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DESIGNING PERFORMANCE MEASUREMENT SYSTEMS IN NEW MANUFACTURING ENVIRONMENTS: A SYSTEMIC APPROACH

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ABSTRACT

The authors propose a "systemic" approach for the development of a Performance Measurement System able to satisfy the needs of new manufacturing environments. From a thoroughly integrated examination of all past performances and future improvements to be made, a quantitative and homogeneous appraisal of major performances is obtained, based upon performance criteria and a weighted ranking technique, which involves different functions and levels The approach assumes that the firm owns an Activity-Based Costing system. An example of application in a medium size mechanical firm is reported.

INTRODUCTION

World Class Manufacturing (WCM) is a conventional term given to a series of fundamental changes that enable the companies to improve their quality, productivity and performance so that they can compete effectively in world markets. The basic assumptions are the recognition of the importance of manufacturing as a strategic weapon and the necessity of strong commitment to manufacturing excellence.

The adoption of World Class Manufacturing methods and techniques has brought into focus the inadequacy of traditional management accounting and performance measurement and control systems [1]. They seems to be irrelevant, complex, or misleading in order to achieve and sustain the excellence in this new manufacturing context. To meet the new production challenges, manufacturers must compete on such issues as quality, on-time delivery, reliability, flexibility [2].

Conventional operational measures include direct labour efficiency, machine utilization, scrap rates and past-due shipments. They tend to focus attention on individual performance, are strictly guided by financial aspects (variance to standard cost, inventory level, overhead absorption), and can encourage untimely and unnecessary production emphasizing aggregate volume rather than adherence to schedule [3].

Designing Performance Measurement Systems (PMS) in new manufacturing environments implies:

- ❑ the consideration that financial measures are not meaningful for managing a production plan. The financial measures are much more important for external reporting than for the daily control of the operations;
- ❑ the determination of links between strategic objectives and performance indicators, because neither accounting reports nor traditional operational measures are directly related to the company's manufacturing strategy;
- ❑ the control of the *overall* operation. This means that management must ensure an integrated planning and scheduling between all the areas and functions, motivate workers to be more responsive and to fill customer needs, encouraging team-work and continuous improvement.

MAIN CHARACTERISTICS OF PERFORMANCE MEASURES IN NEW MANUFACTURING ENVIRONMENTS

The needs in terms of correlation with the manufacturing strategy and full vertical and horizontal integration are of crucial importance for the realization of an effective PMS:

PMS and the Manufacturing Strategy

Though the content may differ from one company to another, a world class manufacturer should invariably have a clearly defined manufacturing strategy: as a consequence, the performance measures must be directly related to the manufacturing strategy [4][5].

There are two main reasons for keeping performance measures in line with the manufacturing strategy: the informative scope (i.e. to know if operations are improving or getting worse in respect to the business plan) and the commitment of the people on the performances measured.

Measurements systems should reflect and spread the company's goals and the management values. Management commitment should be highlighted.

The condition of applicability of this philosophy is the key point: evaluation criteria need to be suited according to the WCM policies adopted by the firm. For example, a time-based competition strategy, based on JIT principles and regarding the entire value-delivery chain, requires performance criteria that do not emphasize individual operation time standards but, instead, stress reduction of set-up time, flexibility of the work force and the capability to produce high quality products by a specified completion date. Some criteria, such efficiency and utilization, may pressure managers and supervisors for short term results, and therefore discourage process improvements; other criteria, such inventory levels, are much less important in a JIT environment [6].

The cross-functional nature of a good PMS

The involvement of all functions, all actors (the suppliers included) and all levels is essential for developing a PMS able to support a world class manufacturing strategy.

The performance measures selected must show where improvement has been made and where improvement is possible. Often some performance of a work centre depend upon those of other centres, so a clear distinction from dependent and independent performances become fundamental [7]. It can be the result of frequent meetings between workers -not only managers- of different centres and different areas [8].

In fact, the participation of several work levels is very important for designing and maintaining an effective PMS. Even the bottom level must understand how its operative activities can match the strategic goals. The bidirectional performance information exchange between lower and upper levels and the clearness in producing synthetic indicators are real competitive weapons often underestimated.

PMS: AN ACTIVITY-BASED MANAGEMENT PERSPECTIVE

Many performance information are already available in the manufacturing planning and control system or in the financial reporting systems. Sometimes the revision of the PMS is less expensive than it could seem. The integration with other information systems is therefore not only a functional need but also an economic one. What is different is how these data can be utilized and by whom.

