</td><td></td><td></td><td>Fitness for use</td><td rowspan="2">Number of change-overs</td><td></td><td rowspan="2">Design man-hours (including projects not completed)</td></tr>
<tr><td>Product design and product engineering</td><td rowspan="2">Activity over-lapping degree</td><td rowspan="2">Work breakdown structure time adherence</td><td rowspan="2">Product reliability</td><td>Carry-over</td></tr>
<tr><td>Process engineering and production start-up</td><td></td><td>Prototype cost</td><td>Engineer-ing hours</td></tr>
</table>

Figure 1.
Performance indicators and the product development process

Second, the differences in the performances to be measured and in the corresponding indicator can be derived from the complexity of the product and the type of production for the manufacturing process (Table II). The complexity of the product is considered in relation to the extent of the bill of materials. The type of production considered is intermittent (job-shop) and repetitive (production line)[20]; the difference between the two depends on whether the time interval between the entry of the product and its exit from the production system is long or short.

Depending on the product complexity and the type of production we can identify: special parts; standard parts; engineering products; standard products.

	Low product complexity	High product complexity
Intermittent production (job-shop)	*Special parts* T – lead times T – machine flexibility Q – part quality C – material costs	*Engineering products* T – adherence to schedule Q – part quality Q – project quality C – project costs
Repetitive production (production line)	*Standard parts* T – throughput time Q – process capability C – material productivity C – machine productivity	*Standard products* Q – product conformance C – labour productivity C – machine productivity C – material productivity

Notes: T = Time performance
Q = Quality performance
C = Cost performance

Table II.
Performance indicators and the manufacturing process

If, for example, production repetitivity increases, it is more important to measure material productivity than material costs, or it is more important to measure throughput time (e.g. pieces/minute) than lead time (e.g. minutes/piece). If product complexity increases, it becomes more important to measure product conformance than process capability.

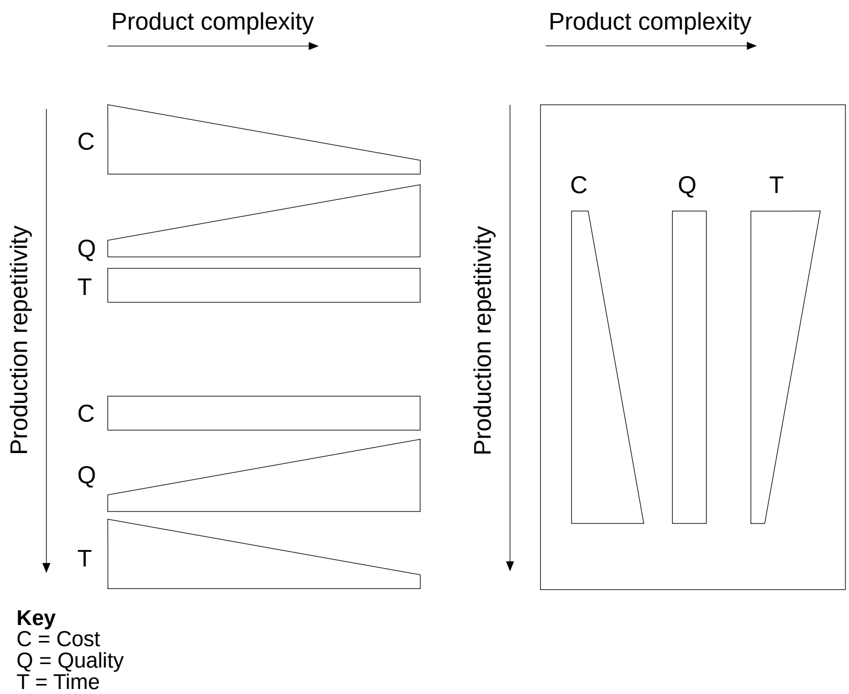


Figure 2.
The importance of the performance dimensions (cost, quality and time) in relation to the production repetitivity and the product complexity

Another observation can be made: independently of the complexity of the product (Figure 2), it can be seen that passing from an intermittent production to a repetitive one the performances involving cost become more important than those concerning time (the quality performances being equal) (Figure 2 – right), while as the complexity of the product increases the quality performances become more important (the time performances being equal and the cost performances becoming less important if the production is intermittent, the cost performances being equal and the time performances becoming less important if the production is repetitive) (Figure 2 – left).

