Methodology for Selecting Manufacturing Automated Systems

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Abstract: In this paper a Methodology for Selecting Manufacturing Automated Systems (MAS) is presented. A methodology of seven points is proposed. In this work just the identification of factors of decision and the justification of the minimum number of factors of decision, into the fisrt two points of the methodology, are analyzed widely. In the first point a review of publications about factor decision is used and for the second one a Multivariate Data Analysis is used.

Key-Words: Manufacturing Automated Systems, Multivariate Data Analysis, Decision Factors.

1 Introduction

The outline that at the moment presents the industry world manufacturer it is observed dynamic and changing, evidently this is caused by the more and more specific and demanding necessities of the customers, customers that have developed a sharper judgment to choose those products, that they cover their necessities in a better way, more and more sophisticated, with shorter cycles of life, with high quality, of great variety and with competitive prices. This way, the ability to adapt to the changes that mark the markets, to the design of the products and the technological developments, is the key factor for the competitiveness of an organization. The above-mentioned, impels the use of production systems able to reprogram its processes, managing the materials automatically, assuring high quality and coordinating the simultaneous production of different parts with low costs and short set up time. All this with the control of a computer. For these reasons, Manufacturing Automated Systems have been a focal point in manufacturing related research since many years ago. For this work, are consider Transfer Line, Batch Flow Line, Flexible Manufacturing System and Manufacturing Cell, into the Manufacturing Automated Systems.

The present work, is part of a methodology of design of FMS that is developing in the Tec of Monterrey [1], that consists in: to create a methodology of design of flexible manufacturing systems of metal-mechanics, from the conceptual phase until the previous phase to the equipment acquisition for their construction, and especially, to conceive an algorithm for the generation, evaluation and selection of alternative of FMS, starting from the geometric and technological analysis of a family of representative pieces that is good later on to develop a system of design of FMS attended by computer, low cost restrictions, time, quality, complexity, flexibility and dependability.

For which the following main stages are presented to develop:

1. To develop of the analysis technique F-Q for the determination of the level of automation of the manufacturing system.
2. To develop an algorithm to select the type of Manufacturing Automated Systems. It is sought to look for a better technique that unit cost/ production rate for the selection of Manufacturing Automated Systems, going by the identification of the necessity of automating a process according to a group of given conditions.
3. To develop of an algorithm of assignment of traditional operations of cut with chip detachment starting from the system of code of pieces.
4. To develop of an algorithm of selection of types of machines tools and generation of a given list of operations a group of processes of metal-mechanics manufacturing.

5. To develop of an algorithm of assignment of the degree of automatic equipment of an automated center.
6. To develop an integrative algorithm for the design of FMS that conjunte the geometric, technological analyses and production, to designate types and number of basic and complementary equipment for the materials handling.

The methodoly of selection Manufacturing Automated Systems proposed in this paper, is part of the second point of the above methodology. A methodology of seven points is proposed. In this work just the identification of factors of decision and the justification of the minimum number of factors of decision, into the fisrt two points of the methodology, are analyzed widely. In the first point a review of publications about factor decision is used and for the second one a Multivariate Data Analysis is used.

2 Multivariate Data Analysis for Selecting Factors.

Multivariate data analysis refers to a wide assortment of such descriptive and inferencial techniques. In contrast to univariate statistics, we are concerned with the jointness of the measurements. Multivariate analysis is concerned with the relationships among the measurements across a sample of individuals, itesms or objects. In this work, the Correspondence Analysis is used for justification of the minimum number of decision factors.

2.1 Correspondence Analysis

Correspondence analysis by Jobson [2], is a technique that uses singular value decomposition analyze a matriz of nonnegative data. The technique simultaneously characterizes the relationship amog the rows an also de amog the comulmns of the data matrix. The outcome of a correspondence analysis is a pair of bivariate plots. The theory of correspondence analysis is based on the generalized singular value decomposition of matrices.

Correspondence analysis ia a descriptive-exploratory technique designed to analyze simple two-way and multi-way tables containing some measure of correspondence between the rows and columns. The results provide information wich is similar in nature to those produced by Factor Analysis techniques, and they allow one to explore the structure of categorical variables included in the table. The most common kind of table of this type is the two-way frecuency crosstabulation table.

