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## PREFACE

Welcome to the second conference of the recently formed European Operations Management Association.

The theme of the conference is *Management and New Production Systems* which throughout the years remains an important umbrella to combine a lot of areas within the production environment which need to be considered very precisely and consistent in order to remain competitive as a company. The contents of the proceedings is organised in an alphabetical way by author, but the large number of papers can be roughly clustered in four main areas: (i) operations strategy, (ii) implementation, including product and process innovation, (iii) operations management, and (iv) monitoring, control, performance measurement and learning. This clustering can be recovered in the organisation of the presentation sessions.

The abstracts of the papers for this conference were all double blind refereed and we would like to express our thanks to the following persons for their help in this process:

prof. Christer Karlsson (EIASM, Belgium)
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Thanks also to Jeannette Visser-Groeneveld, Vera Scholten and Peter Dieltjes for their invaluable help in putting together the final version of the conference proceedings, and carrying out much of the organisation and administration associated with the event.

The conference also owes considerable debt to Scania Zwolle (thanks Frans Ruffini) and Grolsch which allowed us to visit their factory in order to get better acquainted with the most modern ways of practising production management in order to get top-quality products.

Special thanks go to our key-note speakers Dan A. Werbin of Volvo/Nedcar and Christer Karlsson who gave special attention to the problems and solving methods involved in running an industrial joint venture the market-oriented way.

The delegates are the most important stakeholder in the conference and we are very glad that they took the opportunity and also the risk of visiting the University of Twente in a period that rain is very likely. Without them there would be no conference and we are looking forward to meet again in the near future.

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May 1995

# A SURVEY-BASED ANALYSIS OF PERFORMANCE MEASUREMENT SYSTEMS: CHARACTERISTICS AND INDICATORS

## Research methodology and empirical results.

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ABSTRACT

In spite of the increasing importance of the performance measurement in operations management, few empirical studies specifically concern the characteristics and indicators of the Performance Measurement Systems (PMS). Results of a survey conducted in 115 medium and large size Italian manufacturing firms operating in three main industries are presented. Following the construct reliability examination, factor analysis was carried out with the aim of describing the dimensions and the actual state of these systems. The paper illustrates the main PMS characteristics emerging from the survey, and points out the differences between traditional and new performance measures. Practical means for an effective implementation are suggested.

INTRODUCTION

PMS are becoming more and more important, as a consequence of the: 1. revaluation of production to achieve competitive advantages; 2. consideration of several integrated performances, overcoming the trade-off logic; 3. increase in the importance of non-cost performance, in order to satisfy customer needs and to apply management techniques such as Just-in-Time and Total Quality Management [1] [2] [3].

The literature on the importance and architecture of the operations performance measurement systems is still varied and not homogeneous.

The proposed models -in our opinion- can be separated into five classes:

① hierarchical models (from Gold's model [4], which connects productivity and ROI, to the Lynch and Cross pyramid [5], which considers also the non-cost performances and their impact on market and financial performances);
② "balanced scorecard" [6] models, where several separate performances are considered independently;
③ models that we call "truncated cone models", where there is a synthesis of low-level measures into more aggregated indicators, but without the scope of translating non-cost performance into financial performance [7];
④ models which distinguish between internal and external performances [8];
⑤ models which are related to the value chain [9].

Empirical analysis regards especially case studies and the surveys are few [10].

CONCEPTUAL FRAMEWORK AND RESEARCH HYPOTHESES

The framework on which the survey is based consists of three types of variables:

- *PMS characteristics*, with variables regarding:
  - formalization;
  - type of utilization;
  - integration with the Manufacturing Planning & Control System (MPCS), such as MRP2.
- *Performance indicators*, regarding:
  - cost performances (production costs, inventory and WIP level, productivity i.e. output/resources in terms of physical quantities or costs);
  - non-cost performances (quality, time, flexibility).
- *PMS-external variables*, with variables regarding:
  - product and process complexity;
  - supplying and market complexity;
  - implementation of managerial instruments such as TQM, JIT, CE etc.;
  - firm size and cost structure (% of industrial costs, % of direct costs etc).

The research hypotheses can be summarized as hyphoteses on the dimensions of a PMS (which are the main characteristics of a PMS? which are the most used performance indicators?) and hypotheses on the relationships between the PMS variables and the PMS-external variables (do the different forms of complexity, the managerial instruments usage and the firms characteristics influence the PMS structure?).

