ASSESSING THE DEGREE OF PROMPTNESS OF A SERVICE INDUSTRY TO ADOPT LEAN THINKING

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Abstract:
This paper describes the development and implementation of an index able to assess the degree of promptness of a service industry to carry out procedures towards lean thinking. According to the measurements theory and multivariate statistics, an approach to modelling lean thinking is developed. Starting with a theoretical review of concepts, one is able to devise a model making use of appropriate techniques for assessing manifested variables with questionnaires. The application of the model is expected to lead to a treelike structure representing the phenomenon with unitary prediction coefficients linearly combined. The Crombach´s alpha is employed in testing the reliability of the measurements. Non-linear or circular structures are out of the scope of this paper. The model is then applied to the public transportation industry of the City of Porto Alegre, Brazil, where the degree of promptness to adopt lean thinking in the industry as a whole and in the fifteen member companies has been assessed. The results are discussed and suggestions for pursuing the research are presented.

Key-words: lean thinking measurement, lean thinking in service, categorical data modelling

1. Introduction

The strategy for customer service adopted by successful industries is based on the development of new products and services, as much as on the improvement of the products and services already performed, in a controlled total quality environment. Information provided by clients is the cornerstone of the process of continuous quality improvement.

Companies must also consider its internal management process when looking for improvements. According to Ohno [1], when most of the conventional strategies are followed, a significant part of work is wasted and the entailed loss remains often concealed. It may be useful to have an approach based both in the revolutionary steps of *kaikaku* and the on-going improvement of *kaizen*. Lean thinking is a technique that can mingles these two features.

Understanding lean thinking requires comprehending *muda*, the japanese word that expresses the loss in manufacturing or services not perceived by customers [2]. *Muda* means ineffective use of resources. *Mottanai*, on the other hand, is the japanese word for waste, in the sense related to material negligence or inappropriate handling. Ordinary organizational development efforts is usually focused on *mottanai* instead of *muda*, leading to both physical and emotional overburden and results which are not proportional to efforts allocated.

Life cycle of products and services are now shorter than ever. Competition too is hardener than ever. So companies face now the challenge to to survive in nowadays market, getting more throughput from their deliveries and services, which must now be faster and under more efficient control than ever. To do so, companies have to improve their management systems, sometimes sharing with partners, in order to align policies regarding strategic and tactic levels, like customer satisfaction, costs or information. It other words, companies need to become lean.

The fundaments and techniques of lean manufacturing and lean thinking have been originally devised for the manufacturing industry, but they can and must be extended to the service industry as well. At the beginning of the twentieth century, only three out of ten workers in the USA were employees of the service industry. Nowadays, the service sector employs eight out of ten workers in North America, generating about 74% of their GDP [3].

Due to its huge importance, it has become vital to evaluate the applicability of lean thinking to services, transposing and testing techniques that had succeeded in the manufacture sector.

Attempting to fulfill this claim, researchers from UNISINOS decided to study the application of lean principles in the service industry. So a research focused in a service industry, the public transportation industry, was proposed. The objectives of the research are: (i) to develop and test an index able to assess and label the degree of promptness of a city passengers transport industry and its companies, prior to the introduction of practices based in lean thinking; (ii) to construct a lean performance measurement system; and (iii) to formulate a strategic framework, to support implementing lean thinking either in the industry as a whole and or in single companies.

This paper regards to the first objective.

2. The research focus: city passengers transport industry

The public transportation industry plays an important role in Brazil. After ANTP [4], more than 25 million people depend on public transportation, mainly by bus, addressing the social dimension of the industry in Brazil. Due to structural factors that counter stimulates public transportation in Brazil, the industry is now facing a huge lost of passengers, dropped from 433 million in 1994 to 295 million in 2001.

Behind this framework, and in order to survive and improve profits in the new competition environment, there is a need for management changes. To accomplish it, the industry introduced management models based in Malcolm Baldridge Award and supported by ISO 9000 standards. Lean thinking, otherwise, has not been introduced yet.

As prior qualitative studies and consultant actions turned clear, understanding and accepting the lean underlying concepts are not an easy task for this industry. Prior to compose an useful model, lean principles should, somehow, be adapted to that particular reality. Researchers then concluded that assessing the capacity of the industry and its member companies in understanding lean thinking, evaluating their real degree of promptness, in the sense of their responsivity, would be the initial step to a future specific taylor-made management model. The second step should be the performance measurement system, as stated in the overall research objectives.

