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Classification of micro, small and medium enterprises (M-SME) based on their available levels of knowledge

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ABSTRACT

This paper proposes a novel and practical method of classifying micro, small and medium enterprises (M-SME) based on their available levels of knowledge. This classification considers that the specific problems that dominate a company's operations are related to the level of knowledge available. Therefore, identifying the dominant problem groups facing the company can enable an estimate of the level of knowledge available in the enterprise.

Data from 2698 Mexican M-SMEs are used to identify operational problems. The main problem groups are obtained through a cluster analysis. The proposed classification consists of three levels of knowledge based on the interpretation of the dominant problem groups in each enterprise. Each of the 2698 Mexican M-SME are classified by a discriminant analysis.

Nearly half of the M-SME are classified as having a lower level of available knowledge, and only 10% are classified with the highest level. No difference is observed between the size of the company and the level of available knowledge. This means that growth in the number of employees and sales of M-SMEs is not necessarily accompanied by an accumulation of knowledge that companies can use to improve their operations.

1. Introduction

1.1. Enterprise classification

Increasing interest in the classification of micro, small and medium enterprises (M-SME) has led to a variety of investigations aiming to identify a typology of the behavior and the development capacities of these companies (Andersen, 2012). These M-SME classification proposals contain quantitative and qualitative enterprise features with a variety of different focuses.

Current quantitative M-SME classifications are based on the objective measurement of enterprise characteristics. This type of classification is frequently used in the public sector and in the operation of programs focused on M-SME fortification. The most common quantitative measure used for M-SME classification is the size of the enterprise, which is calculated either through its number of employees and/or its annual sales. For example, the *Fondo PYME*, one of the most important programs aimed at supporting M-SME development in Mexico, establishes differences in the amount of support according to the size of companies (Fondo PYME, 2012).

On the other hand, qualitative classifications attempt to determine the development capabilities of the M-SMEs, (Greiner, 1972; Miles et al., 1978; Braglia and Petroni, 2000; De Jong and Marsili, 2006; Macpherson and Holt, 2007; Laforet, 2009; Li and Tsai, 2009). These types of M-SME classifications emerged from the idea that quantitative characteristics only account for a portion of the reality of the enterprise, and that qualitative characteristics of M-SMEs can better explain the development of the enterprise.

These differences in focus embody conceptual differences as well. For example, Davidsson et al. (2005) indicated that the *growth* concept has two connotations. One of these meanings corresponds to the traditional M-SME focus on quantitative classification, which is associated with the enterprise's capacity to collect tangible resources such as the number of employees or the amount of sales. Whereas, the second connotation of the *growth* concept is related to qualitative characteristics and corresponds to the fortification of the capacities and abilities of the organizations. That is to say, the quantitative characteristics of M-SMEs such as the number of employees and the volume of sales do not represent

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the company's development capacity and ability; rather, they represent a portion of their effects. Thus, it is pertinent to analyze which characteristics better explain their development and are based on their capacities and abilities (Davidsson et al., 2005).

The M-SME classification proposed by Miles et al. (1978) based on qualitative factors has been widely used. This classification is based on the way in which enterprises approach and solve three groups of fundamental problems:

- Entrepreneurial problem. How to define the organizational domain: a specific good or service and a target market or market segment.
- Engineering problem. How to create a system that operationalizes management's solutions to the entrepreneurial problem.
- Administration problem. How to rationalize and stabilize the parts of the company involved in its activities and achieve its evolution.

Because M-SME typologies based on qualitative characteristics often lack measurable properties that allow for the classification of every company, several authors have attempted to put the ideas of Miles et al. (1978) into practice (McCann et al., 2001; O'Regan and Ghobadian, 2005; Kabanoff and Brown, 2008).

Other efforts have been made to classify enterprises based on the level of knowledge of enterprises (Bohn, 1994; Albino et al., 2001; Revilla et al., 2005; Wiratmadja et al., 2013). The level of knowledge available in enterprises is closely related to development capacity (McEvily and Chakravarthy, 2002; Galbreath, 2005; Wiklund and Shepherd, 2003).

Therefore, classifications based on the knowledge available in companies did respond more accurately to the identification of capacities and abilities available in a company to sustain its development, as referred to by Davidsson et al. (2005). The next section discusses this type of enterprise classification based on its available level of knowledge.

1.2. Classification of enterprises based on knowledge

The first enterprise classifications based on the level of available knowledge were developed in the mid 1990s by Bohn (1994). This author proposes *"a framework for measuring and understanding one particular type of knowledge: technological knowledge, i.e., knowledge about how to produce goods and services* (p. 61). He defines technological knowledge as *understanding the effects of the inputs variables on the output. Mathematically, the process output, Y, is an unknown function f of the inputs, x: Y=f (x). Then, technological knowledge is knowledge about the arguments and behavior of the function f(x)"* (p. 62).

Bohn (1994) identified eight stages based on the available level of technological knowledge to produce goods or services (Table 1). Enterprises in stage one had rudimentary knowledge related to the production of goods and/or services; on the other hand, enterprises in phase eight achieved complete knowledge of and dominion over the production processes. Companies moved upward from one stage to the next based on their technological learning and their accumulation of knowledge. Analyzing the available level of technological knowledge could be equivalent to solving the engineering problem *sensu* Miles et al. (1978).

Bohn's classification was supported by contemporary ideas that considered the creation of knowledge in an organization as an ascendant spiral. An enterprise accedes to a higher level of development by using available knowledge to solve its problems. At the next level of development, the enterprise acquires more knowledge that allows it to identify new and more sophisticated problems (Nonaka et al., 2000). The solutions to these new problems promote the organization's further learning and accumulation of knowledge. Creation of knowledge in an enterprise represents a fundamental source of its development. Nonaka (1994) defined innovation as the utilization of available knowledge to identify and solve the company's problems.

Table 1
The eight stages of knowledge proposed by Bohn.Source: Bohn (1994).