In this first phase the paper focuses on the PMS dimensions, seeking to validate the above conceptual framework. At a later stage the relationships between all the variables will be explored with statistical analysis such as simple and canonical correlation, uni- and multi-variate analysis-of-variance (M-ANOVA), regression analysis (full, stepwise etc.). The SAS software was utilized in order to perform all the statistical analyses.

RESEARCH DESIGN AND METHODOLOGY

The survey -we think the first large scale study carried out in Italy on this theme- was carried out by means of two self-administered questionnaires sent by mail to 400 Italian large manufacturing firms: the top-200 firms operating in the mechanical industry and the top-200 firms operating in the electro-mechanical and electronic industries. The questionnaires were addressed to two kinds of managers for each firms: the general manager and the plant/production manager. A strict confidentiality was assured.

Each questionnaire is structured in over 250 coded-items. The questionnaires had been pre-tested on experts and pilot-firms, as suggested by [11].

The response rate was very good (28.75%), including firms such as Fiat, Olivetti, Italtel, Zanussi-Electrolux, Aprilia etc. The subsequent statistical analysis was therefore carried out on 115 firms, which returned the questionnaires correctly filled out.

| | |
|---|---|
| Mechanical | 62.6% |
| Electronic | 23.5% |
| Electro-mechanical | 13.9% |
| | 100.0% |

Table 1 - Sub-division (by industry) of the firms that replied.



| | REVENUES (ml. USD) | EMPLOYEES |
|---|---|---|
| minimum | 13.6 | 75 |
| average | 140.6 | 1243 |
| maximum | 2252.1 | 35000 |

Table 2 - Revenues and employees of the firms that replied.

| | Industrial | Non-industrial | Material Purchasing | Direct Labour | Other |
|---|---|---|---|---|---|
| COSTS (mean) | 77.5% | 22.5% | 52.4% | 22.6% | 25.0% |

Table 3 - Percentages of industrial and direct costs of the firms that replied.

DEFINITION AND OPERAZIONALIZATION OF THE VARIABLES

Variables are defined by numerical values or perceptual Likert scales [12]. In this case, people are asked to rate each statement on a 5-point scale, ranging from "Strongly disagree" to "Strongly agree". If a variable is related to a complex concept [13], the connected scale is multi-item and its value corresponds to the mean value of the items.

In determining the measurement properties of the constructs used in the statistical analysis, reliability and validity of the variables in the model were assessed [14], using respectively Cronbach's alpha and principal components analysis.

Reliability has two components [15]: stability (in time) and equivalence (in terms of means and variances of different measures of the same construnct). The main instruments for the reliability assessment are: the "test-retest method" (for stability) and Cronbach's alpha (for equivalence) [16]. We concentrated on the second aspect, because these scales have been developed for the first time. All of the multi-item scales have a Cronbach's alpha of at least 0.67, well exceeding the guidelines set for the development of new scales [17].

Validity regards both the content, the criterion and the construct [15]. Content validity cannot be determined statistically, but only by experts and by referring to the literature. Criterion validity regards the predictive nature of the research instrument to obtain the objective outcome (e.g. the existence of a multi-performance PMS should be correlated with the availability of scores in several different performance). Construct validity measures whether a scale is an appropriate operational definition of the construct («a construct is a concept that is rigorously defined for the purposes of scientific enquiry»[18]).

| | |
|---|---|
| Performance measurement in general | 23% |
| Manufacturing strategy and benchmarking | 13% |
| Advanced accounting practices | 25% |
| Productivity | 7% |
| Quality | 13% |
| Flexibility | 9% |
| Other (time competition, vendor performance, product development performance etc.) | 10% |

Table 4 - Published works about performances.

For the content validity, examining over 700 works, published over the last seven years and concerning performance measurement or correlated themes, we found the following areas of interest, quantified in terms of percentage of works on that theme:

Construct validity was established through the use of principal components analysis. The purpose of principal components analysis [19] is to derive a small number of linear combinations (principal components) of a set of variables that retain as much of the information in the original variables as possible. These linear combinations have coefficients equal to the eigenvectors of the correlation or covariance matrix; the eigenvectors are orthogonal. The principal components are sorted in descending order of the eigenvalues, which are equal to the variances of the components.

Though the term "factor" is often used, it is more correct to refer it to factor analysis [20], characterised by the fact that, in this case, latent variables are not generally computable as linear combinations of the original variables as in principal components analysis.