These methods were originally developed primarily in France by Jean-Paul Benzérci in the early 1960's and 1970's, see Benzérci [3], Lebart, Morineau, and Tabard [4], but have only more recently gained increasing popularity in English-speaking countries, see, Carrol, Green, and Schaffer [5]; Hoffman and Franke [6]. (Note that similar techniques were developed independently in several countries, where they were known as optimal scaling, reciprocal averaging, optimal scoring, quantification method, or homogeneity analysis).

The procedure are based on the following matrices:

- P is the matrix of relative frequencies, i.e., each element of P is computed as the respective frequency from the input table, divided by the grand total of all values.
- r is the vector of row totals of P.
- c is the vector of column totals of P.
- D_r is a diagonal matrix, the diagonal elements of D_r are equal to the row totals of P.

- D_c is a diagonal matrix, the diagonal elements of D_c are equal to the column totals of P.

Singular value decomposition:
The computation of the row and column coordinates is based on the generalized singular value decomposition of P, as:

$$P = A\ DuB' \qquad (1)$$

so that:

$$A\ inverse(Dr)A = B'\ inverse(Dc)B = I \qquad (2)$$

Where:

- A is the matrix of the left-side generalized singular vectors.
- B is the matrix of the right-side generalized singular vectors.
- D_u is a diagonal matrix with the diagonal elements equal to the generalized singular values.
- I stands for the identity matrix (a diagonal matrix with 1's in the diagonal).

Coordinates for row and column points:

The calculed of the coordinates for row and column points depends on the choice of the standardization chosen in the Standardization of Coordinates.

Row and column profiles.
When this option is chosen, then the row coordinates are calculed based on the row profile:

$$matrix\ R = inverse(D_r)P \quad (3)$$

and the column coordinates are calculed based on the column profile matrix calculed analogously. Specifically, the row coordinates are calculed as:

$$F = inverse(D_r)AD_u \quad (4)$$

and the column coordinates as:

$$G = inverse(D_c)BD_u \quad (5)$$

This option is appropriate when you are interested in interpreting both the distances between row points, and the distances between column points (the distances in both coordinate systems for row points and column points are Chi-square distances). However, note that, distances between column and row points are not meaningful.

Relative inertia:
The Quality of a point (see above) represents the proportion of the contribution of that point to the overall inertia (Chi-square) that can be accounted for by the chosen number of dimensions. However, it does not indicate whether or not, and to what extent, the respective point does in fact contribute to the overall inertia (Chi-square value). The relative inertia represents the proportion of the total inertia accounted for by the respective point, and it is independent of the number of dimensions chosen. Note that a particular solution may represent a point very well (high Quality), but the same point may not contribute much to the overall inertia (e.g., a row point with a pattern of relative frequencies across the columns that is similar to the average pattern across all rows).

Relative inertia for each dimension:
This column contains the relative contribution of the respective (row or column) point to the inertia "accounted for" by the respective dimension. Thus, this value will be reported for each (row or column) point, for each dimension.

2.2 Factors of Decision

One of the stages of the present work, is the identification of those factors that help us, to select the type of Manufacturing Automated Systems that more suits according to the particuliar necessities of each company. For this reason, is of the vital importance the definition of this factors, for that which is necessary to carry out a detailed analysis of all and each one of the factors that intervene in this selection.

We have decided to separate this factors according to two levels of importances and detail, as it is mentioned next:

1. Factors of first level.
2. Factors of second level.

The factors of first level, are those that are focused to the part of the conceptual design of the system and that they give us the rule to identify to first instance the system that more we need and the factors of second level that are focused to the detailed design of the system, with which it will become this selection with more precision.

After a revision of articles, magazines and books related with the topic [7-34], no author coincides in the definition of a robust methodology that includes the definition of factors that finish in the selection the type of Manufacturing Automated Systems more appropriate to the particuliar necessities of each company. Many of these are only limited to mention this factors without giving any justification for which should be considered, other they go a little further on quantifying each one of the factors.

3 Metodology of Selection

Next the proposal of the methodology is presented for the selection of Manufacturing Automated Systems:

1. Identification of decision factors.
2. Justification of the minimum number of decision factors.
3. Quantification of decision factors.
4. Definition of ranges of application of decision factors.
5. Generation of the mathematical model of assignment of the Manufacturing Automated Systems.
6. Definition of the space that allows to represent the obtained results of the mathematical model.