The research was led in a brazilian state capital, served by fifteen companies, geographically organized in three cooperative pools. The pools prevent internal destructive competition and promote cooperation in logistics and maintenance, but the cooperation has not yet reached its maximum possible level. Service regulation and quality level control is provided by public regulation staffs and agencies.

3. Lean Thinking

There are too many definitions and descriptions of lean systems and his features. Some have interpreted lean thinking as a collection of tools, such the 5S, JIT, kaizen, or kanban merely put together. Others have described lean thinking as people working harder or smarter in a Total Quality Management system. At a higher level, lean systems give people the skills and a shared way of thinking systematically, in the sense of driving out waste, through the redesign or improving activities, connections and flows [5].

Japan companies experimented more than 50 years of learning and experimentation, creating the lean manufacturing techniques. The Toyota Production System is mainly meant to applied methods to specific activities like engineering, orders, sales, production, exclusive R&D, prices control, leveled off production and cell manufacturing. Lean manufacturing activities are to be controlled by lean manufacturing indicators, classified in six groups: (i) elimination of non-adding-value activities; (ii) continuous development; (iii) working teams; (iv) JIT production and delivery; (v) supplier integration; and (vi) flexible information systems [7].

The lean thinking process must go beyond specific techniques and high-quality philosophical reflections to unify the methods, until now implicit and tacit, in a system [8].

Using principles as a method to organize and align the organization for lean transformation will bring standardized thinking to organization. Lean thinking principles were brought by Womack [6] after the verification that occidental businesses use several inadequate approaches to implement parts of the lean system, without understanding it as a whole. According to Womack [6], lean thinking can be structured in five principles: (i) determine the exact value of a specific product; (ii) identify the value chain; (iii) make the value flow continuously; (iv) let the client pull product value; and (v) seek for perfection. This is a way to offer immediate feedback in efforts about the transformation of waste into value.

[5] suggests a essential point: creating a learning organization at every level and through every activity. According this author, this is the “glue” principle. Reflection on how the organization works, thinks and improves should be a daily activity integrated with the operating activities.

The lean principles have been applied by automotive and non-automotive manufacturers, service and administrative business. Lean construction, for instance, is a project-based production and delivery system, which emphasizes the reliability and the speed in delivering value. It challenges the belief that there is an inevitable trade-off between time, cost and quality [9]. Here, lean theory and its principles and techniques, pioneered in manufacturing, provide the basis for a new form of project management in the construction industry.

The essential starting point of lean thinking is the concept of value. Womack [6] says that only end-users can define value. Value is created by producers and, in the client’s point of view, that’s why producers exist. Deschamps [10] claims that this is a fundamental strategy for competition, generating continuous growth and leading to innovative and radical business restructuring.

Identifying the whole value chain for each specific product is the second step in lean thinking. Value chain analysis always shows three types of actions: (i) stages that certainly add value; (ii) stages that do not add value, but are unavoidable; and (iii) additional stages that do not create value and must be immediately cut.

Jackson [11] emphasizes that the necessary lean organizational mechanism is a continuous fusion of all involved parts to create a value chain as a whole and eliminate any waste. Lean creation requires a new business relation between companies and transparency in all steps of the value flow to guarantee that people behave according to specified principles.

Once the value is precisely determined, the product value chain totally drawn and all the wasting stages eliminated, Womack [6] says the next step is to make the remaining value stages flow. Therefore, it will be necessary to redefine the work of functions, departments and businesses to leverage a value creation approach. Besides, the real necessities of the employees must be taken into consideration to make them really interested in value flow.

The first visual effect is the reduction of the time needed from product conception to its launch, from sales to delivery and the changing of departments into production teams with the shrinking of inventory. When the flow process is introduced, products that used to take years of project development, are made in months, orders that needed days to be processed, are taken in hours and the months requested to process conventional production are reduced to weeks.

According to Womack [6], companies need a lean system flexible enough to produce under any necessary changes in the demand. Companies must also let clients pull the products when necessary. Thus, pull production is considered the fourth step of lean mentality implementation.

Schonberger [12] mentions the importance of concerning ‘non-obvious’ wastes using lean thinking, since a source of losses to the companies is what we call ‘waste automation’. The automation in emission of production orders without stopping the emission of unrequested market orders describes such a practice. The same could happen in the adoption of computerized inventory controls or of bar codes. These actions show the importance of realizing what adds value for clients and assessing how the value flow must maximize resources efficiency.

