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THE MANUFACTURING PROFILE OF FLEXIBLE AND LOW-COST PRODUCERS: AN EMPIRICAL STUDY

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ABSTRACT

Since the introduction of the concepts of lean manufacturing, agility and mass customization it is questioned to what extent the trade-off between cost and flexibility still holds. It has been the objective of our research to test the trade-off theory empirically using the data of the International Manufacturing Strategy Survey (IMSS). Our research confirms the well accepted manufacturing profile of low cost producers, which typically use a line process, and of flexible producers, which typically produce in a job shop. However, we also observe that some companies manage to overcome the cost/flexibility trade-off, by introducing the concept of postponed manufacturing. These companies are characterized by an assembly-to-order policy of standardized semi-finished products, produced in a line process. Flexibility and low cost are thus obtained by playing with the position of the decoupling point.

Keywords***:*** manufacturing strategy, mass customization, flexibility

INTRODUCTION

Ever since Skinner's article in 1969, the manufacturing strategy literature has been intrigued by the idea of a trade-off between seemingly conflicting performance criteria (Skinner, 1969). The product-process matrix, for example, suggests that the process choice is linked to the degree of standardization of the product: high variety in products dictates the need for a job shop, whereas commodity products fit best in a line production, which is tuned for low cost and high efficiency (Hayes and Wheelwright, 1979). Stated differently, this indicates the trade-off between cost and product flexibility in selecting the production process. There also seems to be a trade-off between cost and volume flexibility: volume flexibility can be accomplished through high inventories or through slack capacity, but both solutions have cost implications.

Since the introduction of the concepts of lean manufacturing, agility and mass customization, which strive for lower costs and greater flexibility at the same time, it is questioned to what extent the trade-off between cost and flexibility still holds. This discussion is present in among others Hayes (1996), Suarez (1995), Gupta (1991) and Pine (1993). Skinner responded to this discussion by arguing that the trade-off still exists, albeit a new trade-off at different levels (Skinner, 1996).

OBJECTIVE AND HYPOTHESES

The objective of this paper is to test empirically whether indeed some companies manage to break through the traditional cost-flexibility trade-off. The paper focuses on those companies that show high performance on both cost *and* flexibility, and compares the manufacturing characteristics of these companies with the characteristics of companies that show high performance on either cost *or* flexibility. This allows us to test whether indeed the profile of a low cost producer differs from the profile of the flexible producer. It also allows us to describe the profile of the producers that manage to escape from this traditional trade-off.

An important aspect of the manufacturing profile of a factory is the type of production process it has adopted. The relationship between the competitive advantage of factories, the type of products they produce and the type of process they have adopted, has been described in the product/process matrix (Hayes and Wheelwright, 1979). According to this framework, standard products are preferably produced in a line or mass production process, which can be organized for high efficiency and low cost. High variety of products on the other hand dictates the need for a job shop, which allows for (product) flexibility but typically at a higher cost. However, the more recent concept of postponed manufacturing offers the possibility to combine variety and efficiency: the idea is to design the product such that a standard set of components leads to standard modules, which can be produced in a line process. Product variety is obtained by combining these standard modules on demand (Feitzinger and Lee, 1997). Mass customizers, therefore, use production postponement to obtain flexibility in a line production process, which deviates from the idea behind the product-process matrix (Pine, 1993; Waller, Dabholkar et al., 2000). This leads to the following hypothesis:

> H1a: Low cost producers are more likely to adopt a line as their process structure. Flexible producers are more likely to adopt a job shop as their process structure.
>
> H1b: The combination of low cost and high flexibility can be obtained through a line production process.

Companies that adopt a make-to-stock policy (MTS) can use their inventory of finished goods as a buffer for fluctuations in demand. However, this leaves no flexibility to adapt the products to customer requirements. An engineer-to-order (ETO) or make-to-order (MTO) policy, on the other hand, allows the company to be responsive to the market. In this case, the factory typically has to cope with demand fluctuations, which makes it more difficult to optimize costs. By shifting the decoupling point to the level of semi-finished products or in other words by postponing the point of product differentiation and adopting an assembly-to-order policy (ATO) the combination of low cost and high flexibility can be achieved (Beckman, 1990; Pine, 1993; Feitzinger and Lee, 1997).