Third, the difference in the performances to be measured and the corresponding indicators can also be derived from the phase in the logistical flow in relation to logistics process (Table III). The following phases are identified: in-bound logistics, internal logistics and out-bound logistics. Time performances are separated into delivery and flexibility. Delivery consists of readiness, punctuality and reliability (in terms of foreseen quantity and mix). Flexibility is considered as a time performance because it corresponds to the time required to change something (e.g. volume or mix), or alternatively it corresponds to the possible amount of change in a time interval.

	Time performance			
Phrase	Delivery	Flexibility	Quality performance	Cost performance
In-bound logistics	Supply readiness, punctuality and reliability (volume and mix)	Supply volume and mix flexibility	In-bound statistical control results	(Raw materials and parts) storage level + stock rotation
Internal logistics	Materials availability and flow synchronization	Alternative routeings and over-capacity availability	Statistical process control (SPC) results	Work-in-progress level
Out-bound logistics	Delivery readiness, punctuality and reliability (volume and mix)	Delivery volume and mix flexibility	Final testing results and transportation security	(Finished products) storage level + stock rotation

Table III.
Performance indicators and the logistical process

The case study

Zanussi Elettrodomestici SpA, a company of the Swedish Electrolux holding, is the largest European producer of domestic appliances, with a revenue of around 920 million ECU (the commercial companies Zanussi Italia SpA and Zanussi International SpA excepted), 7,600 employees and several mono-productive plants (which belong to the divisions: washing-machines; dish-washers; fridges and freezers; cookers).

Management by process and new organizational functions

The company has introduced management by process by three new organizational functions: integrated process manager (IPM); integrated management areas (IMAs); and supply centre manager (SCM).

These three new organizational functions support the three processes indicated in the theoretical discussion: product development; manufacturing; logistics. This organization (Figure 3) was set up following pilot tests and now is operative in each division.

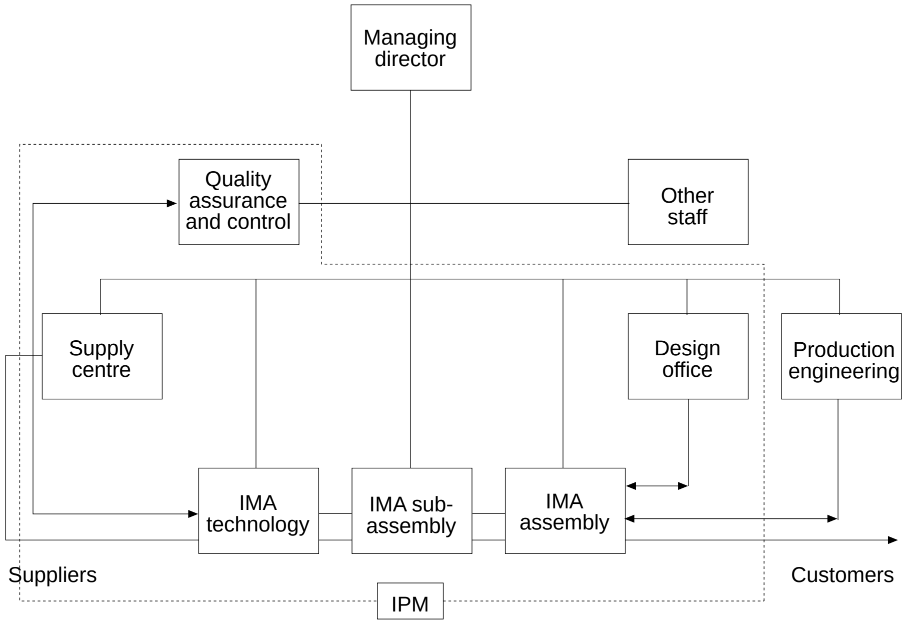


Figure 3. The new Zanussi-Electrolux organizational functions: integrated process manager (IPM), integrated management areas (IMAs), supply centre manager (SCM)

The IPM (integrated process manager). This person is held responsible (a sort of "business process owner"[12]) for managing all the activities which lead to the industrialization of a new product; the IPM plans the resource utilization and co-ordinates all the departments involved in the process of product development during all the phases (these departments are within the dotted line in Figure 3). The members of the interdisciplinary teams for product development are linked by functional dependence to the department to which they belong and by hierarchical dependence to the IPM. The solution adopted confirms that Zanussi has abandoned the sequential logic in the management of new product development activities in favour of an integrated multidisciplinary approach.