As long as organizations begin to specify value with precision, to identify the whole value chain, to introduce procedures to increase value flow, and to let their clients pull the companies values, it becomes necessary to aim perfection. An important stimulus for perfection is transparency, because, in a lean system, everybody – partners, suppliers, distributors, clients, employees – can see everything and find out better ways to create value [6].

3.1 Value

A critical analysis of a company's value proposal is necessary, no matter what its market situation is. Six items are suggested by Tucker [13]: (i) evaluate if the company is competing in price or in value; (ii) evaluate how the company is adding value to its customers; (iii) identify what is exclusive in its value proposal; (iv) identify the client; (v) evaluate how clients perceive value; and (vi) identify what the company is committed to do to deliver better value.

Womack [6] emphasizes that producers want to offer novelties without altering their structure. When suppliers and customers decide to rethink value, they normally resort to simple formulas like low cost or prompt delivery and do not realize what is really vital to add value.

Another reason why companies have difficulties to define the 'right value', although many businesses frequently create value, is that each company defines value in the form this fits it best. When different value definitions are aggregated, they probably will not generate good results.

One important task in value specification, after defining value, is determining the target cost based on the volume of resources and on production effort, if all visible waste is eliminated of the process. Lean companies look first to price and characteristics of the products offered by others companies and then seeks how much can be saved by lean methods. After having discarded any unnecessary stages, their question is: how much does the product cost when value starts flowing? This becomes the target cost for development activities and production [6].

According to Womack [6], once the target cost is defined, it becomes the lens to examine each stage of the value chain, like product development and registration of production orders.

3.2 Value Chain

As stated by Womack [6], value chain is the aggregation of all specific actions to take a specific product through three critical tasks in any business: (i) problem solving, from conception to launch; (ii) managing information systems, from order to delivery, respecting a detailed timetable; and (iii) the physical transformation, from raw materials to the product.

Porter's [14] definition of value chain is linked to the way companies do their individual activities, which are a mirror of their history, strategy and the way processes are implemented. He also claims that the value chain of a company fits in a broader chain of activities named value system. The value chain of the suppliers provides inputs to the value chain of the company. Suppliers do not deliver only products, they can affect the performance of a company in different other ways. Moreover, a lot of products are delivered to the value chain of a distribution channel before being purchased. Distribution channels also affect the company's own activities and its customers. Sometimes, the products of a company become a part of their customers' value chain. The basis for differentiation lies on the role of the company and its products in the value chain of its customers, and this is crucial to determine the necessities of that company. Obtaining a sustainable competitive advantage depends not only on understanding the value chain of the company, but also on the way it can adapt to the general value system.

Porter [14] says that the value chain of a company begins with a generic chain, in which each individual activity generating value can be identified with a particular company. The value chain shows the total value of a product and consists of margins and value activities. Value activities are activities that improve the real value of a product, in the clients' point of view, with new physical and technological processes. Margin is defined as the difference between total value and the total cost of making value activities.

3.3 Value Flow

Rother [15] defines value flow as all actions concerning a product, consisting of the production flow, from raw materials to customers, and the project flow, from conception to launch.

Following Rother [15], drawing a value flow is very important, because it helps to realize the development of material and information flow during the whole process. As a result, it helps to identify sources of waste in the value flow. Besides, it can integrate lean techniques as a whole, avoiding partial implementation. Therefore, a value flow diagram is able to explicit the relation between information and material flow, identifying where waste comes from.

Womack [6] considers three steps to apply flow techniques in practice. The first step, after the identification of the whole value chain, focuses on the real object. In other words, we should concentrate on the specific project and product from the beginning to the end of the flow. The second step, which makes the first possible, is to ignore traditional boundaries in tasks, functions, departments and businesses to create a lean company. This stage must eliminate barriers against a continuous flow of products in organizations. The third step is to rethink working practices and specific tools, enhancing performance and reducing rework and waste.

3.4 Pull production – allowing clients to pull value

Pull production means, in simple terms, that an initial process should not produce goods or services without the client's authorization. This rule is not so simple in practice.

Womack [6] points out the necessity of lean production to keep pull production. However, he also emphasizes the importance of lean distribution in this process. The reason is that leveled off production is followed by leveled off sales. In the whole world, retailers' and customers' mentality is stamped by actions like the sales cycle of discounts. It is probably very hard to change the way retailers and customers think about the process of orders and sales, yet this change is fundamental to implement the principles of lean mentality.