Stage	Name	Comment	Typical form of knowledge
8	Complete knowledge	Nirvana	
7	Know why	Science	Scientific formulas and algorithms
6	Process characterization	Tradeoffs to reduce costs	Empirical equations (numerical)
5	Process capability	Local recipe	Hardware and operating manual
4	Control of mean	Scientific method feasible	Written and embodied
3	Measure	Pretechnological	Written
2	Awareness	Pure art	Tacit
1	Complete ignorance		Nowhere

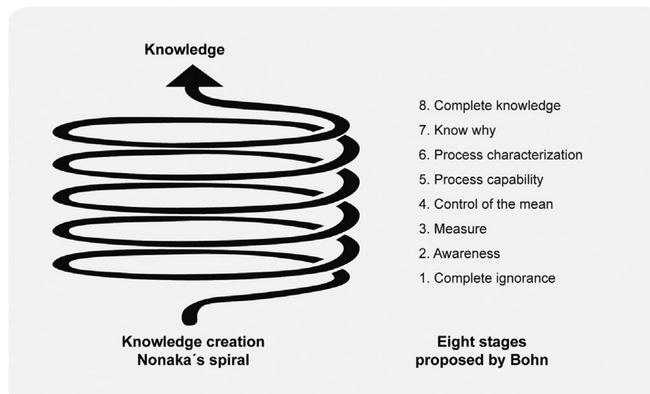

Fig. 1. Nonaka spiral knowledge creation concept and the eight stages of available knowledge proposed by Bohn. *Source:* adapted from Nonaka et al. (2000) and Bohn (1994).

Fig. 1 summarizes both Nonaka's and Bohn's ideas by showing an ascendant and accumulative knowledge spiral that matches the eight knowledge levels.

At each turn of the spiral, an enterprise identifies the most relevant problems related to its operations and identifies solutions. When the relevant problems are solved, the company reaches the next available level of technological knowledge. At this new level of knowledge, the most relevant problems related to the company's operations will be more complex, and by solving them, the enterprise will advance to the next level of technological knowledge.

The enterprise learns and accumulates knowledge during the period of time it resides at each level; therefore, the organization can identify new relevant problems that can be solved because of the knowledge acquired in the previous stages.

In a similar concept of knowledge creation, Albino et al. (2001) uses the Bohn (1994) knowledge definition to propose a classification of the type of knowledge utilized by enterprises. According to Albino et al. (2001), knowledge is an ability function characterized by the type of information used and the way of processing such information.

Albino et al. (2001) propose a metric based on the way in which the enterprises acquire and process information related to productive activities and the opportunities to improve those activities. That is to say, the metric expresses the characteristics of

Table 2
Five types of knowledge available in enterprises according to information utilized and processing characteristics.Source: adapted from Albino et al. (2001).

Knowledge type	Basic information type	Processing type
Scientific	Accurately measurable	Scientific
Quantitative	Accurately measurable	Quantitative
Qualitative	Almost accurately measurable	Qualitative
Tacit	Not accurately measurable	Experience-based
Intuitive	Partially known	Intuitive

information and processing utilized by enterprises to identify and solve their problems.

This metric consists of five types of knowledge based on the basic information utilized and the way in which this information is processed by enterprises to create new knowledge. Table 2 shows the five types of knowledge proposed by Albino et al. (2001).

According to Albino et al. (2001), enterprises evolve in their ability to transform information into new knowledge. Nonaka (1994) states that evolution in knowledge helps the company identify increasingly complex problems and solve them. Then, enterprises have access to a higher level of expertise which will be used to identify new problems.

Fig. 2 expresses the way that Bohn (1994) and Albino et al. (2001) represent the existing knowledge in a company. If this knowledge is used to identify production problems, the output will be the production problems identified in accordance with the company's level of knowledge, as suggested by Nonaka (1994).

As O´Regan and Ghobadian (2005) attempted to put into practice the ideas of Miles et al. (1978), Albino et al. (2001) attempted to put into practice the ideas of Bohn (1994) and Nonaka et al. (2000) related to enterprise classification based on the level of available knowledge. Nevertheless, Albino et al. (2001) propose a theoretical framework based on parameters, not a practical method, which allows for the consistent identification of a set of enterprises at different proposed knowledge levels.

The ideas of Bohn (1994) and Nonaka et al. (2000) are important theoretical bases to analyze the development of the M-SME based on the accumulation of knowledge. However, the difficulty in assessing the knowledge accumulated in a company has hindered the empirical verification of these theoretical bases.

This paper describes a practical and reproducible method to evaluate the level of knowledge available in a company, based on the dominant problems that the enterprise faces. Therefore, the set of production problems identified as dominant in its operations (the output in Fig. 2) could represent its available knowledge level.

The evaluation of the dominant problems prevailing in a group of Mexican M-SME, show different available knowledge levels in the companies analyzed regardless of their size. Therefore, the method presented here constitutes an empirical verification of the theoretical proposals of Bohn (1994) and Nonaka et al. (2000).

The method for classification of M-SME described here is a novel contribution in that it is the first to practically identify the level of knowledge available in a company. This is important because it provides an empirical way of verifying theoretical proposals related to M-SME development based on knowledge creation. Also, the method can be utilized in order to identify knowledge bottlenecks in company groups. Recognizing the level of knowledge that a group of M-SME has available, is relevant for the design of public policies aimed at promoting their competitiveness.

2. Methodology

2.1. Research approach

According to Nonaka (1994), a company utilizes its available knowledge to identify and solve its problems. Therefore, the set of problems identified as dominant in its operations could represent its available knowledge level.

We use the concept of problem group to understand the set of specific problems that may have common causes. The specific problems grouped in a problem group are generally concurrent in the enterprise.

The dominant problem group is considered to be the one that presents the greatest number of specific problems for a particular company. In this manner, a company that has a high level of knowledge will exhibit a dominant problem group that is different from the corresponding problem group of another company that has a low level of knowledge. The first company would have already solved the specific problems faced by the company with a smaller body of available knowledge.

For this reason, we claim that the available knowledge level of a company is directly related to its operational problems, which are most often related to the production process. Therefore, the more frequently that specific problems can be identified, the easier it will be to infer the available knowledge level in the company.