Our second hypothesis is then:

> H2a: Low cost producers typically have a make-to-stock policy, while the flexible producers follow an engineer-to-order or a make-to-order policy.
>
> H2b: The combination of low cost and high flexibility can be obtained through an assembly-to-order policy.

Upton argues that operational flexibility is determined primarily by a plant's operator and by the relationship between the managers and the operator (Upton, 1995). Flexibility on the shop floor requires training of the workers. The workers need to acquire certain skills and to learn different tasks so that job rotation is possible. Managers should emphasize the importance of flexibility in their communication to the workers (Upton, 1995; Gupta and Somers, 1996). This leads to our third hypothesis:

H3: Flexibility requires a high level of skills on the shop floor and an HR policy of job rotation, irrespective of the performance on cost.

While there are many non-technology mechanisms for achieving flexibility, technology remains a critical driver in the creation of flexible organizations. New technologies, such as flexible manufacturing systems, computer-controlled equipment and robotics allow for more flexibility on the shop floor at lower costs (Beckman, 1990; Upton, 1995). Also, the use of Information Technology for the supply of materials and parts through the implementation of an ERP system is regarded as an important support tool in reaching flexibility.

H4a: Automation in manufacturing is an important element in the combined accomplishment of low cost and high flexibility.

H4b: Information technology to support manufacturing is an important element in the accomplishment of high flexibility.

RESEARCH METHODOLOGY

The sample

Our research uses the data of the International Manufacturing Strategy Survey (IMSS) 2001. IMSS is a global research network aimed at gathering data on manufacturing and supply chain strategy, competitive priorities, capabilities, operational policies and performance. Data have been collected in the engineering/assembly industry (ISIC 38 classification) in the period 2000-2002 by national research groups using a standard questionnaire, in Argentina, Australia, Belgium, China, Denmark, Germany, Hungary, Italy, Ireland, Netherlands, Norway, Spain, Sweden and the United Kingdom. The small companies (less than 100 employees) have been omitted from the analysis. In total our sample consists of 356 respondents.

OPERATIONALIZATION OF CONSTRUCTS

Performance on cost and flexibility

Plant performance is measured through a set of 17 variables that measure the change in level of performance on a five-point Likert scale (1= strongly deteriorated; 5 = strongly improved). These variables are listed in Table 1. It is important to note that the performance data used in the analyses are not absolute measures of performance, but are measures of *change* in performance. That is, the respondents have been asked to rate the improovement (or deterioration) of performance they have reached on a set of performance variables. Since the performance data is self-reported and to a large extent perceptual, the reliability of absolute measures of performance would have been too low. In asking for relative performance (improvement) we help the respondents by offering them a reference point for rating their performance, ie their own past performance.

A principal component analysis (eigenvalue >1) with a varimax rotation and a reliability analysis on these variables results in 5 performance factors, as shown in Table 1: delivery performance, cost performance, flexibility performance, quality performance and other. Given the scope and objectives of this paper, we focused on the cost and flexibility performance factors only. The cost performance factor is composed of labour productivity, capacity utilization and inventory turnover. Volume and mix flexibility form the factor flexibility performance.

Insert Table 1 About Here

A reliability analysis, to check the internal consistency of the flexibility and cost performance factors, results in a Cronbach's alpha of 0.68 for the factor flexibility and 0.61 for the factor cost, which is acceptable (Hair, Anderson et al., 1998).

Subsequently, performance on flexibility and cost has been calculated as the mean of the responding variables.

In order to detect differences in the manufacturing profile between companies that reach clearly different levels of performance improvement, we have focused our analyses on the top and bottom quartile of cost and flexibility performance. (See Figure 1) Four categories have been identified for further analysis: the first are companies with a high flexibility and a low cost, which we will call the “flexible/low cost producers”. The second group, which we call the “flexible producers” are the companies that also have a high flexibility, but with a high cost. The third group is the companies that have a low flexibility and a low cost, the “low-cost producers”. Finally, the fourth group of respondents are those that have a low flexibility and a high cost, the “unflexible/high cost producers”.

191 respondents are not classified because they either have a medium score on flexibility or a medium score on cost or both.