Here principal components analysis was conducted in order to uncover the underlying dimensions, eliminate problems of multicollinearity between the variables and ultimately reduce the number of variables to a limited number of orthogonal factors. First each scale was factor analyzed separately: if the items in a scale loaded on more than one factor, the items responsible for the other factors beyond the first were eliminated (or considered in another scale) and Cronbach's alpha was recalculated. The presented scales are all in their final version.

A similar procedure has been adopted to group several variables in order to get a more manageable set of variables without lacking too much information. Rotation was applied to aid interpretation. Rotation is the application of a linear transformation to components: the most used is "varimax rotation", which maximizes the variation of the squared factor loadings for each component; factor loadings represent correlations between the original variables and each factor [21]. Usually only the components (or factors) with eigenvalues greater than one are retained, because together they account for most of the overall variance (the cumulative proportion of total variance explained is generally greater than 70%) [22].

Interpretation of the matrix of factor loadings was carried out following a rule according to which only loadings superior to 0.65 would be considered: imposing such a limit allows one to retain only those variables which contribute in a high degree to the formation of a given factor, called according to the name of the variable/s with higher factor loading/s.

## SUMMARY OF FINDINGS

The Tables 5-10 show:

- the mean value of the variables (for the sake of space, we omitted another important indicator: the coefficient of variation, defined as the ratio between standard deviation and mean; in our analysis it is rarely greater than 30-35%, with highest values around 50-60%);
- the Cronbach's alpha (if the scale is multi-item);
- the percentage of variance explained by the first factor according to the principal components analysis carried out on the items of the scale (if the scale is multi-item);



- the factor loadings according to the principal components analysis carried out on the scales of a class of variables and to the successive varimax rotation (All possible combinations of aggregates of variables were tested in order to find the groups with the highest eigenvalues).

Tables refer to the PMS characteristics and performance indicators of the framework.

In regard to PMS formalization, the rotation of the first two factors (explained cumulative variance = 72.7%) shows two groups of variables which we call: measure formalization and measurement formalization, as respectively they regard the objects to be measured and the way of measuring (Table 5).

Concerning PMS/MPCS integration, MPCS is present in all the firms, sometimes it is supported by a L.A.N. (Local Area Network), while few examples exist of E.D.I. (Electronic Data Interchange) with customers or suppliers. The rotation of the first three factors (explained cumulative variance = 88.8%) distinguishes data-shares concerning: the inventory control, the production process management (time and quality), the order management (Table 6).

In relation to PMS utilization, the rotation of the first three factors (explained cumulative variance = 83.3%) shows three different types of use: 1. planning, coordination and control; 2. human resources involvement and evalutation; 3. benchmarking. The control aspect is present in the 2nd component too (Table 7).

| | Value | Cronb.α | 1C-Var. | 1st | 2nd |
|---|---|---|---|---|---|
| Measure object definition | 3.76 | 0.70 | 62.9% | 0.852 | 0.220 |
| Responsibility individuation | 3.58 | 0.87 | 61.2% | 0.869 | 0.195 |
| Measure detail degree | 3.63 | 0.77 | 68.9% | 0.654 | 0.422 |
| Synthetic reports compilation | 3.60 | 0.74 | 66.3% | 0.206 | 0.862 |
| Measurement procedure formalization | 3.61 | 0.79 | 70.0% | 0.267 | 0.777 |

Table 5 - The characteristics of PMS: formalization.

| | Value | Cronb.α | 1C-Var. | 1nd | 2nd | 3rd |
|---|---|---|---|---|---|---|
| PMS/MPCS int.: working capit. | 4.47 | 0.77 | 81.2% | 0.112 | 0.986 | 0.115 |
| PMS/MPCS integration: time | 3.28 | 0.85 | 77.0% | 0.868 | 0.139 | 0.140 |
| PMS/MPCS integration: quality | 2.60 | 0.81 | 72.0% | 0.841 | 0.043 | 0.242 |
| PMS/MPCS integration: orders | 3.37 | 0.86 | 87.6% | 0.257 | 0.126 | 0.956 |

Table 6 - The characteristics of PMS: integration with the MPCS.

| | Value | Cronb.α | 1C-Var. | 1st | 2nd | 3rd |
|---|---|---|---|---|---|---|
| Control | 3.74 | 0.89 | 54.6% | 0.634 | 0.625 | 0.026 |
| Planning | 3.59 | 0.87 | 61.0% | 0.861 | 0.260 | 0.189 |
| Coordination | 3.59 | 0.78 | 70.1% | 0.905 | 0.125 | 0.019 |
| People involvement | 2.63 | 0.85 | 57.8% | 0.322 | 0.770 | 0.197 |
| People evaluation | 2.62 | 0.87 | 79.8% | 0.092 | 0.872 | 0.172 |
| Benchmarking | 2.80 | 0.84 | 76.0% | 0.102 | 0.216 | 0.967 |

Table 7 - The characteristics of PMS: utilization.