The IMAs (integrated management areas). These are focused sub-plants, which co-ordinate, on the shopfloor, the activities of production, production planning, management of technology, quality control and maintenance (Figure 4 – left). If necessary, and according to the problem, the IMAs refer to the appropriate departments of supplying, quality assurance and control, design office, production engineering or other IMAs (Figure 3).

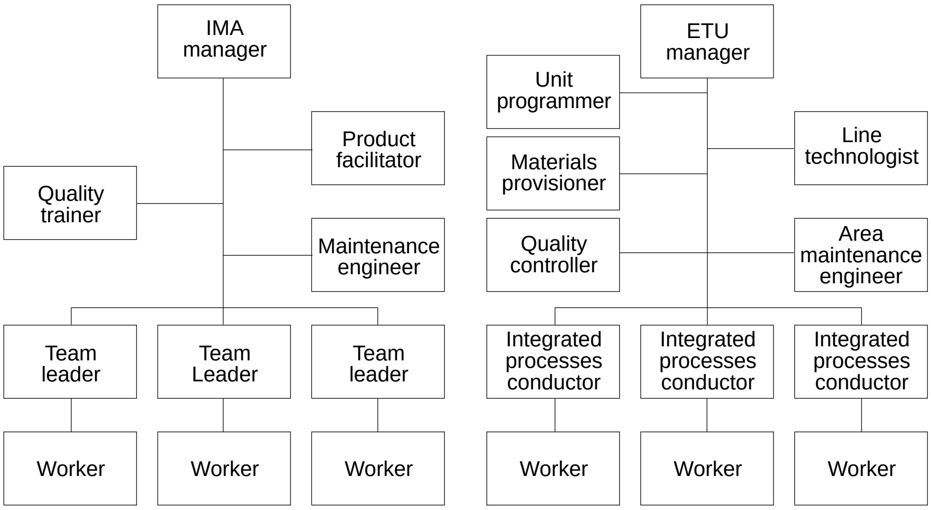


Figure 4.
The sub-factories' IMAs (integrated management areas) and ETUs (elementary technological units) at Zanussi and Fiat respectively

The implementation of the IMAs has meant a reconfiguration and reallocation of central support services (maintenance, quality, procurement, etc.) and the assignment to the IMAs of all the skills required. Each IMA can thus count on having its own maintenance and quality operator who is under the authority of the IMA manager but retains close links with the central departments.

As a consequence, both full-time (machine workers) and part-time (maintenance or quality operator, etc.) employees are involved in IMAs. The staff of each IMA is part time, while full-time employees, guided by a team leader, make up the groups involved in permanent work. The staff of an IMA includes (Figure 4 – left): the maintenance engineer, the quality trainer, and the product facilitator. The maintenance engineer is generally part time and a member of the production engineering department; he/she can also work in more than one IMA and train and bring him/herself up to date in the department of production engineering. The quality trainer transfers quality principles, methodologies and operational instructions to the IMA, while the central quality department (named quality assurance and control) determines the general policy, fixes the quality control methodologies and the relative statistical analysis, audits the process and the quality of the finished products and benchmarks them. The product facilitator links the supply centre and the IMA; his/her task is to integrate the flow of materials with the other IMAs. The typical configuration is that of three IMAs: technology; subassembly; and assembly (Figure 3). Each is one link in the manufacturing chain and operates according to the internal customer logic. Each IMA manager is directly responsible to the managing director.

The SCM (supply centre manager). This person controls the purchasing activities, in-bound logistics, material management and out-bound logistics; in other words, he/she presides over the logistics flow which links the suppliers to the buyers, integrating a series of responsibilities which had previously been distributed within the organization. The objective pursued is the flow link-up, without interruption, from the entry to the exit of the plant.