In Mexico, a survey was conducted using an intervention technique called Reengineering Process Workshop (RPW) for 2698 M-SME to collect relevant information. This workshop identified specific problems related to production through the active participation of all parties involved in the production process: employees, supervisors, and the company owner.

A database was constructed with collected information including the company description and the identified operational problems. Based on the information in the RPW database, statistical analysis was performed to identify the problem groups and to classify companies based on their dominant problem groups.

A cluster analysis was applied to the data. This analysis was based on the degree of co-occurrence of specific problems. For instance, if specific problem i appeared in enterprises that also identified specific problem j, the co-occurrence level between *specific problems* i and j was considered to be higher. On the other hand, if specific problem i did not appear frequently in enterprises where specific problem j was identified, then the level of co-occurrence between specific problem i and specific problem j was considered to be lower.

If the co-occurrence was higher, then the distance between specific problems i and j was considered to be lower, and vice versa. Based on this consideration, a cluster analysis was carried out. The results indicated the existence of three problem groups containing specific problems:

– Problems group *I*: technical operation and process dominion problems
– Problem group *II*: integrated production management and planning dominion problems
– Problem group *III*: integrated maintenance facilities, product

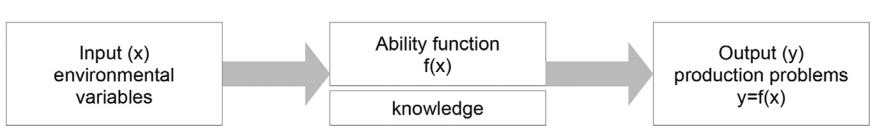

Fig. 2. Systemic representation of knowledge applied to identify production problems. Source: adapted from Bohn (1994), Albino et al. (2001) and Nonaka (1994).

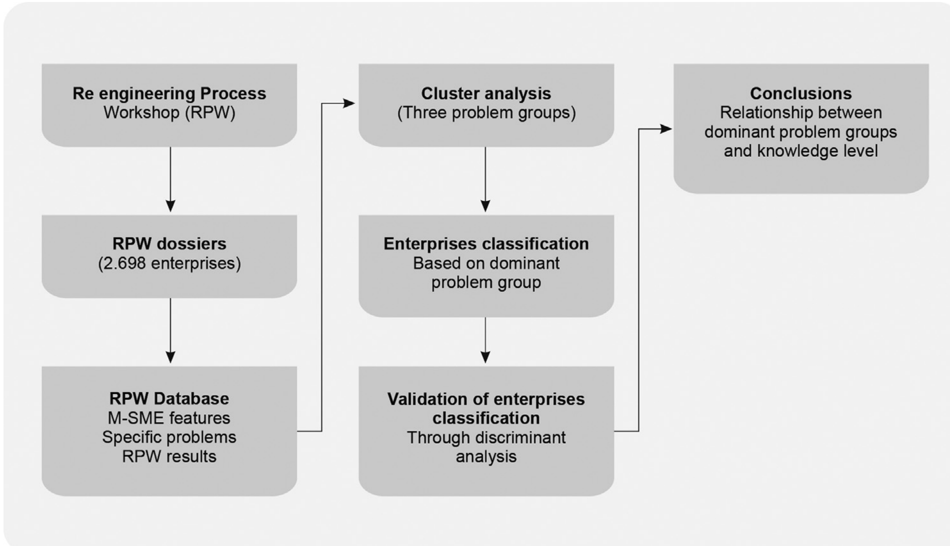

Fig. 3. Overview of the applied methodology.

design, process documentation, customer services, and other problems.

All 2698 surveyed M-SMEs were classified within one of the three problem groups. For example, enterprises in which the dominant problem group was related to technical operation and the process domain were considered as *type I* enterprises. Enterprises where the majority of their specific problems were associated with production management and planning were classified as *type II* enterprises. Finally, the enterprises in which the dominant specific problems were related to maintenance facilities, product design, process documentation, and/or customer services were classified as *type III* enterprises.

A discriminant analysis was carried out and compared with the cluster analysis. The results of this analysis showed a high level of correspondence with the previous enterprise classification: 93.8% of the firms classified were positioned at the same type by both the cluster and the discriminant analyses.

Fig. 3 shows an overview of the methodology applied in this paper.

2.2. Data source: RPW database

Reengineering Process Workshop (RPW) interventions have been used in Mexico since 1998 to improve companies' production processes. This method is implemented by the National Committee of Productivity and Technological Innovation (COMPITE, 2012) and proceeds as described below.

- The workshops are coordinated by a consultant over four days and are applied to a production line, or if the organization is micro or small, to the whole company.
- During the RPW, the production activity on the intervention area was suspended.
- The RPW is carried out in the same company facilities with all the people involved in the production process, including participants, workers, production supervisors and the owner/manager.

During the first day of the RPW, the participants identify and discuss the most important problems in the production process. Participants define the actions required to solve each problem (solving actions). According to the characteristics of each solving action, the participants decide which should be applied during the workshop.

The productivity of the analyzed process was measured before and after implementing the solving actions, enabling the participants to confirm the increase in productivity accomplished by the solving actions agreed upon during the RPW. It was found that the RPW achieved significant increases in productivity, with an average increase over 32.0% (IIUNAM, 2007). This result demonstrated the effectiveness of the RPW, as well as the low knowledge level of the Mexican M-SMEs that were surveyed.

The consultant documents the problems that are identified and discussed. The results of each RPW is captured in a dossier elaborated by the consultant and validated by the enterprise representative (owner or manager).

The RPW was applied between 1998 and 2006 to 2698 Mexican M-SMEs, all of them were manufacturing companies related to different sectors: clothing and footwear products (27.3%), food products (17.9%), machinery and equipment (16.1%), wood products (14.9%), chemical and allied products (6.7%), printing and paper products (5.4%), and others (11.7%). There are companies from the 32 Mexican states.

Every Mexican M-SME can have access to RPW with a subsidized price by the Mexican Government. Therefore, the 2698M-SMEs are representative of those companies interested in improving productivity through intervention processes, such as RPW. Table 3 shows the distribution of the 2698 M-SMEs according to number of employees.