Lean production can contribute to the end of the traditional business cycle. Economists agree that half the downsizing in economic activity is due to elimination of inventory. The reverse effect, which accounts for possible oscillations in the business cycle, is the creation of new inventory with the expectancy of higher prices and better sales. Womack [6] says that, unfortunately, this expectation of a greater provisioning in the distribution channel hardly happens.

3.5 Seek for perfection

The seek for perfection can be made by incremental improvements, known as *kaizen*, and by revolutionary improvements, known as *kaikaku*. Womack [6] stresses that, for both methods, it is necessary to envision what perfection is and what kind of waste must be eliminated first. Imai [16] defines *kaizen* as improvement, going beyond the idea of progress in processes. He means by improvement all kinds of personal, social and working enhancement. When applied to work, *kaizen* means continuous improvements for all, from managers to employees.

The importance of incremental improvements is not the amount but the probability of continuity. This means an endless process, whose cyclic nature is summarized by PDCA (Plan, Do, Check, Action), proposed by W.E. Deming. Campos [17] emphasizes the importance of goals for the control indicators at planning time, claiming for the need of a method to achieve these goals.

Crisp improvements (*kaikaku*) state that fast modifications in work procedures are the best way to provide changes. Their impact represents a leap in practice changing (improvements in performance are expected as well). Frequently, they also cover structural modifications in products and technological processes [18]. Womack [6] reinforce the role of transparency in all processes as the cornerstone for searching perfection. This search is an open process that must align people and resources to face improvement challenges. Only then, problem-solving will be made by teams who historically did not talk or respect each other as equals.

3.6 Lean thinking and scientific management in service companies

Davies [19] suggests that process involving services are much less structured, more complicated and less predictable than most manufacturing or based on high technology processes. An important attribute that can distinguish better service organizations is the kind of the interaction between employees and customers. This interaction must be flexible, but strongly focused on techniques of customer relationship management, inasmuch lean thinking begins by identifying how customers perceive value. The concept of lean thinking in Toyota's Production System too has been adapted from manufacturing to technological processes, recognizing the importance of demands from customers. However, after Davis [20], service companies are too much focused on process and should concern more about client interaction. The right balance between customer and process orientation is the key for a perfect interaction with customers.

When concerning about lean principles in the service industry, it is worthy developing a problem solving approach based on scientific management. By scientific management is meant the use, as used in pure science, of scientific methods in the management, in opposition to intuitive management methods, that do not recognize explicit knowledge, relying only on tacit one. Scientific methods in management is found in two forms: (i) inductive methods, which make use of the benchmarking technique as learning approach; and (ii) deductive methods, which, by means of theoretical syllogisms, propose and refine a set of theory and knowledge for each process. For the sake of efficiency, both methods require explicit knowledge, which implies performance measures as the feedback loop for the scientific management process, even if sometimes the decision maker should rely on incomplete or uncertain data.

3.7 Theoretical support: measurement theory, cluster analysis, reliability of measurement

The research employs unidirectional unitary models with a treelike spanning form will be useful. Non-linear or circular models are outside this scope. Non-unitary constraint will be relaxed in the next step for the research. For the sake of the analysis, elements of the measurement theory, cluster analysis and reliability of measurements, provided in [21], [22], [23], [24] will be used.

Measurements theory is a field lying somewhere between mathematics and philosophy of science, which concerns with numerical modelling qualitative, verbal descriptions of preferences and beliefs of individuals. To describe a system under observation, one can require qualitative relations like: for a given sake, object A is more reliable than object B or object A is equivalently worth as object B. To precisely depicts the system, it may be required to represent the qualitative relations in terms of numbers: in other words, to find a mathematical model. In representing the stated relations, numbers A1 and B1 are assigned to A and B. In the former relation, A1 is greater than B1, while in the second A1 equals B1: the relative magnitudes of the numbers state an structure of preferences or beliefs about the objects. Arbitrary choices can be made about numbers A1 and B1, provided that some rational underlying relationship between numbers and qualitative preferences remains, in terms that elementary arithmetical operations regarding preferences can be made. French [24] demonstrates that is possible to represent any consistent qualitative preference relationship by numerical variables.