Insert Figure 1 About Here

Production Process

The IMSS-questionnaire measures the type of production process by asking the respondents to indicate to what extent their activity uses the process types one of a kind, batches and mass production. The majority of the companies report they use one type of production process for more than 80% of their production. The other respondents report they use two types of production processes that are adjacent. In order to examine the differences in process type between the respondents this variable needs to be recoded. The choice of process structure, as defined in the Product-Process matrix, is operationalized as a continuous variable, ranging from 1 for companies that have adopted a pure line process, to 5 for companies that have adopted a pure job shop process. Appendix 1 explains how the process variable has been constructed. Table 2 shows the distribution of the sample on the process structure variable.

Insert Table 2 About Here

Since the classification describes a continuum ranging from very small to very large batch sizes, it is acceptable to treat the 1 to 5 scale as an interval scale.

Inventory policy and strategic positioning

The inventory policy is operationalized by means of the number of days of production that is kept in inventory as raw material, work in process and finished goods. Since it is our objective to compare the inventory policy of the different categories of companies, these absolute figures are recoded into relative figures, expressing the percentage of stock kept as raw material, as WIP and as finished goods. For example, a company with 10 days of inventory of raw materials, 5 days of inventory of WIP and 5 days of finished goods would have an inventory of 50% RM, 25% WIP and 25% FG.

The strategic positioning of the companies is measured by the percentage of customer orders they design/engineer to order, manufacture to order, assemble to order and produce to stock.

HR policy

The IMSS survey examines the percentage of multi-skilled production workers and the job rotation of these workers on a five-point Likert scale, with 1 meaning they never rotate and 5 meaning they frequently rotate between jobs or tasks.

Use of technology

Firstly, the survey measures the use of 13 technologies (see Table 3). Principal component analysis (eigenvalue>1) with varimax rotation results in 3 factors: stand-alone/NC machines, machining centres, CNC-DNC and automated tool change load on the first factor, which we have labeled "production automation". The use of robots, automated guided vehicles and automated storage-retrieval systems load on the second factor, which we have labeled "handling". The third factor, labeled "design and engineering", consists of the following technologies: computer-aided inspection–testing-tracing, computer aided design-engineering, integrated design-processing systems, engineering databases and LAN-WAN or intranet and internet systems. The variable flexible manufacturing and assembly systems is left out of further analyses because it loads on 2 factors, namely "production automation" and "design and engineering". This had no influence on the result of the initial factor analysis.

Insert Table 3 About Here

The reliability analysis for the three factors results in a cronbach's alpha of 0.75 for the factor production automation, 0.49 for the factor handling and 0.73 for the factor design and engineering. Because of the low alpha, the factor handling is left out of the further analyses.

The survey also measures to what extent materials management, production planning and control, purchasing and supply chain management are supported by an Enterprise Resource Planning systems (1 = no use and 5 = high use).

Financial performance

Finally, we have used the financial performance data provided in the survey. The questionnaire asked for the ROS (return on sales: earnings before interests and taxes/ sales) and ROI (return on investment: earnings before interests and taxes/ total assets).

RESULTS

The differences in financial performance, process type, inventory policy, strategic positioning, HR policy, automation and the use of ERP between the "flexible/low-cost producers and the other categories of companies are measured by anova analysis.
The results of these analyses are listed in Table 4.

Process type

The "flexible/low-cost producers" make significantly more use of a line process than the "flexible producers" and than the "unflexible/high-cost producers". We can conclude that hypotheses 1a and 1b are supported by the data in this analysis.

Inventory policy and strategic positioning

The “flexible producers” have most of their inventory early in the production process, while the “flexible/low-cost producers” and the “unflexible/high-cost producers” have most of their inventory later in the production process. The “low-cost producers” spread their inventory equally in the process.

The analysis of the strategic positioning results in the following conclusions. Firstly, the use of ATO occurs more frequently in “flexible/low-cost” companies than in the other categories. Secondly, more “flexible producers” use an ETO/MTO policy than the “flexible/low-cost producers” and “low-cost” producers. And thirdly, more “low-cost producers” have adopted a MTS policy than in the “flexible” and “flexible/low-cost” producers.

This means that also hypotheses 2a and 2b are supported by the data.

Insert Table 4 About Here

HR policy

We did not find a significant difference in the use of job rotation between the four categories of companies. We did however, observe differences in the use of multi-skilled workers. The “flexible producers” have more multi-skilled workers than the other three categories, although this difference is not significant between the “flexible producers” and the “low cost” producers. This means that hypothesis 3 is only partially confirmed. The two categories of companies with a high performance on flexibility do not use more job rotation than the others and only the “flexible producers” have more multi-skilled workers, while the “flexible/low-cost producers” do not gain their flexibility by a different HR-policy.