7. Simulation and Optimization.

As we have mentioned previously, the work, only analyzes the development of the first two points of the proposed methodology.

3.1 Identification of Decision Factors

We proposed thre factors of first level, listed in number, and into eache one, we proposed factors of second level, listed in letters, that they are:

1. Flexibility
   a. Machine type
   b. Variety of products
   c. Production volume
   d. Material handling
   e. Variety of operations
   f. Manufacturing processes
   g. Routing
   h. Expansion
   i. Variety in the production
   j. Market
2. Quality
   a. Reliability
   b. Maintenance
   c. Automated systems of quality
   d. Organizational structures
   e. Information systems
   f. Requirements of qualified manpower
3. Cost
   a. Investment
   b. Cost for piece
   c. Operation costs
   d. Total cost
   e. Net Present Value
   f. Inventory in process
4. Products and Market
   a. Product type,
   b. Lot Size,
   c. Rate of introduction of new products
   d. Order winners,
   e. Qualifiers,
   f. Life cycle product
5. Productivity
   a. Lot size
   b. Cycle time
   c. Delivey time
   d. Production time
   e. Set-up time
   f. Production volumes
   g. Use of the machinery and manpower

3.2 Justification of the Minimum Number of Decision Factors

In order to choose the minimun number of factors for selecting the Manufacturing Automated Systems according to the necessities of the customers, we use the correspondence analysis technique. In this work, a Flexible factors are chosen tos show the procedure.

Fist, create a contingency table (*r x c*). In rows (r_i) we place to the the different authors that have been plentiful in the study of the factors of flexibility, in this case we chose fifteen autors. In the columns (c_j), we place the different factors of second level that define flexibility. Into the cells, we place the decision of the each one of the autors, if they consider important the factor (yes) or is not important (no), see table 1.

Table 1

Factores para Medir Flexibilidad

	Machine	Product	Expansion	Process	Volume	Routing	Operation	Production	Material	Market
aut 1	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
aut 2	yes	yes	no	no	yes	yes	no	no	no	no
aut 3	yes	yes	no	no	yes	yes	no	yes	yes	no
aut 4	yes	no	no	no	no	no	no	no	no	no
aut 5	yes	yes	no	yes	yes	no	yes	no	yes	yes
aut 6	yes	yes	no	yes	yes	yes	yes	no	no	no
aut 7	yes	no	yes	yes	yes	no	yes	yes	yes	no
aut 8	yes	yes	yes	yes	no	yes	no	no	no	no
aut 9	no	yes	yes	no	no	no	no	no	no	no
aut 10	no	yes	no	no	yes	yes	no	no	yes	no
aut 11	yes	yes	no	no	yes	no	yes	yes	yes	no
aut 12	yes	no	no	yes	yes	no	no	no	yes	no
aut 13	no	yes	yes	no	no	yes	no	yes	no	no
aut 14	yes	no	no	no	yes	no	no	no	no	no
aut 15	yes	yes	no	yes	yes	yes	yes	yes	yes	no

Second, we calculetd the eigen-values, for the table 1, Note that the dimensions are "extracted" so as to maximize the distances between the row or column points, and successive dimensions (which are independent of or orthogonal to each other) will "explain" less and less of the overall Chi-square value. Thus, the extraction of the dimensions is similar to the extraction of principal components in Factor Analysis. First, it appears that, with a single dimension, 32.24% of the inertia can be "explained," that is, the relative frequency values that can be reconstructed from a single dimension can reproduce 32.24% of the total Chi-square value (and, thus, of the inertia) for this two-way table; two dimensions allow you to explain 52.64%. table 2.

Table 2

Eigenvalues and Inertia for all Dimensions

	Singular Values	Eigen-Values	Perc. Of Inertia	Cumulatv Percent
1	0.567812219	0.322410716	32.24107161	32.24107161
2	0.451735912	0.204065334	20.40653339	52.64760501
3	0.376400802	0.141677564	14.16775638	66.81536139
4	0.332254376	0.110392971	11.03929706	77.85465845
5	0.291311209	0.08486222	8.486222032	86.34088049
6	0.225769633	0.050971927	5.097192699	91.43807319
7	0.20522811	0.042118577	4.211857708	95.64993089
8	0.158344089	0.02507285	2.50728504	98.15721593
9	0.12105616	0.014654594	1.46545939	99.62267532
10	0.061426759	0.003773247	0.377324678	100.000000

Since the sums of the frequencies across the columns must be equal to the row totals, and the sums across the rows equal to the column totals, there are in a sense only (no. of columns-1) independent entries in each row, and (no. of rows-1) independent entries in each column of the table (once you know what these entries are, you can fill in the rest based on your knowledge of the column and row marginal totals).