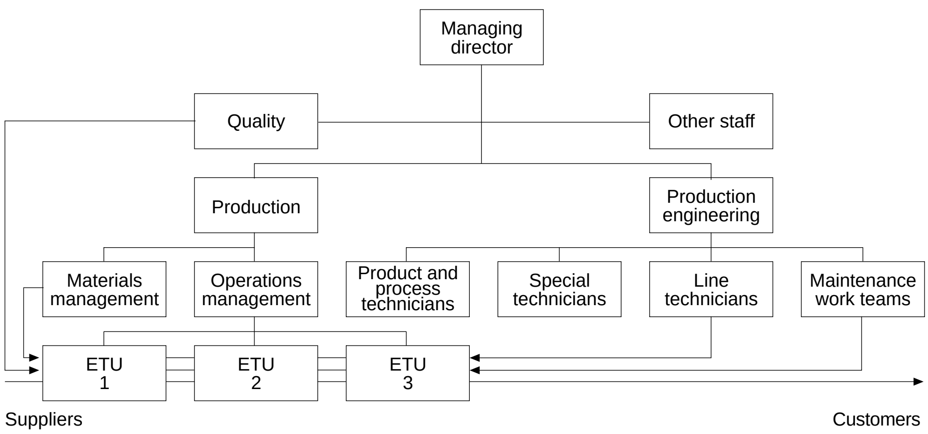
The SCM determines the sourcing policies and in particular he/she defines the number and profile of the (external) suppliers, the quality level of the pool of suppliers and the time horizon of the supply relationship; in addition, he/she checks on the possibility of joint purchasing with other divisions of the group.

On the other hand, the product facilitator, who belongs to one particular IMA, takes care of the operational management of purchases and, together with the supplier (who can be external or internal, i.e. another IMA), determines the quality parameters, packaging and delivery requirements, as the various IMAs have different needs. Many procurement decisions are left to the discretion of the IMA, especially those concerning technical aspects, but the link between the IMA and suppliers of strategic components cannot bypass the SCM.

The SCM must also integrate the different levels of production and delivery planning: the demand planning operated by the Zanussi-Electrolux's sales units (SUs) and separated into product families; the master production scheduling (MPS), which defines the capacity and material requirements of the preceding input; the vendor scheduling, which defines the requirements and transmits them (via EDI – electronic data interchange) to the suppliers.

The SCM is envisaged as a pipeline integrator/supervisor of these three distinct planning levels and a co-ordinator of the flow from the suppliers to the sales units through the IMAs. He/she has the advantage of an overall view of the process and can evaluate the impact of purchasing and logistical decisions (such as the lot size, the packaging procedures, the nature and timing of delivery, costs associated with poor quality and adaptability to changes in production planning).

Analysing Figures 3-5, some interesting similarities emerge between Zanussi-Electrolux and another large Italian company – Fiat (Turin), a leading car manufacturer in Europe.



Key
ETU = elementary technological unit

Figure 5. The Fiat management-by-process orientation (ETU = elementary technological unit)

Fiat introduced a process-oriented organization, based on the ETUs (elementary technological units), which has a similar internal customer logic and several similarities between the sub-factory ETU and IMA. Teamwork, job enrichment and a competent online approach are widespread.
Like the IMAs, the ETUs (Figure 4) have a manager (ETU manager), work groups, each co-ordinated by a team leader (integrated processes conductor) and staff which ensure an expertise on the line traditionally not part of manufacturing. Production engineering is present on the line with a technologist and an area maintainer, materials management is present with a materials provisioner, quality management is present with a quality controller, while a vice-ETU manager is responsible for the unit programming.

The fact that these two large industrial companies adopted a similar management-by-process system supports a generalization of the presented schemes and seems to indicate a trend for the future.

Performance measurement and the indicators used in the management of the processes

As discussed, management by process has some bearing on the performance measurement system (PMS).

The PMS in Zanussi is subdivided according to process (IPM, IMAs, SCM), encompasses three kinds of performance (cost, quality and time) and is summarized weekly in a production performance report and monthly in an operational/financial report and in a quality report. Production managers, accountants and quality experts are involved.

Here we briefly describe the indicators used, following the framework proposed by Figure 1, Tables II and III: the product development and logistics performances are classified by phase, while the manufacturing performances are classified by IMA (technology, sub-assembly, assembly in sequence) and refer to a repetitive production and high product complexity, which is the case in Zanussi (standard products – Table II).

The following Figures 6, 7 and 8 respectively show the IPM, the IMAs and the SCM measures. Each process is represented by an arrow pointing from left to right and divided according to the phase (or type of IMA). For each phase (or IMA) the performances are of cost, quality and time.

The single performances are synthesized in aggregated indicators. The synthesis can be:

- *Horizontal.* Cost, quality and time performances, transversely considered along all the phases (or IMAs) that make up the process, are analysed separately (e.g. cost performance of all the phases versus quality performance of all the phases).
- *Vertical.* All the cost (or quality or time) performances of a single phase (or IMA), or some individual performances (relative to a same dimension-cost quality or time) of phases of different processes, are analysed at the same time.