Objects whose variables have some degree of similarity, sometimes, are to be gathered in individual clusters. Members of a cluster must be very similar to each other and must highly differ from members of others clusters, according to its describing variables. Cluster analysis interest in at least three situations: (i) taxonomical description; the researcher classifies a large quantity of observations according to a typological structure; (ii) data simplification; each case is identified only by the structure of the cluster it belongs to; (iii) identification of relationships between cases not covered by the previous situations and that could influence cluster building. The choice of the variables should focus on the objective of the analysis: the researcher must trim those that do not count on it. Yet cluster analysis should be used only as an exploratory basis, because it does not imply any statistical basis from which inferences could be drawn. Moreover, the solution obtained is not unique and the cases are always divided in groups, even if no suitable differentiation structure is available. Cluster construction requires some measure of similarity between cases, which can be: (i) the similarity between variable profiles, infered from the correlation between cases; or (ii) the Euclidean distance between the values of the variables.

There are two kinds of cluster construction methods. Hierarchical methods derive a new solution from a previous one. On the agglomerative mode, each case under consideration is initially considered a cluster. Then, the clusters that are more similar to each other merge to form a new one, until the desired number of clusters is attained. Since this procedure is hierarchical, each new solution is inserted in the last one. So, it suffices to undo the step described above to return to the previous cluster. The divisive mode begins with a unique cluster containing all observations. Each step of the method splits its most dissimilar subset into a new cluster and this procedure ends when the appropriate number of clusters is reached. Softwares generally employ agglomerative methods. Divisive methods work on the opposite direction, which make them less likely to be used. In light of this, we will focus on the agglomerative mode.

The single-linkage procedure is based on the least distance between cases: the two cases closest to each other are combined, generating the first cluster. On the next step, the case with least distance to an existing cluster merges into it. This process goes on until all cases belong to some cluster or the appropriate number of clusters is attained. The complete-linkage procedure works similarly to this, but has a different inclusion criterion. Instead of choosing least distance, the two cases with the least greatest distances are taken. This helps to avoid one inconvenient of the last procedure, which is the formation of queuelike structures. Another possibility is called average-linkage, which uses the least average distance between clusters as inclusion criterion. This method tends to produce clusters with little internal variation, inasmuch as extreme values are avoided. There is the centroid procedure as well, where the distance between clusters is defined as the distance between the centroids of each cluster. Due to the changes in centroids from one step to the other, this method may lead to some iterativeness. The last agglomerative method is Ward's method. Here, the sum of squares of the distances between the cases contained in each cluster is minimized, which fosters the formation of small-sized clusters comprising the same number of cases [23].

Non-hierarchical methods, or K-means, do not resort to span constructions, but simply allocates cases to clusters in accordance with the number of clusters desired. Therefore, a solution for six clusters is not derived from a previous solution for five or seven clusters, yet is the best solution for six clusters given by some method. Typically, a cluster seed and a region involving the seed must be chosen. There are distinct approaches for picking a seed and specifying the limits of the region involving it: the sequential limit method just chooses a seed and a region, allocates the cases contained in the region to the seed and proceeds picking a new seed and a corresponding region, till all cases are associated to some cluster. The parallel limit method picks several seeds and regions. The cases are then allocated simultaneously to the appropriate seed and the regions are expanded until allocation is complete. The last method is the optimization method, which is similar to the preceding ones, but allows allocated cases to migrate to another cluster. The main problem with non-hierarchical methods lies in seed selection. Even if the seeds are chosen randomly, the solution obtained may change. The researcher must pay attention to the impact of seed selection on the final solution [23].

On table 1, methods for cluster analysis are presented and classified.

Table 1: Classification of the methods for cluster analysis (Source: HAIR et al., 1999)

<table>
<tr><td rowspan="6">Hierarchical methods</td><td rowspan="5">Agglomerative</td><td>Single-linkage</td></tr>
<tr><td>Complete-linkage</td></tr>
<tr><td>Average-linkage</td></tr>
<tr><td>Centroids</td></tr>
<tr><td>Ward's method</td></tr>
<tr><td>Divisive</td><td>agglomerative reverse</td></tr>
<tr><td rowspan="3">Non-hierarchical methods (k-means)</td><td>Sequential limits</td><td rowspan="3"></td></tr>
<tr><td>Parallel limits</td></tr>
<tr><td>Optimization</td></tr>
</table>

In analyzing phenomena related to a prediction model, two kinds of errors can be made: conceptual errors, derived from misinterpretation of latent concepts, and lack of reliability on the measurements. The assessed correlation between variates will be always smaller than the real correlation, unless we can count on perfectly reliable measurements. Consequently, if reliability on measurements rises, the precision of the method is improved.