Table 3

Eigen-vectors

	Dimension 1	Dimension 2
Machine:yes	-0.042245685	0.041243745
Machine:no	0.042245685	-0.041243745
Product:yes	-0.005633347	-0.077017089
Product:no	0.005633347	0.077017089
Expansio:yes	0.015602097	-0.063229221
Expansio:no	-0.015602097	0.063229221
Process:yes	-0.058097515	-0.007339242
Process:no	0.058097515	0.007339242
Volume:yes	-0.058469812	0.025807882
Volume:no	0.058469812	-0.025807882
Routing:yes	-0.000226567	-0.075067627
Routing:no	0.000226567	0.075067627
Operation:yes	-0.07266194	-0.016777131
Operation:no	0.07266194	0.016777131
Production:yes	-0.037726262	-0.051025606
Production:no	0.037726262	0.051025606
Material:yes	-0.067429236	-0.002291743
Material:no	0.067429236	0.002291743
Market:yes	-0.034577903	-0.017792891
Market:no	0.034577903	0.017792891

In table 3, the eigen-vector are shown, which represent coefficients of a vector, those coefficients that are bigger in absolute value, it is considered that it contributes bigger information. As consequence those factors that contain a bigger coefficient, are considered as the most important to define flexibility, and the other ones are discarded.

This factor are: variety of operations (0.07266), material handling (0.06742), production volume (0.05846), manufacturing processes (0.05809), and machine type (0.04224).

Finally, we generate a matrix of log-lineal correlation among the different factors. See table 4.

Table 4

Contingence Table

	Machine	Product	Expansion	Process	Volume	Routing	Operation	Production	Material	Market
Machine	1	-0.30151134	-0.35355339	0.46770717	0.45226702	-0.13363062	0.40824829	0.06804138	0.20044593	0.19611614
Product	-0.30151134	1	0.10660036	-0.04029115	-0.02272727	0.64465837	0.18463724	0.18463724	0.04029115	0.23652496
Expansion	-0.35355339	0.10660036	1	0.18898224	-0.53300179	0.09449112	3.8145E-18	0.28867513	-0.18898224	0.13867505
Process	0.46770717	-0.04029115	0.18898224	1	0.26189246	0.07142857	0.6000992	0.05455447	0.33928571	0.41931393
Volume	0.45226702	-0.02272727	-0.53300179	0.26189246	1	0.04029115	0.49236596	0.18463724	0.64465837	0.23652496
Routing	-0.13363062	0.64465837	0.09449112	0.07142857	0.04029115	1	-0.05455447	0.21821789	-0.07142857	-0.02620712
Operation	0.40824829	0.18463724	3.8145E-18	0.6000992	0.49236596	-0.05455447	1	0.44444444	0.49099025	0.48038446
Production	0.06804138	0.18463724	0.28867513	0.05455447	0.18463724	0.21821789	0.44444444	1	0.49099025	0.08006408
Material	0.20044593	0.04029115	-0.18898224	0.33928571	0.64465837	-0.07142857	0.49099025	0.49099025	1	0.36689969
Market	0.19611614	0.23652496	0.13867505	0.41931393	0.23652496	-0.02620712	0.48038446	0.08006408	0.36689969	1

Table 4, is used to determine if the factors that were not considered important inside the analysis of correspondences they are or not defined by the factors that were considered as important. In this case all thae factor are define with the most important factor, that mean, correlation exists among the factors that were chosen as the most important in agreement with the analysis of correspondence and the others were eliminated. With this we say that the information of those variables that were eliminated will be given by those that were chosen

4 Conclusion

A Methodology for Selecting Manufacturing Automated Systems (MAS) was presented, particularly, the definition of the factors that will help us to this selection, as well as the technique to justify the minimum number of variables to consider. In a same way it is suggested to make the same procedure for the other factors of first level and their factors of second level.

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