We have studied together all the so-called "cost performances" (production costs, inventory and WIP level, productivity [23]). The rotation of the first five factors explained a cumulative variance of 72.4% and points out (Table 7) four main dimensions (a fifth dimension, regarding design productivity, has an eigenvalue greater than one but a lot less than the other four; design productivity is a scale with items that refer to measures such as projects/man-hours, days for concluded projects / total days of design activity etc.):
- material and labour costs (4th component);
- machine consumption (3rd component);
- capital productivity (1st component);
- labour productivity, inventory and machine saturation (2nd component).

Financial ratios are much in use, including cash-flow analysis; flexible budget and standard costs are also widely employed.

| | Value | 1st | 2nd | 3rd | 4th |
|---|---|---|---|---|---|
| Material costs | 4.64 | 0.006 | 0.176 | 0.146 | 0.653 |
| Labour costs | 4.44 | 0.042 | 0.009 | 0.332 | 0.816 |
| Energy costs | 3.43 | -0.010 | 0.073 | 0.824 | 0.314 |
| Material consumption by machine | 3.03 | 0.240 | -0.001 | 0.838 | 0.233 |
| Inventory level | 4.29 | -0.042 | 0.753 | 0.007 | -0.083 |
| Total productivity | 3.62 | 0.568 | 0.600 | 0.209 | 0.207 |
| Material productivity | 3.30 | 0.565 | 0.512 | 0.239 | 0.256 |
| Energy productivity | 2.24 | 0.414 | 0.313 | 0.531 | -0.082 |
| Direct labour productivity | 4.39 | 0.279 | 0.790 | -0.030 | 0.228 |
| Indirect labour productivity | 3.59 | 0.373 | 0.537 | -0.137 | 0.201 |
| Fixed capital productivity | 3.36 | 0.751 | 0.149 | 0.264 | -0.167 |
| Working capital productivity | 3.49 | 0.765 | 0.130 | 0.228 | -0.146 |
| Value-added productivity | 2.95 | 0.873 | 0.042 | 0.082 | 0.064 |
| Value-added productivity / employee | 2.96 | 0.766 | 0.005 | -0.133 | 0.219 |
| *Design productivity* | 2.62 | 0.166 | 0.168 | 0.107 | 0.084 |
| Machine saturation | 3.40 | -0.032 | 0.697 | 0.429 | -0.061 |

Table 8 - Indicators of cost performances.

Time performances [24] are clearly divided into external (1st component in Table 8) and internal (2nd component). From a more detailed analysis (rotation of the first six factors, with a cumulative variance explained of 77.2%), it emerges that internal time performances are split into run/set-up times on one hand and wait/move times on the other; externally-perceived times are split into: 1. lead times (supplying, manufacturing and distribution), 2. delivery reliability (both from suppliers and to clients), 3. inventory turn-over and order carrying-out time; 4. flexibility.

Flexibility is assimilated into time performance as it is the ability to change something (volume, mix, design specifications etc.) in time. By analyzing flexibility [25], differences between volume/mix flexibility, product/process design flexibility, program flexibility and plant expansion/conversion can be found.



| | Value | Cronb.α | 1C-Var. | 1st | 2nd |
|---|---|---|---|---|---|
| Time-to-market (product developm.) | 2.96 | 0.83 | 75.5% | 0.654 | 0.309 |
| Distribution lead time | 2.65 | 0.92 | 92.5% | 0.587 | 0.268 |
| Delivery reliability (to clients) | 3.22 | 0.82 | 60.0% | 0.780 | 0.136 |
| Supplying lead time | 3.62 | 0.72 | 78.1% | 0.590 | 0.400 |
| Supplier delivery reliability | 3.03 | 0.86 | 65.0% | 0.683 | 0.239 |
| Manufacturing lead time | 3.43 | 0.74 | 79.5% | 0.568 | 0.399 |
| Standard run times | 4.49 | - | - | 0.267 | 0.568 |
| Actual run times | 4.21 | - | - | 0.074 | 0.547 |
| Wait times | 2.23 | 0.68 | 75.8% | 0.280 | 0.776 |
| Set-up times | 3.46 | 0.68 | 75.5% | 0.101 | 0.811 |
| Move times | 2.03 | 0.80 | 83.1% | 0.168 | 0.731 |
| Inventory turn-over | 3.74 | - | - | 0.668 | 0.064 |
| Order carrying-out time | 3.66 | 0.67 | 75.3% | 0.672 | -0.013 |
| Flexibility | 3.32 | 0.84 | 57.2% | 0.572 | 0.188 |