The data contained in the RPW database were grouped in three sections:

- Enterprise features: location, industrial sector, number of employees.
- Production problems identified by the participants.

Table 3
Distribution of M-SME analyzed according to number of employees.

Enterprise size	Number of employees	Number of enterprises	Percentage (%)
Micro	1–10	572	21.2
Small	11–50	1623	60.2
Medium	51–250	503	18.6
	TOTAL	2698	100.0

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Table 4
Problem areas and specific problem categories.

Problem area	Specific problem categories
Staff	1. Lack of training
	2. Lack of personnel commitment
	3. No security procedures
	4. High staff turnover
	5. Unwilling to work collaboratively
Process	6. Unbalanced production line
	7. Lack of production planning and control
	8. Deficient quality control
	9. Deficient layout
	10. Frequent extra labor time
	11. Inadequate process techniques
Equipment and tools	12. Irregular availability of equipment and tools
	13. Lack of control of equipment and tools
	14. Unsafe use of tools
	15. Inadequate tools and equipment
	16. Equipment and tool maintenance problems
	17. Inefficient use of equipment and tools
	18. Obsolete equipment and tools
Administration	19. Deficient assignment of jobs and responsibilities
	20. Lack of internal policies
	21. Lack of administrative controls
	22. Inefficient production forecasting
	23. Lack of goals in the short and medium term
	24. Deficient/insufficient process documentation
	25. Inefficient costumer services
	26. Insufficient personnel
Workplace	27. Ergonomics problems
	28. Occupational health and safety problems
	29. Inappropriate work areas
	30. Lack of facilities maintenance
Materials	31. Poor management of orders and deliveries
	32. Inadequate material handling
	33. Inadequate materials utilization
	34. Inappropriate materials
Product	35. Insufficient or inefficient product design
	36. Lack of product specifications

– RPW results: change in productivity and RPW evaluations by each participant.

To capture the production problems in the database, a list of 36 specific problem categories were developed as is shown in Table 4.

Each problem reported was classified within one of the 36 specific problem categories as shown in Fig. 4.

The interpretation process was performed in two steps. First, each documented problem was located in one of the following problem areas: staff, process, equipment and tools, administration, workplace, materials and products. Second, the documented problem was classified within one of the 36 specific problem categories (Table 4).

Table 5 provides four examples of the process of categorization of the problems documented in the RPW dossiers to build the RPW database.

Table 5
Illustration of the interpretation of the problems documented in the RPW dossiers.

Documented problem	Problem area interpretation	Specific problem category interpretation
Lack of communication between operators	Staff	Unwilling to work collaboratively
Balance with calibration error	Equipment and tools	Equipment and tool maintenance problems
Dirty baths with a bad scent	Work place	Occupational health and safety problems
Tasks obstructed by drilling process due to materials delay	Materials	Poor management of orders and deliveries

Each documented problem was associated with only one problem area and only one specific problem category. On average, 10.9 problems were identified in each RPW dossiers; therefore, the RPW database contains approximately 29,400 specific problems.

3. Enterprise classification through the dominant problem group

The high prevalence of concurrent specific problems found in the survey supports the hypothesis that there are groups of specific problems that are driven by the same cause. This cluster of specific problems can represent the dominant problem group of the enterprise.

3.1. Specific problem cluster identification

Problem groups based on the concurrence of specific problems were identified by recording the number of companies that reported any two problems (i, j). A contingency table was elaborated for any two problems (i, j) (Table 6).

Based on the concurrence of specific problems, we calculated the Pearson's correlation coefficient (φ) of each pair of specific problems i, j (Manly, 2005).

A 36×36 co-occurrence matrix was constructed based on the calculated Pearson's correlation coefficients for each specific problem combination. A cluster of the specific problems was built by conducting a cluster analysis over the co-occurrence matrix.

The cluster analysis technique allowed for different individuals (specific problems) to be grouped based on set distances between problems (Jajuga et al., 2002). The distance between specific problems was represented by the Pearson's correlation coefficient. The cluster analysis was used to develop a dendogram (Fig. 5) in the SPSS (Statistical Package for Social Science) software (Landau and Everitt, 2004).

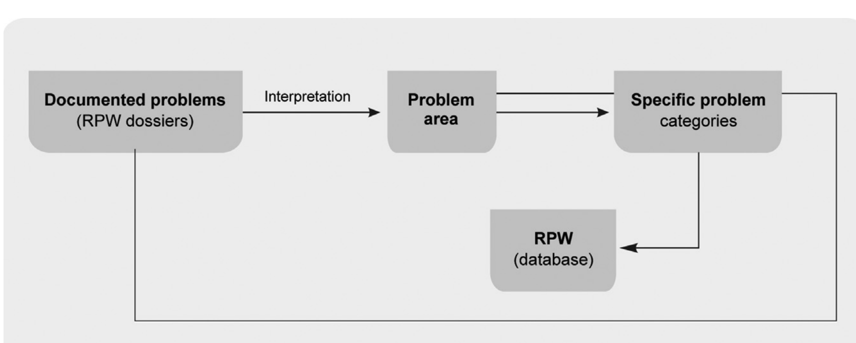

Fig. 4. Procedure used to interpret each reported problem into a RPW database.

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Table 6
Co-occurrence representation of specific problems (*i*, *j*).

		Specific problem *j*	
		0	1
Specific problem *i*	0	*A*	*B*
	1	*C*	*D*

0, No specific problem reported.
1, Specific problem reported.
A number of companies without reports of the specific *i*, *j* problems.
D number of companies with both specific *i*, *j* problems (co-occurrence).
B and ***C*** number of companies with the *i* or *j* specific problem, respectively.
A+***B***+***C***+***D*** is equal to the total number of companies in the RPW database (2698 enterprises).

We decided to set the distance to 5 on the *rescaled distance cluster combination* axis, which allows for the identification of different clusters (Fig. 5). This distance led to the identification of five clusters of specific problems based on their co-occurrence (Table 7).