Among the instruments that can provide useful informations for the development of an effective PMS, Process Value Analysis (PVA) [9] and particularly Activity-Based Costing (ABC) [10] are of undoubted interest. Here we will not examine the opportunity of introducing an ABC systems, its costs and advantages: there are several contributions about this matter [11][12][13]. We only note -and then propose a model and the results of its application- that, if an ABC systems already exists for better calculating product costs, it can be useful for implementing a PMS having the characteristics mentioned above.

ABC has been widely heralded as a better approach than traditional product costing methods. ABC recognizes that costs originate from and are driven by factors other than volume; only raw materials and direct labour costs can be directly allocated to products. ABC is based upon five steps:

- O identify the major activities performed, independently from the location in the firm;
- O determine the cost of those activities, as a consequence of the consumption of resources by the activities (first-stage drivers are used to trace the costs of inputs to an activity cost pool);
- O identify what drives those activities (second-stage drivers or simply "drivers", e.g. number of components, number of purchase orders, number of engineering changes);

O combine each second-stage driver with every product;
O compute activity-based product costs.

An exhaustive literature review about the developments in theories and practice concerning cost and management accounting has been made by Spicer [14].

Here we intend to consider the ABC system not simply a product costing system, but a source of information for developing a PMS. In particular, we consider activities and their resulting costs.

A MODEL FOR AN INTEGRATED PMS

Seven single performances are examined:

1) *efficiency;*
2) *timely delivery;*
3) *reliability;*
4) *time required for the introduction of new products or substantial changes;*
5) *volume and mix flexibility;*
6) *quality capability;*
7) *quality consistency (conformance).*

Managers and workers allocate a *figure* "X_{ip}" to each value-added activity "i", in relation to each performance "p", with a particular weighted ranking technique. A similar procedure is used for each nonvalue-added activities "j" to establish "Y_{jp}", a negative influence *figure.*

The weighted ranking technique [15] considers every single performance versus every other single performance, and assigns a value of one to the performance considered more important and a value of zero to the one considered less important; if a decision can not be made regarding relative importance, then each performance is assigned a value of one-half. After all the performance have been compared, the sum of the values should be equal to N(N-1)/2 i.e. 7*(7-1)/2=21. The comparison is made for every activity considered by the ABC system.

The figures "X_{ip}" and "Y_{jp}", which result from a single activity (respectively value-added *va* and non-value-added *nva* one) in each performance, are weighted against the activity cost itself, in turn obtained from the ABC system, so as to determine an *activity-cost weighted performance rank* (positive "C_iX_{ip}" and negative "C_jY_{jp}").

These ranks are then added together (summing the ranks obtained in each activity) in an *aggregate performance rank* "Z_p" and "U_p", for each single performance "p":

$$Z_p=\sum_i C_iX_{ip}\,;\,U_p=\sum_j C_jY_{jp}$$

From the total *va* and *nva* activities cost "T_{va}" and "T_{nva}", it is possible to work out a cost for each performance gained and a cost of the negative influences on each performance, deriving respectively from *va* and *nva* activities, according to the following formulas:

$$M_p=\frac{Z_p}{\sum_k Z_k}T_{va}\,;\,N_p=\frac{U_p}{\sum_k U_k}T_{nva}$$

The positive *aggregate performance rank* scale "Z_p" is then normalized (to 21) and compared with an *optimum scale* that agrees with business strategy.

A "D_p" difference between real and expected results is estimated for each performance, and its absolute value is assessed on the basis of the cost "T_{va}" (divided by 21) to get the *partial variance:*

$$\widetilde{D}_p=\frac{T_{va}}{21}|D_p|$$

This partial variance, increased with the cost of all non-value-added activities connected to the negative effects for the performance "p" (i.e. N_p), determines the *total variance* of cost for each performance "p":

$$\widehat{D}_p=\widetilde{D}_p+N_p$$

THE APPLICATION

The model has been tested in an Italian medium size mechanical firm, which has implemented an ABC system.

The system controls twelve value-added activities and seventeen non-value-added activities (for simplicity, here we have considered together all the set-ups, all the queues and all the moves).

The results of the application of the ranking technique, in order to establish X_{ip} and Y_{ip} (respectively, positive and negative influences on performances by the activities), are illustrated in Table 1 and Table 2.

All judgements derive from cross-functional and multi-level meetings, on the basis of the low-level operational measures used in the firm (such as scrap rate, reworking rate, on-time delivery rate, centre adherence-to-schedule-rate, lead-times, centre mean downtime, etc.).