Table 9 - Indicators of time performances.

| | Values | Cronb.α | 1C-Var. | 1st | 2nd | 3rd | 4th | 5th |
|---|---|---|---|---|---|---|---|---|
| S.P.C. | 2.76 | 0.86 | 65.8% | 0.417 | 0.761 | 0.108 | 0.019 | 0.199 |
| Mach. reliabil. | 1.85 | 0.95 | 95.3% | 0.299 | 0.172 | 0.070 | 0.198 | 0.770 |
| Re-works | 3.69 | - | - | 0.840 | 0.058 | -0.053 | 0.057 | 0.201 |
| Final tests | 4.60 | - | - | 0.729 | 0.072 | 0.295 | 0.144 | -0.045 |
| Quality system | 3.21 | 0.83 | 66.0% | 0.705 | 0.392 | 0.053 | 0.094 | 0.176 |
| Inbound ctrl(nc) | 4.00 | - | - | 0.153 | 0.138 | 0.790 | -0.068 | -0.134 |
| Inbound ctrl(c) | 2.99 | - | - | 0.042 | 0.021 | 0.734 | 0.169 | 0.344 |
| V.Q.R. | 3.18 | - | - | 0.000 | 0.489 | 0.502 | -0.044 | *0.508* |
| Custom. satisf. | 2.59 | 0.87 | 79.9% | 0.273 | 0.463 | 0.194 | 0.636 | -0.250 |
| Service perf. | 2.82 | 0.81 | 72.7% | 0.088 | 0.002 | -0.032 | 0.870 | 0.287 |
| Returned goods | 3.36 | - | - | 0.054 | 0.831 | 0.080 | 0.120 | 0.079 |

Table 10 - Indicators of quality performances.

The quality performance measurement regards several aspects [26]; principal components analysis unites (after the rotation of the first five factors, explaining a cumulative variance of 74.1%):
- measures regarding the quality produced (results from the S.P.C. - Statistical Process Control, and the number of defective goods returned during the warranty period) (2nd component in Table 9);
- measures regarding the in-bound quality (in-bound controls on certified "c" and non-certified "nc" purchasing, and results from V.Q.R. - Vendor Quality Rating; it should be noted that 88 of the 115 firms are certified according to the ISO9000 EN29000 standards) (3rd component);
- measures of external quality (customer satisfaction and service performance) (4th component);

- measures regarding quality costs (rework costs, final test costs and the quality system costs such as S.P.C. costs, maintenance costs and total quality program costs) (1st component).

Of far less importance (as relative eigenvalue) is a fifth component: machine reliability.

## CONCLUSIONS

The great number of firms taking part in this survey bears witness to the high level of interest that the PMS design aroused. This is mainly due to the fact that any program to improve performances must be supported and monitored by an adequate PMS. The literature and the empirical evidence indicate a state of advancement of the present day PMS which does not correspond to the numerous initiatives undertaken by the firms to improve their performances (programs such as TQM, JIT etc.). So the managerial implications of the studies on PMS design and implementation can become operative.

Results from this survey (see the mean values from Table 4 to Table 9) reveal that system formalization must regard both measure definition and measurement procedures, that the integration with MPCS should be improved and that today's PMS do not support people's efforts and benchmarking as they could. Furthermore, direct costs, inventory, labour productivity and process times are measured more intensively than time-to-market and delivery, while in-bound quality control and final testing seem to be privileged in respect to the SPC and the customer satisfaction measurement.

The integration with MPCS could economise in the data collection, with the distinction of: data regarding working capital (inventories and work-in-progress), data regarding production processes (time and quality performances), data regarding customer orders. The use of PMS may concern process control, human resources management or benchmarking (though still not widespread). The operations performances can be classified into: cost, time and quality performances. Cost performances include production costs, working capital level and productivity. Time performances can be divided into two groups: those directly perceived by the customers ("external") and those not ("internal"). Finally, quality performances regard both the quality produced, the quality perceived by the customers and the in-bound quality (or the quality performance of the suppliers); a fourth dimension of quality performance links quality and cost performances.