Automation

No significant difference is observed in the use of automation between the four categories. Hypothesis 4a is therefore not supported. Rather, the results seem to confirm the results of a study by Suarez, Cusumano Fine and Upton, who conclude that flexibility has more to do with non-technology factors than with technology itself (Suarez, Cusumano et al., 1995; Upton, 1995).

We do observe differences in the use of ERP systems. The two subsamples of companies that perform well on flexibility make more use of ERP to support their purchasing and supply chain management than the other two groups of companies. It seems that their flexibility is supported by the use of adequate software.

The manufacturing profile of the four categories of companies are summarized in Figure 2.

Financial performance

The question remains whether the differences in competitive priorities and the corresponding manufacturing profile have implications for the financial performance of the companies. Our expectation is that the combination of high performance on cost and flexibility results in higher financial performance than a focus on cost or flexibility only.
Our data gives very weak support for this assumption. The flexible/low cost producers show a higher Return on Sales than the flexible producers. However, there is no significant difference in Return on Investment. Also, we didn't observe any significant difference between the low cost producers and the flexible/low cost producers.

It is intriguing to observe that the ROS and ROI of the low cost producers is considerabley higher than for the flexible producers. However, the lack of significance in these differences may be an indication of rather low reliability of the financial data. There was indeed a lot of missing values for these variables: 37% of values missing for ROS; 48% of values missing for ROI.

An alternative explanation may well be that too many other factors play a role in explaining the financial performance. The marketing approach, the innovativeness of the company, the environment in which the company competes, are definitely examples of elements that have an impact on the overall financial performance of the company.

LIMITATIONS

As stated earlier, the paper relies on self-reported, perceptual measures of performance. Moreover, it discusses different levels of performance improvement, rather than absolute performance levels. This limits the conclusion of our paper to stating that cost reductions and flexibility improvements are related to certain manufacturing profiles.

A second limitation is the industry focus. The data is limited to the ISIC 38 sectors. Whether the conclusions are valid for other industries is an subject for future research.

CONTRIBUTIONS

The value of this paper is twofold.

The paper provides empirical support for the traditional concepts behind the product/process matrix (Hayes and Wheelwright, 1979) and the focused factory (Skinner, 1974). The paper shows empirically that improvements on different competitive priorities match with different manufacturing choices and policies. The paper also validates the manufacturing profile of the mass customizer, thus adding some empirical observations to the trade-off discussion (Skinner, 1996).

For the practitioner, the paper shows that within this engineering/assembly industry, some companies manage to distinguish from the competitors by scoring well n two seemingly different factors, cost and flexibility. It may urge them to consider this as their strategy for the future.

CONCLUSIONS

We conclude from our analyses that there are indeed companies that manage to be flexible and low on cost at the same time. While some companies (16%) make a clear trade-off between cost and flexibility, we find in our sample that 22% of the companies do achieve a high performance improvement on both.

Depending on which of the two factors companies focus on, they have a different manufacturing "profile". As expected, a line production process, an MTS policy and higher automation characterize the manufacturing profile of the low-cost producer. The flexible producer is characterized by a batch process, an inventory early in the production process, an ETO/MTO policy, more multi-skilled workers and a lower level of automation than the low cost producer.

The manufacturing profile of the flexible/low-cost producer corresponds to the profile of mass customizers as described in the literature (Feitzinger and Lee, 1997). The trade-off between flexibility and cost is avoided by a “clever” organization: assembly to order of low cost, standard modules, produced in a line process and supported by the use of ERP for purchasing and supply chain management. Postponed manufacturing is a reality in these companies.

Our final comment refers to the companies that show low performance on cost and flexibility. While companies normally use a job shop to be flexible, these companies use it in combination with an MTS policy, which leaves little possibility for product variety. Furthermore, they have few skilled people, contrary to what one expects in a job shop process. These companies seem to underestimate the potential of their production process, which results in a misfit between their strategic priorities and their manufacturing capabilities.