The specific problems in each cluster may indicate different levels of knowledge available in the enterprises. Each *cluster* was interpreted based on the knowledge level of the organization.

Cluster 1. Problems associated with designing and planning the production process. The majority of specific problems identified in this cluster were related to design and production planning. The RPW participants were able to identify specific problems associated with production design (deficient layout, unbalanced production line, inadequate process techniques, deficient quality control), and production planning (lack of production planning and control).

Cluster 2. Problems associated with the implementation of the production process. This cluster exhibited a lack of control over the technical operation of the production process. These companies have not rigorously designed their production processes, using an intuitive approach instead. Organizations closest to pre-industrial workshops typically display these types of specific problems. The problems found in this cluster indicated a lack of the expertise required to improve the production process.

Cluster 3. Problems associated with managing the production

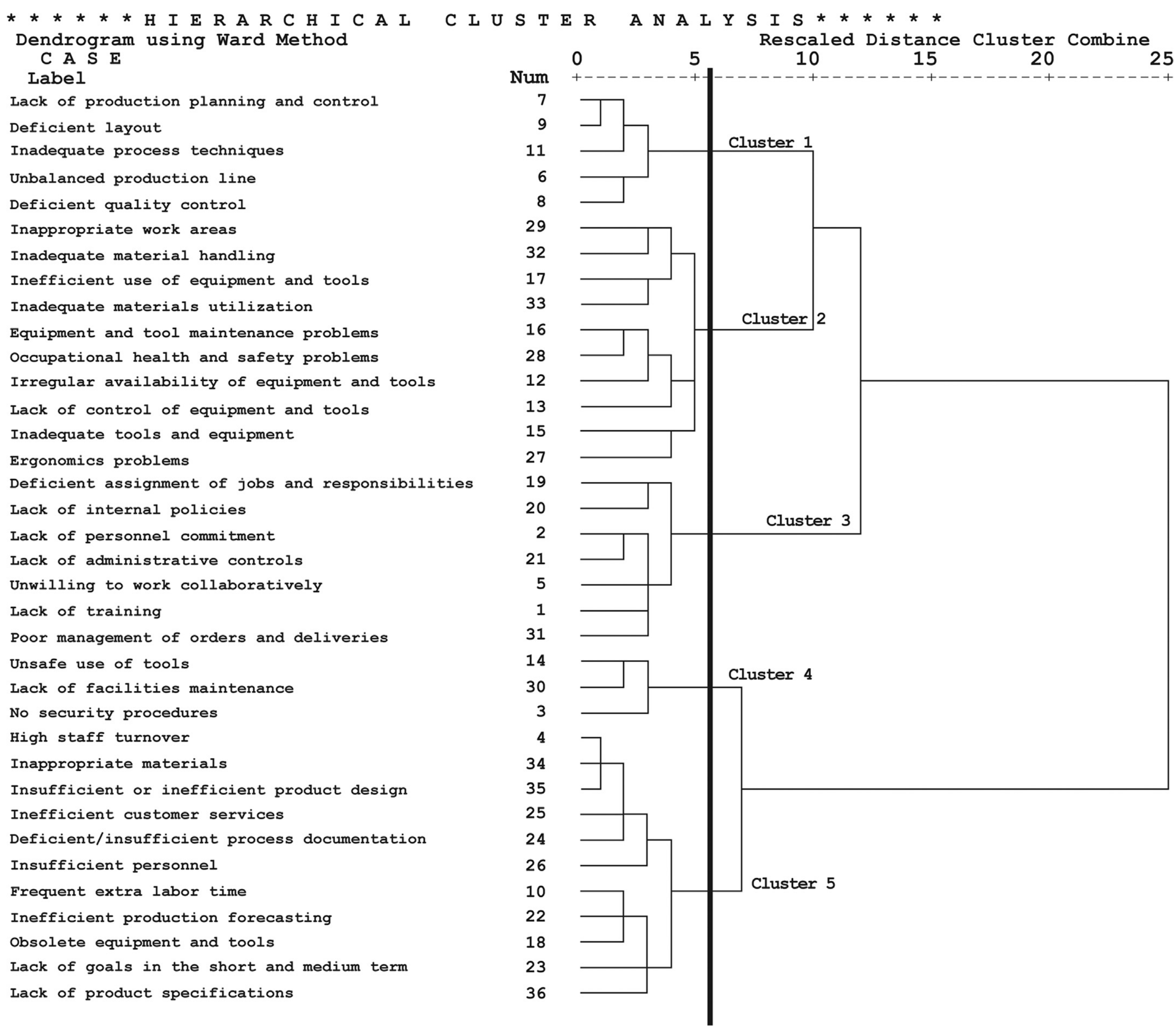

Fig. 5. Dendrogram showing the clustering of specific problems.

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Table 7
The five clusters and their specific problems.

No.	Specific problems		No.	Specific problems	
7	Lack of prod. planning and control	***Cluster 1***	29	Inappropriate work areas	***Cluster 2***
9	Deficient layout		32	Inadequate material handling	
11	Inadequate process techniques		17	Inefficient use of equip. and tools	
6	Unbalanced production line		33	Inadequate materials utilization	
8	Deficient quality control		16	Equip. and tool maintenance problems	
			28	Occupational health and safety probs.	
14	Unsafe tool use	***Cluster 4***	12	Irregular availability of equip. and tools	
30	Lack of facilities maintenance		13	Lack of control of equip. and tools	
3	No security procedures		15	Inadequate tools and equipment	
			27	Ergonomic problems	
4	High staff turnover	***Cluster 5***			
34	Inappropriate materials		19	Deficient assign. jobs and responsib.	***Cluster 3***
35	Insufficient/inefficient prod. design		20	Lack of internal policies	
25	Inefficient customer services		2	Lack of personnel commitment	
24	Deficient/insufficient proc. docum.		21	Lack of administrative controls	
26	Insufficient personnel		5	Unwilling to work collaboratively	
10	Frequent extra labor time		1	Lack of training	
22	Inefficient production forecasting		31	Poor manag. of orders and deliveries	
18	Obsolete equipment and tools				
23	Lack of goals in short and medium term				
36	Lack of product specifications				

process. This cluster was primarily comprised of specific problems associated with the administration of the production process. The problems found in this cluster indicated a lack of knowledge related to production management.