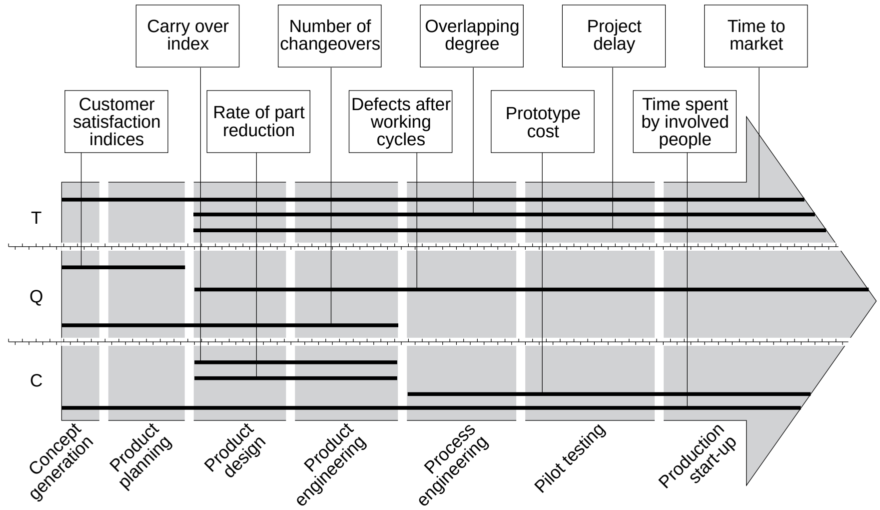


Figure 6. The integrated process manager (IPM) performance measures

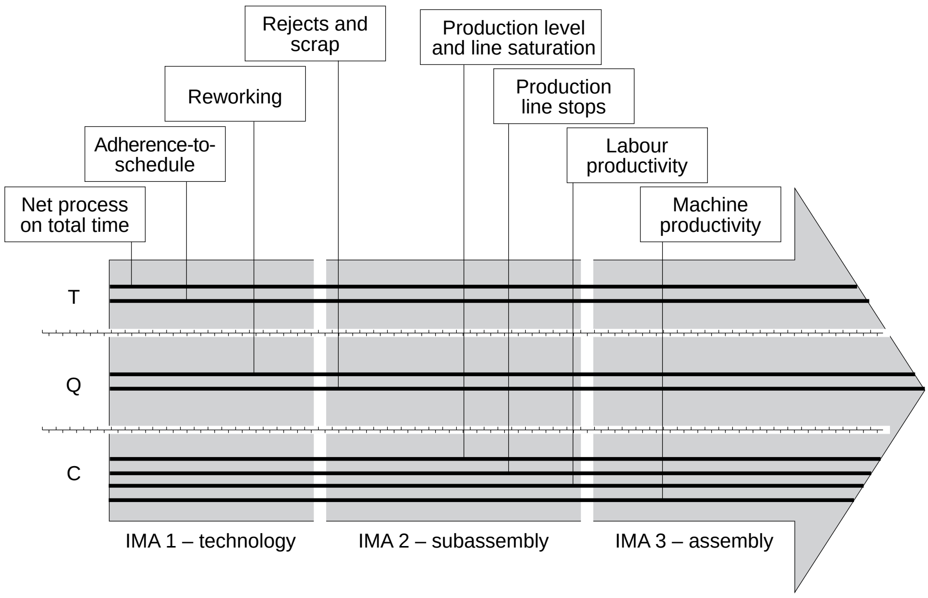


Figure 7. The integrated management area (IMA) performance measures

With regard to the horizontal synthesis of the measures, on the arrow representing each process there are: continuous lines crossing all the phases, if the measures concern the whole process transversely (the same indicator is used); broken lines at the same level, if the measures are carried out separately but are homogeneous (it is possible to construct an indicator of synthesis); and broken lines on different levels, if the measures are completely independent (different and heterogeneous indicators are used).