APPENDIX 1

The questionnaire measures the type of production process by asking the respondents to indicate to what extent their activity uses the process types one of a kind, batches and mass production. This data needs to be translated into a variable that reflects the process structure adopted by the company. A set of rules has been applied to construct this variable. We explain the procedure through examples of cases in Table 5.

Insert Table 5 About Here

If 80% or more of the production is done by one process type, the respondent is divided into the responding category (see case 1 and 2). If the company reports the use of two types of processes and none of them has more than 80% of the total volume, the company is divided in the corresponding 'in-between' category (see case 3). If both earlier mentioned rules do not apply and so the company uses the three processes, two options are possible. If one of the process types is used for less than 15% of the total volume of production, the company is classified in the 'in between' category of the other two process types (see case 5). If on the other hand the lowest percentage is 15 or more, the company is not classified (see case 4). Only 3,2% of the companies cannot be classified through the procedure.

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TABLE 1

Principal Component Analysis with Varimax rotation on 17 performance variables

	FACTOR LOADINGS				
VARIABLES	**Delivery**	Cost	*Flexibility*	*Quality*	*Other*
Delivery speed	*0.800*				
Customer service	*0.719*				
Delivery reliability	*0.759*				
Labour productivity		*0.641*			
Capacity utilization		*0.800*			
Inventory turnover		*0.627*			
Volume flexibility			*0.765*		
Mix flexibility			*0.845*		
Manufacturing conformance				*0.770*	
Product quality				*0.829*	
Procurement costs					*0.794*
Overhead costs					*0.572*
Production lead time					*0.795*
Product customization				*0.346*	
Time to market	*0.406*		*0.439*		
Environmental performance		*0.323*		*0.377*	
Manufacturing lead time	*0.326*		*0.307*		*0.372*

FIGURE 1

Respondents according to their performance on cost and flexibility

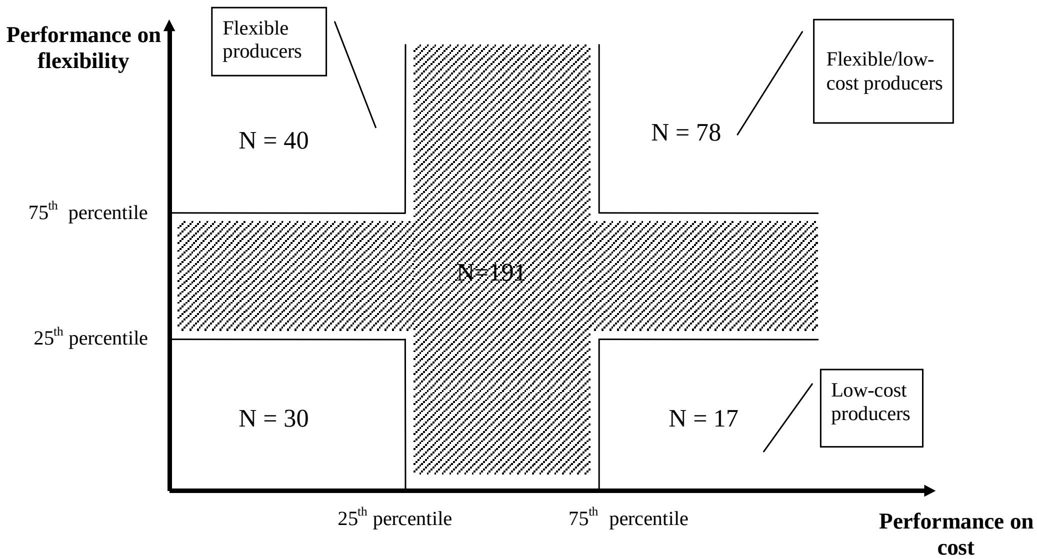

TABLE 2

Process structure

Category	**Percentage of Respondents**
Line process	14,1%
Large Batch	11,6 %
Medium Batch	38,3 %
Small Batch	15,0 %
Job shop	17,8 %

TABLE 3

Principal Component Analysis with Varimax rotation on 13 technology variables

	Factor Loadings		
Variables	*Production automation*	*Design and engineering*	*Handling*
Stand-alone / NC machines	*0.735*		
Machining centres	*0.754*		
CNC-DNC	*0.780*		
Automated tool change- parts un-/ loading	*0.648*		
Computer-aided inspection/testing/tracking		*0.568*	
Computer-aided design/engineering		*0.634*	
Integrated design-processing systems		*0.600*	
Engineering databases, product data management systems		*0.786*	
LAN-WAN / Intranet / Shared databases / Internet		*0.745*	
Robots			*0.546*
Automated guided vehicles			*0.659*
Automated storage-retrieval systems			*0.676*
Flexible manufacturing/assembly systems		*0.376*	*0.470*