Therefore, we determined that the specific problems of *cluster 1* demonstrated a higher level of knowledge than *clusters 2* and *3*. A company must master the technical and administrative execution of the production process (specific problems in *clusters 2* and *3*, respectively) before identifying problems in the design and planning of the production process (specific problems in *cluster 1*).

Cluster 4. Problems related to the safety and maintenance of the production process. This cluster contained the fewest specific problems, but those problems largely correspond to issues of safety and facilities maintenance. These specific problems arise when the production process lacks sufficient safety and maintenance procedures.

Cluster 5. Specific problems in various areas. The specific problems exhibited by *cluster 5* are from an assortment of problem areas: product improvement (product design, product specifications and inappropriate materials), process documentation, customer satisfaction (customer service) and the stability and training of staff (excessive staff turnover, staff insufficiency and extra time labor). This cluster also includes the need to strengthen production planning (production forecasting and goals in the short and medium term).

We believe that problems of *clusters 4* and *5* are identified when the company has solved most of the problems associated with production process implementation and management, and also when it has established production planning and control procedures.

Thus, the problems of *clusters 4* and *5* are related to the interest of achieving improvements in the planning of the production (e.g. production forecasting, as well as short and medium term goals). These problems are also an expression of the concern for ensuring continuity of production (e.g. excessive staff turnover, staff insufficiency and extra time labor, as well as facilities maintenance). They also make visible the need to improve the management system through better documentation or incorporation of procedures (including security procedures). The problems of *clusters 4* and *5* also reveal there is interest in improving the products and the service offered to the customer (e.g. inappropriate materials, product design, product specifications, and customer service).

Therefore, we determined that the specific problems of *clusters 4* and *5* demonstrated a higher level of knowledge than those of *clusters 1, 2* and *3*. A company must master the technical and administrative execution of the production process (specific problems in *clusters 2* and *3*, respectively) and also implement production planning and control (specific problems in *cluster 1*) before identifying specific problems associated to *clusters 4* and *5*.

3.2. Problem group identification

The five clusters can be ranked into the following three different problem groups, each indicating different levels of expertise available in the companies.

The first problem group (*I*) corresponded to *clusters 2* and *3*. All specific problems in *clusters 2* and *3* fit with companies that have not achieved complete mastery of the production process. The specific problems that dominate the operations of these companies are related to the equipment and poor labor administration.

Therefore, the immediate objective of enterprises in this group is to achieve control of the productive procedures carried out day by day. An enterprise where problem group *I* is dominant is an organization with the lowest level of knowledge.

Problem group *II* includes the specific problems found in *cluster 1*. This problem group describes companies with control over the technical implementation and management of the production process and mastery of problems related to the equipment and the administration of work. Therefore, the greatest number of specific problems identified here are related to production planning, such as the need to ensure the best quality products or services, or the balancing of the lines and layout. These specific problems are still related to the production process but denote a dominion and control over the process and the intention to make specific improvements. Then, the immediate objective of the companies whose dominant problems correspond to group *II* consists of maintaining the continuity of production through production average control.

Enterprises in problem group *II* exhibit a higher knowledge level than organizations in which problem group *I* is dominant. These enterprises solved most of the specific problems associated with problem group *I* and then moved on to the specific problems related to problem group *II*.

Problem group *III* includes the specific problems of *clusters 4*

Table 8
Types of problem groups found for the M-SMEs who received an RPW.

Problem group/ enterprise type	Dominant production problems (*y*)	Objective
I	Problems related to technical operation and process dominion	Production procedures control
II	Problems related to management and planning of production	Production average control
III	Problems related to facilities maintenance, product design, process documentation and customer satisfaction	Production variance control and customer satisfaction

and *5*. This problem group *III* can be associated with enterprises who have mastered the technical operation and production and have planned their production and steadily improved their efficiency. Therefore, the specific problems identified in this group are related to the improvement of working conditions (*cluster 4*) and the development of the enterprise (*cluster 5*), based on product improvement (product design and specifications) and better process documentation, as well as the need to improve the forecasts of production, delivery services, control orders and customer service.

Arguably, the immediate objective of the companies located in group *III* is to improve customer satisfaction through variance control in the production process.

When problem group *III* is dominant, it is possible to assume that this enterprise has a superior level of expertise and has solved many of the problems related to problem groups *I* and *II*.

Table 8 shows the dominant production problems (output *y* as is it proposed in Fig. 2) that characterize the three types of enterprises.

3.3. Company classification according to dominant problem groups

All of the 2698 companies present in the RPW database were classified according to groups in Table 7.

For each enterprise in the RPW database, it was possible to identify the dominant problems by grouping the more abundant specific problems together. While enterprises can exhibit specific problems from all three types of problem groups, only the most frequently occurring specific problems determine the dominant problem group.

Thus, we identified the dominant problem group in each enterprise using the average number of specific problems for each problem group. For example, the average number of specific problems in problem group *I* was calculated using the following expression:

$$A_{\mathrm{I}} = \sum \mathrm{SP}_{2,3}/E$$

A_{I}=Average number of specific problems associated with problem group *I*.

$\mathrm{SP}_{2,3}$=Total number of specific problems belonging to *clusters 2* and *3*.

E=Number of enterprises contained in the RPW database (2698).

The A_{I} value was 7. A_{II} and A_{III} were calculated by the following expressions:

$$A_{\mathrm{II}} = \sum \mathrm{SP}_1/E = 4; \quad A_{\mathrm{III}} = \sum \mathrm{SP}_{4,5}/E = 1$$

If a company had more than A_{I} specific problems from *clusters 2* and *3*, their dominant problem group matched *type I*; thus, this enterprise was considered *type I*. Otherwise, the dominant specific problems of this company could correspond to problem group *II* or *III*.

The algorithm used to classify the 2698 enterprises in the RPW database is described in Fig. 6.