The next steps in the research will regard the relationships between the aforementioned PMS-internal variables and the existence of some causal models (or PMS-external variables, such as complexity, managerial choices and firm size determining the PMS structure).

## REFERENCES


[1] Dixon J.R., Nanni A.J., Vollmann T.E., *The New Performance Challenge (Measuring Operations for World Class Competition)*, DowJones-Irwin, Homewood, IL, 1990

[2] Hall R.W., Johnson H.T., Turney P.B.B., *Measuring Up (Charting Pathways to Manufacturing Excellence)*, Business One Irwin, Homewood, IL, 1991

[3] Maskell B.H., *Performance Measurement for World Class Manufacturing*, Productivity Press, Cambridge, MA, 1991

[4] Gold B., *Foundations of Productivity Analysis*, University of Pittsburgh Press, PA, 1955





[5] Lynch R.L., Cross K.F., *Measure Up! (Yardsticks for Continuous Improvement)*, Blackwell, Cambridge, MA, 1991

[6] Kaplan R.S., Norton D.P., «The Balanced Scorecard: Measures That Drive Performance», *Harvard Business Review*, pg.71-79, jan./feb. 1992

[7] Hronec S.M., *Vital Signs (Using Quality, Time and Cost Performance Measurement to Chart Your Company's Future)*, AMACOM, American Management Association, New York, 1993

[8] Thor C.G., «A Complete Productivity and Quality Measurement System», in Christopher W.F., Thor C.G. (eds.), *Handbook for Productivity Measurement and Improvement*, Productivity Press, Cambridge, MA, 1993

[9] Sink D.S., Tuttle T.C., *Planning and Measurement in Your Organization of the Future*, Industrial Engineering and Management Press, Norcross, GA, 1989

[10] Neely A., Mills J., Platts K., Gregory M., Richards H., «Mapping Measures and Activities: A Practical Tool for Assessing Measurement Systems», *1th EOMA Conference*, pg.313-318, Cambridge University Press, 1994

[11] Dillman D.A., *Mail and Telephone Surveys: The Total Design Method*, John Wiley & Sons, New York, 1978

[12] Rossi P.H., Wright J.D., Anderson A.B. (eds.), *Handbook of Survey Research*, Academic Press, New York, 1983

[13] Fowler F.J.jr., *Survey Research Methods*, Sage University Press, Beverly Hills, CA, 1984

[14] Dick W., Hagerty N., *Topics in Measurement (Reliability and Validity)*, McGraw-Hill, New York, 1971

[15] Flynn B.B., Sakakibara S., Schroeder R.G., Bates K.A., Flynn J.B., «Empirical Research Methods in Operations Management», *Journal of Operations Management*, vol.9, pg.250-284, 1990

[16] Cronbach L.J., «Coefficient Alpha and the Internal Structure of Tests», *Psychometrika*, vol.16, pg.297-334, 1951

[17] Nunnally J.C., *Psychometric Theory*, McGraw-Hill, New York, 1978

[18] McCutcheon D.M., Meredith J.R., Conducting Case Study Research in Operations Management, *Journal of Operations Management*, vol.11, pg.239-256, 1993

[19] Pearson K., «On Lines and Planes of Closest Fit to a System of Points in Space», *Philosofical Magazine*, vol.2, pg.557-572, 1901

[20] Spearman C., «"General Intelligence", Objectively Determined and Measured», *American Journal of Psychology*, vol.15, pg.201-293, 1904

[21] Dillon W.R., Goldstein M., *Multivariate Analysis (Methods and Applications)*, John Wiley & Sons, New York, 1984

[22] Kaiser H.F., «The Varimax Criterion for Analytic Rotation in Factor Analysis», *Psychology*, vol.23, pg.187-200

[23] Kurosawa K., *Productivity Measurement and Management at the Company Level: The Japanese Experience*, Elsevier, Amsterdam, 1991

[24] Blackburn J.D. (ed.), *Time-based Competition: The Next Battleground in American Manufacturing*, Business One Irwin, Homewood, IL, 1991

[25] Gerwin D., «Manufacturing Flexibility: A Strategic Perspective», *Management Science*, vol.39, n°4, pg.395-410, 1993

[26] De Toni A., Nassimbeni G., Tonchia S., «An Instrument for Quality Performance Measurement», *Internationl Journal of Production Economics*, forthcoming