TABLE 4

Results anova analysis

	Unflexible high cost producers	Low-cost producers	Flexible producers	Flexible/ low cost producers	Significant differences
Process type (scale 1 to 5)	3,14	2,87	3,32	2,63	C>D (5%) A>D (5%)
Inventory policy (%)					
Raw materials	44	35	57	43	A<C (5%) B<C (5%) C>D (5%)
WIP	28	43	23	30	A>B (10%) B>C (<5%)
Finished goods	26	21	20	27	n.s.
Strategic positioning (%)					
ETO	21	13	19	12	n.s.
MTO	43	41	39	41	A>D (5%)
ATO	17	18	24	27	n.s.
MTS	18	28	16	20	n.s.
HR policy					
Multi-skilled workers (%)	36	45	56	44	A<C (5%) C>D (10%)
Job rotation (scale 1-5)	2,83	3,00	3,15	3,12	n.s.
Automation					
Production automation	2,66	3,14	2,67	2,60	n.s.
Design and engineering	2,95	3,31	3,36	3,23	n.s.
ERP					
Material Management	3,57	3,44	4,05	4,01	n.s.
Production planning and control	3,10	3,56	3,59	3,87	A<D (5%)
Purchasing and Supply Chain Management	3,33	3,19	3,95	3,85	A<C (5%) A<D (10%) B<C (5%) B<D (10%)
Financial performance					
Return on investment	6,73	15,00	6,73	17,82	n.s.
Return on sales	7,32	12,06	5,94	10,55	C<D (5%)

FIGURE 2

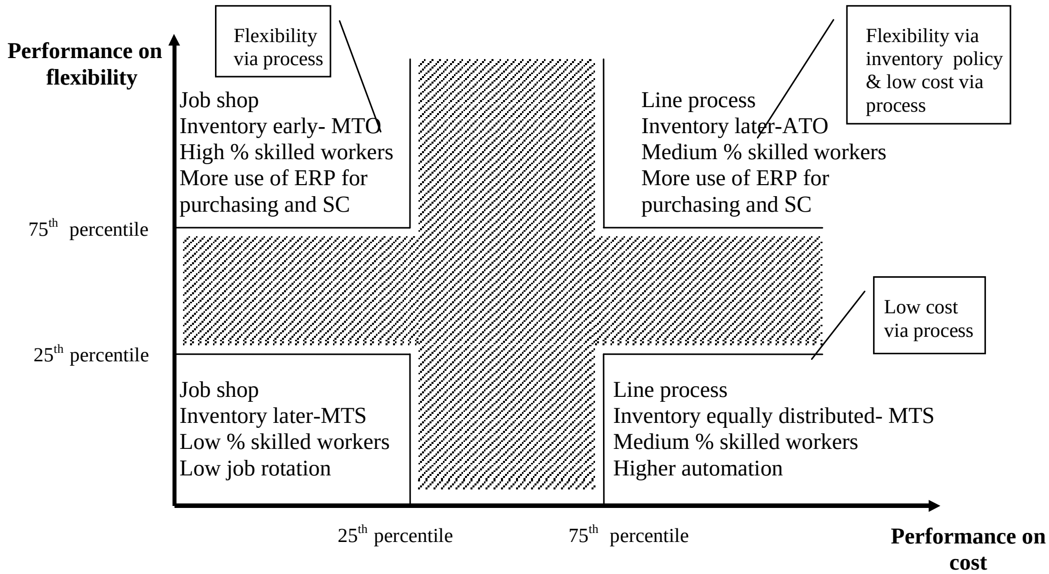

Figure 2: Summary of results

TABLE 5

Example of rules to classify according to process type

Case	*% One of kind*	**% Batches**	*% Mass production*	*% Classification*
Case 1	5	10	85	Line process
Case 2	85	5	10	Job shop
Case 3	40	60	0	Small Batch
Case 4	15	30	55	Not classified
Case 5	10	50	40	Large Batch