Table 9 presents the results obtained by applying the algorithm shown in Fig. 6. This procedure allowed for the classification of 2252 enterprises (83.5%) in one of the three enterprise types, while the remaining 446 companies (residual group) could not be classified based on this algorithm.

Problem group *I* was dominant in almost half of the companies in the database. A quarter of companies were dominated by problem group *II* and nearly 10% by problem group *III*.

The residual group (446 companies) could not be classified through the algorithm shown in Fig. 6 because of the small number of specific problems identified during the RPW. Two hypotheses could explain this result:

- Procedures used in the RPW were not able to identify enough specific problems to qualify companies in any of the three types.
- The number of specific problems in the 446 companies is small

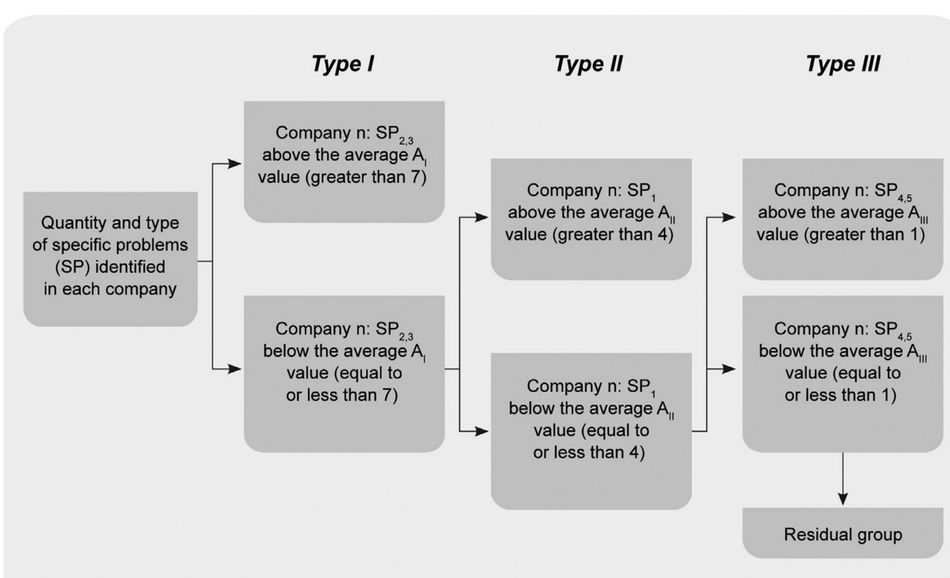

Fig. 6. Algorithm used to classify enterprises according to the dominant problem group.

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Table 9
Classification of enterprises according to their dominant problem group.

Enterprise type	Classified enterprises	Percentage (%)
Type *I*	1278	47.4
Type *II*	700	25.9
Type *III*	274	10.2
Residual group	446	16.5
TOTAL	2698	100.0

because they have a higher level of knowledge than the others. Therefore, the number of specific problems identified through the RPW is lower.

Based on the application of discriminant analysis and on the results that are shown in the next section, the second hypothesis seems to be the more likely.

4. Validation of the M-SME classification

The classification of companies based on their dominant problem was verified using discriminant analysis. According to Hair et al. (1995), this technique allows for the verification of significant multivariate differences between previously constructed groups. This analysis was conducted using the cross validation option.

The discriminant analysis was carried out using a matrix of 2252 rows (companies classified) by 36 columns (specific problems). This matrix contains values of 1 (one) or 0 (zero). In this matrix, the cell i, j has a value of 1 if company i recorded the specific problem j. Otherwise, the value is 0. We added a column with the classification assigned to each company according to the algorithm shown in Fig. 6.

Based on this information, the discriminant analysis generated two discriminant functions that were used to locate each company on a two dimensional space formed by the two functions. The location of each company in this space graphically represented the dispersion or concentration of enterprises according to the previously assigned classification. Fig. 7 graphically presents the discriminant analysis results.

Each small circle in Fig. 7 represents a company. The colors differentiate the firms according to the previously assigned classification.

Fig. 7 shows an appropriate differentiation among *type I*, *II*, and *III* companies in the company space.

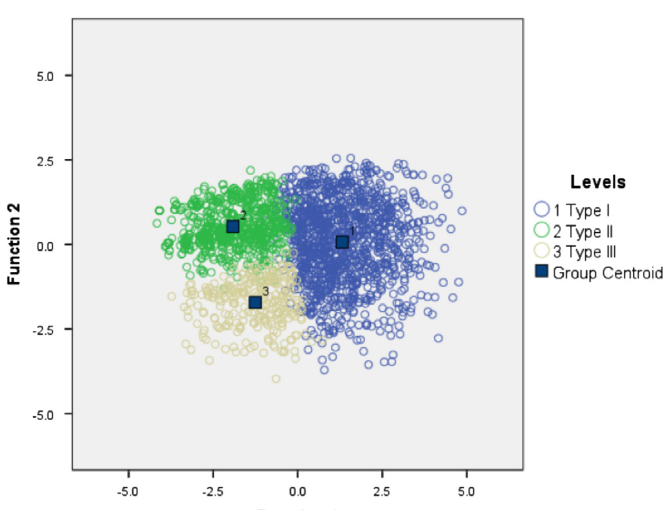

Fig. 7. Discriminant analysis graphical results.

Table 10
Enterprise classification based on discriminant analysis and cluster analysis.

	Company type	Companies classified by cluster analysis			Total
		I	*II*	*III*	
Companies classified by discriminant analysis*	***I***	**1169**	38	71	1278
	II	7	**671**	22	700
	III	1	1	**272**	274
Rate agreement for both classifications	***I***	**91.5%**	3.0%	5.5%	100.0%
	II	1.0%	**95.9%**	3.1%	100.0%
	III	0.4%	0.4%	**99.2%**	100.0%
Companies not classified by cluster analysis (residual group)		**5.6%**	**26.5%**	**67.9%**	100.0%

* The discriminant analysis was conducted with the cross validation option in which each case is classified by the discriminant functions derived from the other cases.