Conceptual errors arise due to latent constructs required in the model, investigated by questions, which may not represent it trustworthily or the respondents may not succeed in recognizing it. If the magnitude of these errors could be assessed, the reliability of the model could improve. If a set of indicators is unidimensional, that is, each indicator takes part in a single construct, it is possible to test its reliability. By indicator reliability, it is meant the consistency of the representation of a construct through this indicator. Highly reliable indicators representing some constructs are deeply correlated, which implies that all of them represent the same construct. Conversely, errors in measurements appear when the respondents consider that the indicators represent different constructs, which causes the reliability index to drop. A way to assess the reliability of a set of indicators assigned to a construct is the Crombach's alpha test. This test results in a value between 0 and 1, where 0 stands for total lack of reliability and 1 stands for perfect reliability. This test offers a second value, the reliability index when a single indicator is deleted from the model. It turns possible to identify indicators or respondents that reduce the reliability of the assessment and then trim it [23]. Crombach's alpha test relies on the correlation between variables, quantified by the ratio of covariances to variances. The more combined variations of distinct assesses of a phenomenon overshadow single variations; better will be the reliability of the construct. Likewise, reliability is proportional to the number of indicators. Crombach's alpha is obtained by equation 1, where k is the cardinality and cov and var are the covariances and variances of the indicators. [22]:

$$a = \frac{k.\left(\frac{\overline{\text{cov}}}{\overline{\text{var}}}\right)}{1+(k-1).\left(\frac{\overline{\text{cov}}}{\overline{\text{var}}}\right)}$$ **Equation 1**

4. Methodology

It is now proposed the method to build an index to assess the degree of promptness, in the sense of responsivity, of an industry to implement lean thinking.

The procedure is organized in six steps: 1- based on the five principles theory, the term "lean thinking" is divided into unitary coefficient constructs; 2- in brainstorming sessions with teams of experts in each construct, each one is related to indicators, in unidimensional treelike structures; 3- each indicator is assessed by questionnaires and a final index for each respondent is achieved; 4- the reliability of assessment is verified by Crombach's alpha test, which can address questions or respondents to be trimmed; 5- the probability distribution of the set of final index is analyzed; and 6- a case study is conducted to validate the quantitative conclusions.

4.1 Applying the methodology to the focused industry

As already stated, the methodology has been applied to the fifteen passengers transportation companies from a brazilian state capital. The top term has been divided in five constructs [6]: (i) ability to identify what adds value in the customer's point of view; (ii) ability to eliminate losses in the chain of value production; (iii) ability to make the operation predictable; (iv) ability to allow the client to pull the operation; (v) ability to evaluate and improve the results continuously.

Experts in each construct, in brainstorming sessions, with the aid of cognitive maps, assessed the relationships and mental models underlying the perception of the constructs in the industry, assigning to each one six mutually exclusive manifest categorical variables of nominal type, to be assessed by questionnaires. Five possible choices were provided to each question, ranging from "completely negative" to "completely positive", with a neutral option and intermediate gradations. As the theory does not allocate coefficients to the indicators, all coefficients will be, by now, taken unitary. Since each construct is assessed by an specific approach, theory allows representing this model as a treelike structure from Table 2. Discuss of how to connect the principles to the indicators and how to assess relative importance of constructs and indicators with multicriterial decision support techniques is addressed to the next steps of the research.

All the fifteen questionnaires were returned by respondents. Values ranging from 1 (completely negative) to 5 (completely positive) have been assigned to each variable and the data obtained are presented on table 3, whose last two lines include the single results and the rank of respondents. The results can be interpreted as a assessment to the real degree of comprehension of lean thinking by each respondent company, from which can be inferred the responsivity each company would present to an eventual future approach to lean thinking. The Crombach's alpha associated to each construct is recorded on table 3 as well. The values 70% and 50%, (this refers to an exploratory research) stand to be acceptable values in accordance to [24]. The least reliable construct is the fourth one, followed by the third one. The analysis provided by the software SPSS and the alphas, 0.64 and 0.67, which stand just a little below the higher limit value, are presented on table 4. The manifest variables "importance of customer's opinion" and "ability to understand multifunctionality" raised more doubts in respondents.