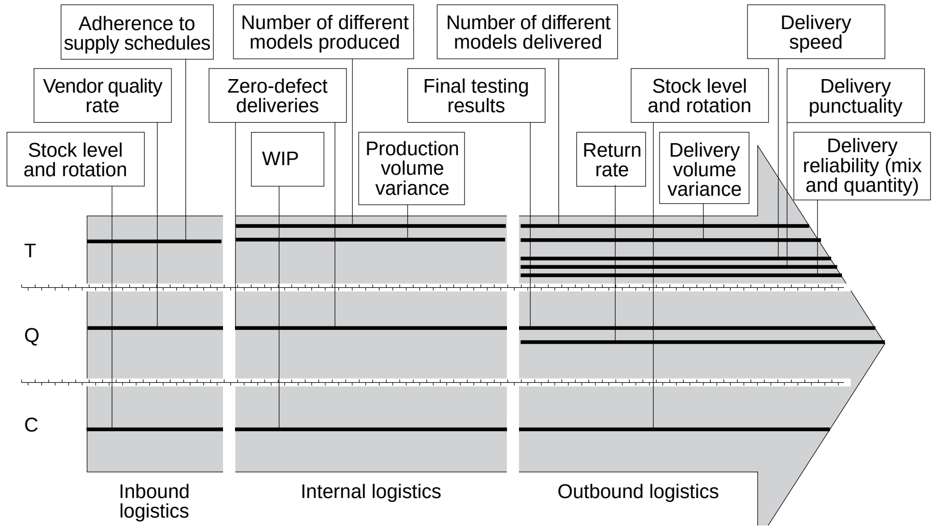


Figure 8.
The supply centre manager (SCM) performance measures

For example, time-to-market (Figure 6) is a continuous line crossing all the phases as it is an overall (time) performance of the process of product development; it is measured by the sum of the same indicator applied in all the phases. Production volume variance and delivery volume variance (Figure 8) are represented by two lines at the same level as they are related performances, measured by homogeneous indicators. Net process on total time and adherence-to-schedule (Figure 7) are represented by lines on different levels as they are different and independent performances, measured by heterogeneous indicators.

When horizontal synthesis of the indicators is made, a multi-phase approach takes place, since the performances of all the phases of one process are considered at the same time.

Vertical synthesis of the indicators may be multi-performance if the synthesis is made within one phase or IMA (e.g. delivery speed, punctuality and reliability – Figure 8 – can be considered all together as one regarding performance of delivery), or it may occur on a higher level – so-called multi-process – when phases of different processes are involved (e.g. production line stops and work-in-progress level – Figures 7 and 8).

In both cases, synthesis is possible only with performances having the same dimension (e.g. time). In the case of multi-process vertical synthesis, besides having the same dimension, the performances must be directly connected to each other (e.g. the cost performances: production line stops and work-in-progress level).

IPM, IMAs and SCM performances are now presented according to this representation.

IPM (integrated process manager) performances (Figure 6). First of all, these include both costs and time spent by workers in product development activities, according to specific codes (regarding the type of activity, product, function or unit to which the worker belongs). The carry-over index and the rate of parts reduction are other cost indicators used, together with the cost of prototyping.

Quality (reliability) performances are measured after having classified defects into four categories: critical, primary, secondary, tertiary, regarding respectively: user safety, the product not functioning, its efficiency decreased and the product aesthetics. Quality (reliability) indices are calculated as the percentage of these defects emerging after pre-determined product working cycles (1, 6, and 60 cycles); a weighted quality index for all kinds of defects is also calculated. Another quality index is the number of changeovers (measured both before and after the production launch).

Time-to-market is defined as $t_{\text{launch}}-t_{\text{concept}}$, where launch is the market introduction stage; the project delay is measured as

$$\sum_{i=1}^{n} \frac{\Delta t_i}{\text{DT}};$$

the overlapping degree is

$$\sum_{i=1}^{n} \frac{t_i}{\text{DT}}$$

where DT is the development time; Δt_i is the difference between the actual and the forecast duration of the i-activity; t_i is the i-activity duration, actual or forecast.

IMA (integrated management areas) performances (Figure 7). These are contained in the production performance report, which includes:

- The production levels (including line saturation).
- The production line stops because of both lack of materials and machine breakdown (with the cost of maintenance), indicating causes and responsibilities (at the level of activity inside the IMA).
- The amount of rejects and scrap, with details of the causes and responsibilities (at the level of activity inside the IMA); $\bar{x}$ and R control charts are utilized.
- The direct labour and total labour productivity (output per man-hour), and the machine efficiency (output per machine-hour, output per maintenance cost), where output is measured as first-pass quality and maintenance costs are both preventive and corrective. The adherence to schedule of each activity.
- The net machine process time in relation to the total time and the improvement in this ratio (corresponding to a reduction in set-up time).