The numerical results of the discriminant analysis also supported the difference between the previous classification and that based on the discriminant functions. In addition, unclassified enterprises based on the algorithm of the previous section (446 organizations) were classified using the obtained discriminant functions (Table 10).

The cluster analysis and discriminant analysis classified 2112 companies on the same level (Table 10), representing 93.8% agreement. *Type I* enterprises had the lowest agreement rate at 91.5%, while *types II* and *III* exhibited greater than 95% agreement between the two methods (cluster and discriminant analysis).

Enterprises that were not classified in the cluster analysis (residual group) were classified in the discriminant analysis. Most of these companies were classified as *type III* enterprises (67.9%) by discriminant analysis. Thus, we expect that this residual group mainly consists of organizations with the highest knowledge level. Therefore, most cases belonging to the residual group may correspond to *type IV* companies with the highest level of available knowledge among the 2698 organizations in the RPW database.

Fig. 8 reports the classifications by the level of available knowledge for different size companies. The three enterprise types with different levels of available knowledge (*types I*, *II* and *III*) are distributed in the same manner regardless of the companies' size.

This even distribution of enterprise types between different size categories suggested that enterprise growth, measured by the number of employees and the amount of annual sales, did not lead to an accumulation of available knowledge. Thus, it is possible for the number of employees and sales to grow without observing a progression based on the accumulation of available knowledge.

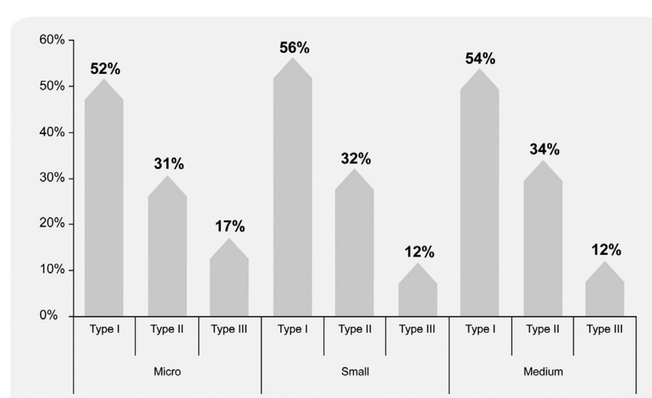

Fig. 8. Classification of enterprises based on knowledge level and size.

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5. Conclusions

This research explored the ideas proposed by Bohn (1994) and Albino et al. (2001) to classify enterprises based on their knowledge level. Both authors proposed a typology of enterprises based on their skill level without establishing a practical way to objectively identify enterprises' knowledge levels. This paper proposes that the knowledge level that exists in an enterprise can be identified through the recognition of the dominant problem groups in the production processes. In the spiral proposed by Nonaka et al. (2000) (Fig. 1), at each level an enterprise identifies its dominant problem groups, solves their most relevant specific problems, and thus reaches a superior level of knowledge. At the next level, the specific problems will correspond to a different dominant problem group. Consequently, the problems that dominate the enterprise's production processes are an expression of the available knowledge level of the organization.

Information obtained from enterprises subjected to the Reengineering Process Workshop (RPW) were statistically analyzed in two ways. The results confirmed that it was possible to identify the available knowledge level in an M-SME by recognizing the dominant problem groups. This paper identified three types of enterprises according to their available knowledge levels. These three types were identified as *I*, *II* and *III* and could correspond to the first knowledge levels described by both Albino et al. (2001) and Bohn (1994).

Type I enterprises typically had problems associated with their technical operations and with the management and ownership of the process (problem group *I*).

In these companies the use of available knowledge aims to control their production procedures. These enterprises probably present characteristics very similar to those of the companies with less knowledge available according to typologies proposed by Albino et al. (2001) and Bohn (1994).

Type II enterprises had a dominant problem groups generally associated with design and production planning. An enterprise must achieve mastery and control of the production process prior to focusing on production planning. Therefore, *type II* enterprises included in the RPW database have solved the major problems associated with the control of technical operations and have achieved mastery over the production process.

Thus, the enterprises classified as *type II* use available knowledge in order to achieve control over their production average in terms of the output.

Type III enterprises have a higher knowledge level, suggesting that they have solved most of the specific problems related to the problem groups *I* and *II*. These companies use their available knowledge to control the variance in production and achieve client satisfaction.

More than half of the 2112 enterprises classified by the discriminant analysis fell under *type I* (55.3%), with the lowest knowledge level, while *type II* accounted for only a third of the population of enterprises with 31.8%, and only 12.9% of the enterprises were classified as *type III* (see Table 10).

The enterprises contained in the RPW database are those willing to accept an intervention to improve their performance. This could represent a sampling bias and thus may preclude the extrapolation of these findings to the entire population of Mexican M-SMEs. Nonetheless, our results suggest that a significant percentage of enterprises have very low levels of available knowledge (*type I*).

As seen in Fig. 8, no relationship is observed between company size and the level of available knowledge. The fact that *type I* enterprises were distributed regardless of their size suggested that the growth of enterprises, measured by the number of employees, does not necessarily lead to an accumulation of available knowledge.

We concluded that growth in the number of employees can occur without development based on the accumulation of available knowledge. This conclusion challenges other works that claim that the size of the company establishes its capacity for development (Gilinsky et al., 2001).

These results also indicate a potential bias in programs aimed at improving production companies in Mexico that must be addressed. Current programs are set up according to the size of the company. Our results stressed the need to support production according to the available knowledge of the company rather than only based on the size of the company. The results of this study show that the needs of an M-SME are not necessarily linked to its size but rather to the level of knowledge available.

The last conclusion indicates a need for further research related to *type I* and *type II* companies. Most of the studies related to M-SMEs are based on enterprises with higher levels of knowledge (*type III*). In this regard, Tidd et al. (2005) noted "*the lack of systematic research on the majority of firms that are not particularly innovative*" (p. 126).

This gap is a significant problem, as our results indicate that *type I* and *type II* companies represent more than 87% of the organizations in the RPW database. These companies represent the least developed Mexican organizations, but they also have expressed a commitment to improving their performance through the identification and resolution of their most relevant specific problems.

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