Step 5 deals with the analysis of the results. For the sake of clarity, it is worth to form clusters. Applying the K-means method, respondents have been sorted in three clusters: weak, medium and strong comprehension. Sums of constructs have been favored since the thirty individual questions did not differentiate the cases clearly enough. The composition of the clusters and the distance from each case to the respective center is presented on table 5.

Finally, step 6 refers to case studying. Its aims to validate or not the conclusions of the survey by matching quantitative results with state of the art of management, and to verify the potential for organizational learning. A technique of qualitative research, the focusing groups, has been employed. The following questions have been investigated in different groups: I) Is the necessity of scientific thinking in management clear for the companies? II) Do companies perceive themselves as elements of a production system? III) Do companies consider focus on work a key necessity? IV) Are companies aware of internal losses? V) Are companies mature enough to implement a lean mentality plan? VI) If they are, how should this program be conducted? Four groups were formed: (A) companies of lowest score in the survey; (B) companies with highest scores in the survey; (C) a benchmark public company from the city but not surveyed; and (D) the owners union. A single company has been chosen in composing groups A and B. Training material written in academic format has been released to companies A and B after the first interview. The interview was repeated, verifying the reactions to formal training. The interviews with C and D verified the state of the art of management in industry.

Table 2: Structure of the object under investigation

Theoretical Term	Construct	Manifest variable
Lean thinking	Value analysis: ability to identify what adds value	Knowledge of customer’s characteristics
		Knowledge of customer’s objectives
		Knowledge of the factors that affect client decision
		Knowledge of the moment client requires service
		Knowledge of the rhythm client requires service
		Knowledge of place client requires service
	Continuous flow: ability to eliminate losses in the chain of value production	Knowledge of the concept of wastes
		Ability to identify wastes
		Ability to classify wastes
		Ability to measure wastes
		Ability to eliminate wastes
		Understanding of the importance of speed
	Balanced flow: ability to make operations predictable	Understanding of the processes accomplished
		Appreciation of process mapping
		Appreciation of the measurement of internal processes
		Appreciation of the measurement of partnership processes
		Disposition to modify processes
		Ability to comprehend multifunctionality
	Pull production: ability to allow the customer to pull the operations	Ability to listen to customer’s opinion
		Appreciation of customer’s opinion
		Importance gave to customer’s opinion
		Ability to take advantage of customer’s opinion
		Disposition to take advantage of customer’s opinion
		Intensity of the interaction with customers
	Continuous improvement: ability to evaluate and improve the results continuously	Understanding of continuous improvement
		Ability to implement continuous improvement
		Ability to focus on continuous improvement
		Ability to control continuous improvement
		Appreciation of continuous improvement
		Intensity of continuous improvement

Table 3: Tabulation of results (Crombach's a computed using SPSS for Windows, v. 8.0.0)