The information system is very sophisticated as theorized in the literature[21]. Each IMA is an autonomous cost centre. All the information includes both the single IMA and the whole manufacturing process as a series of IMAs (technology + sub-assembly + assembly); much of the information also concerns the single activities which constitute one IMA.

According to the scheme in Table II, we can see that, for high production volumes and high product complexity (i.e. in the case of Zanussi), quality and cost performances are the most important.

SCM (supply centre manager) performances (Figure 8). These are evaluated in terms of timeliness, quality and cost. Some performances are the direct responsibility of the SCM, such as stock rotation and delivery. Others are measured and controlled by the SCM, who, however, is not responsible for the results (for example, he measures the quality and promptness of the suppliers and carries out the final testing of the products awaiting delivery).

The in-bound performances are not as crucial as the out-bound ones, due to Zanussi's advanced co-makership policy and the EDI with the suppliers; nevertheless vendor quality performances (by vendor quality rating – VQR) and vendor adherence-to-schedule are monitored.

Production/delivery volume variance, work-in-progress (WIP) and stock level and rotation are measured as well as mix flexibility (in terms of number of different models produced/delivered). The nature of consumer products such as domestic appliances requires complete customer satisfaction both as regards product reliability and mix availability. Final testing, packaging and stock management are therefore very important.

Conclusions

The aim of this article is to contribute to the subject of performance measurement in management by process. In lean production, management by process is an organizational method the aim of which is to carry out, at the same time, several performances, including their continuous improvement, by means of an organization structure based on operational flows, oriented towards results and flexible with regard to changes.

Management by process implies orienting all the activities and efforts towards common tasks, which must be reached by closely integrating and co-ordinating all the activities. It can be considered as links in a customer/supplier chain, even within the firm.

This way of managing activities, the strong point of which lies in the synergic effect of the operations, obviously influences the PMS: the performances are separated into overall performances of the process (result performances) and single performances of the activities which contribute to the process (process performances). It is then necessary to specify the organizational units which carry out the above mentioned activities, and to what extent the performance of one unit depends on that of the preceding one.

It has been seen that in a manufacturing firm there are three main processes (macro-processes) which must be managed: product development; manufacturing; and logistics.

With regard to these, the differences in the PMS and the indicators were analysed, both on a theoretical and a case study level. The organizational solutions adopted by a large firm, a European leader in its industry, are described. These give concrete suggestions for the adoption of management by process. The selected performance indicators fully support the type of organization chosen, and they vary not only when passing from one macro-process to another, but also within the phases/activities forming each process. The single indicators may be synthesized either horizontally (along the phases of a process for homogeneous performance – cost, quality, time) or vertically (taking into account the different performances of a single phase in a process, and the relationship between performances of phases of different processes).

The figures given, which refer to the case study, are a clear example of the variety of performances that may be found and the possibility of carrying out:

- a horizontal synthesis, by adopting *a multi-phase approach* instead of a *mono-phase approach* (e.g. the time-to-market expressed as the sum of the lengths of the single phases of each process);
- a vertical synthesis within a process, that is adopting a *multi-performance approach* instead of a *single-performance approach* (e.g. the delivery speed, punctuality and reliability as an only performance as opposed to the delivery speed, punctuality and reliability as independent performances);
- a vertical synthesis between the processes, that is adopting a *multi-process approach* instead of a *mono-process approach* (e.g. considering at the same time the production line stops and the work-in-progress level, which are cost performances of the manufacturing and the logistics processes respectively).

Synthesis indicators (both horizontal and vertical) supersede trade-off logic among performances, and lead to the adoption of a cumulative approach, so that in time all the performances are reached and increased.

Finally, the reports on performances, as well as containing data on the single indicators, also contain information on single process performances (e.g. production performance report) and on performance dimensions (e.g. quality report). Moreover, performance responsibility is considered from a customer/supplier point of view inside the firm (for example, the out-bound logistics has its own performances such as delivery time, and also performances, such as return rate, which are influenced by others, in this case by manufacturing).

The case study described, supporting the presented framework on the relationship between management by process and PMS, is of great interest, since it shows an innovative organizational solution and the systematization of the performance indicators according to the three processes regarded as fundamental in every manufacturing firm.

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