	A	B	C	D	E	F	G	H	I	J	K	L
efficiency	5	6	0	6	4	5	2.5	1	5	4	5	6
delivery	5	2.5	5	2	0.5	5	2	0.5	3	3	2	2
reliability	5	2.5	5	2	0.5	4	0.5	2	2.5	3	2.5	3
innovations	1.5	2.5	3.5	0	2.5	0	3	6	3	2	2	0.5
flexibility	1.5	2.5	1.5	2	3	2.5	3	2.5	5	4	4.5	0.5
quality capab.	1.5	2.5	3	4.5	5	1	5	5	0	0.5	2.5	4.5
quality conf.	1.5	2.5	3	4.5	5.5	3.5	5	4	2.5	4.5	2.5	4.5

Table 1: value-added activities and positive performance ranks (X_{ip})

	M	N	O	P	Q	R	S
efficiency	4	4	4	3	5	5	5.5
delivery	5.5	5	5	4	5	6	5.5
reliability	5.5	6	6	4	5	1.5	2
innovations	1.5	0.5	1.5	0.5	0.5	1.5	2
flexibility	1.5	0.5	1.5	0.5	0.5	1.5	2
quality capab.	1.5	2.5	0.5	3	1	1.5	2
quality conf.	1.5	2.5	2.5	6	4	4	2

Table 2: non-value-added activities and negative performance ranks (Y_{ip})

A: raw materials purchasing
B: nuts & bolts purchasing
C: parts purchasing
D: milling machines
E: lathes
F: drilling machines
G: gear cutting machines
H: special works
I: sub-assembly1
J: sub-assembly2
K: final assembly
L: preventive maintenance

M: set-ups
N: queues
O: moves
P: changeovers
Q: reworking
R: maintenance
S: inspection

From the activities costs (Table 3), aggregate performance ranks -positive and negative- and performance costs are calculated (Table 4):

	A	B	C	D	E	F	G	H	I	J	K	L
rounded cost	9	2	7.5	4.5	8	2	4	7	1.5	1	2.5	1.5

	M	N	O	P	Q	R	S
rounded cost	4	3.5	1.5	2	2	2.5	1

Table 3: activities costs (mld. of lire)

	Z_p	U_p	M_p	N_p
efficiency	176.00	70.00	8.38	3.33
delivery	137.50	85.50	6.55	4.07
reliability	142.00	75.75	6.76	3.61
innovations	131.00	17.75	6.24	0.85
flexibility	120.75	17.75	5.75	0.85
quality capab.	171.55	29.25	8.17	1.39
quality conf.	181.50	50.50	8.65	2.40

Table 4: positive aggregate performance ranks, negative aggregate performance ranks, performance costs (mld. of lire)

The optimum performance ranks scale, derived from a more sophisticated weighted ranking technique (weights: 0, 0.25, 0.33, 0.50, 0.66, 0.75, 1.00), is Z_{po}, while the actual normalized performance ranks scale is Z_{pn} (Table 5):

	Z_{po}	Z_{pn}	$\lvert D_p \rvert$
efficiency	4.50	3.49	1.01
delivery	4.08	2.72	1.36
reliability	4.58	2.81	1.77
innovations	1.42	2.60	1.18
flexibility	1.92	2.39	0.47
quality capab.	2.75	3.40	0.65
quality conf.	1.75	3.59	1.84

Table 5: optimum and actual performance ranks scales

After calculating $\widetilde{D_p}$, $\widehat{D_p}$ (Table 6) gives an estimate of the difference between actual and desired performance:

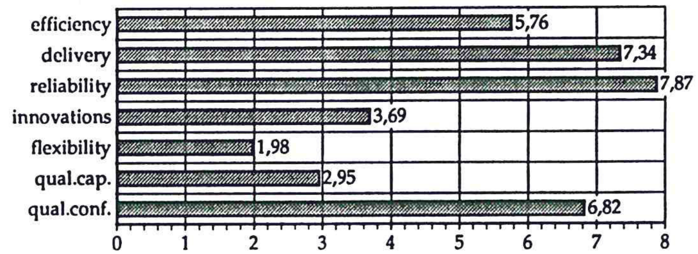

Table 6: the total variance of cost for each performance (between strategic issues and actual performances)

The approach can be particularly useful to redirect energies and resources to improve the most strategic performances, permitting going back to the single activities that have produced major differences too. In the examined case, reliability, delivery, quality conformance and then efficiency are the performances which do not support the strategic objectives as they should do.

CONCLUSIONS

The authors have developed an integrated model for the development of an advanced PMS, able to examine several single performances and future improvements to be made, according to the strategic issues. All the functions and different levels are involved. A *quantitative* and *homogeneous* appraisal of actual and desired performances is obtained, based on both objective and subjective measures. A cost for each single performance is calculated using ABC system data. Further, the costs of differences between actual and desired performances is estimated, and a cause-analysis by activity is permitted.

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