	question	respondent 1	respondent 2	respondent 3	respondent 4	respondent 5	respondent 6	respondent 7	respondent 8	respondent 9	respondent 10	respondent 11	respondent 12	respondent 13	respondent 14	respondent 15	question	ranking	Construct/order	Crombach's α
value specification	1	5	4	4	4	2	4	5	3	3	4	2	4	3	2	2	51	21	343 3	0,86
	2	4	4	4	5	3	4	4	4	3	5	3	5	3	2	3	56	14		
	3	4	4	3	4	4	4	4	4	3	5	4	4	3	2	3	55	17		
	4	5	5	4	5	4	4	4	5	1	5	5	4	4	4	3	62	8		
	5	5	4	4	4	5	5	4	5	1	5	5	4	4	3	2	60	9		
	6	4	4	4	4	5	5	4	4	3	5	3	4	4	3	3	59	10		
flow acceleration	7	4	3	4	3	3	4	3	1	4	4	2	4	3	1	2	45	25	268 5	0,92
	8	4	4	5	2	2	4	4	1	3	4	3	4	3	1	2	46	24		
	9	4	4	4	3	3	4	3	1	3	4	3	3	2	1	2	44	28		
	10	3	4	4	3	3	4	4	1	3	4	3	3	2	1	3	45	25		
	11	5	5	4	5	4	5	4	1	4	4	1	4	1	1	1	49	22		
	12	3	3	3	3	3	2	3	3	3	3	3	3	1	1	2	39	29		
continuous and consistent flow	13	5	5	5	5	5	5	5	4	5	5	3	4	4	5	4	69	1	345 2	0,67
	14	5	4	5	4	5	5	4	1	4	5	1	1	1	5	5	55	17		
	15	5	5	5	5	5	5	5	1	4	5	1	4	4	5	5	64	6		
	16	5	5	5	5	4	5	1	4	1	5	1	4	4	4	5	58	11		
	17	5	5	4	4	4	5	4	4	1	5	4	4	4	5	5	63	7		
	18	2	3	2	2	2	1	3	3	3	3	3	3	2	2	2	36	30		
pull production	19	5	5	4	4	3	5	5	1	4	5	1	5	5	1	5	58	11	379 1	0,64
	20	5	5	4	4	4	5	5	5	4	5	2	5	5	4	5	67	3		
	21	5	4	4	4	5	5	5	4	4	5	5	4	4	4	5	67	3		
	22	5	4	4	4	5	5	4	4	4	5	4	4	5	4	4	65	5		
	23	5	5	5	5	4	5	4	5	4	5	4	4	5	4	5	69	1		
	24	4	4	4	4	2	5	4	3	3	4	4	3	4	3	2	53	19		
quest for perfection	25	5	4	5	4	4	4	5	1	4	4	3	4	3	2	4	56	14	313 4	0,93
	26	5	5	5	5	5	5	4	1	4	5	1	4	1	1	5	56	14		
	27	5	5	5	5	1	5	4	1	4	5	1	4	1	1	5	52	20		
	28	5	5	4	5	4	5	4	1	4	5	1	4	4	1	5	57	13		
	29	5	5	4	1	1	5	4	1	4	4	1	4	4	1	3	47	23		
	30	4	4	3	3	3	4	3	1	3	4	2	3	3	1	4	45	25		
%		87,5	83,3	78,3	73,3	64,2	85,8	74,2	40	56,7	88,3	40,8	70	55	37,5	63,3				
ranking		2	4	5	7	9	3	6	14	11	1	13	8	12	15	10				

Table 4: Reliability test for constructs 3 and 4 (Source: software SPSS for Windows, v. 8.0.0)

```
 R E L I A B I L I T Y   A N A L Y S I S   -   S C A L E   (A L P H A)
              Scale          Scale      Corrected
              Mean          Variance      Item-           Alpha
             if Item        if Item       Total          if Item
Construct 3  Deleted        Deleted    Correlation       Deleted
VAR00001     21,4000         3,6857        ,6241           ,5200
VAR00002     20,8000         7,0286        ,5299           ,5369
VAR00003     20,8000         9,3143        ,1541           ,6544
VAR00004     20,9333         8,4952        ,4688           ,5928
VAR00005     20,6667         8,3810        ,4866           ,5866
VAR00006     21,7333         8,0667        ,2755           ,6287
Reliability Coefficients     Alpha = 0,6392

Construct 4
VAR00001     18,4000        16,6857        ,6746           ,5972
VAR00002     19,3333        10,3810        ,6537           ,5080
VAR00003     18,7333        11,6381        ,7407           ,4777
VAR00004     19,1333        12,6952        ,4942           ,5898
VAR00005     18,8000        16,3143        ,3941           ,6305
VAR00006     20,6000        23,6857       -,5709           ,7901
Reliability Coefficients     Alpha =  0,6683
```

Table 5: Cluster analysis for the observations (Source: software SPSS, v. 8.0.0)

case number	sum	value specification	flow acceleration	continuous flow	pull production	quest for perfection	cluster membership	distance
1	135	27	23	27	29	29	1	3,0
2	130	25	23	27	27	28	1	4,7
3	124	23	24	26	25	26	1	7,6
4	118	26	19	25	25	23	1	8,1
5	107	23	18	25	23	18	2	12,6
6	133	26	23	26	30	28	1	3,9
7	119	25	21	22	27	24	1	8,3
8	78	25	8	17	22	6	3	0,0
9	98	14	20	18	23	23	2	0,0
10	136	29	23	28	29	27	1	0,0
11	79	22	15	13	20	9	3	9,3
12	114	25	21	20	25	23	1	10,8
13	96	21	12	19	28	16	3	13,1
14	75	16	6	26	20	7	3	13,1
15	106	16	12	26	26	26	2	12,2

The analysis has led to conclusions. Companies from group A do not see management as a scientific process, since intuitive methods, based in tacit knowledge, were observed in practice. They neither concern nor identify their business environment, as well as internal wastes or performance measurements, focusing efforts only in the mission. Although companies in group A are not ready to introduce a structured approach, the response to training was good, inasmuch as concepts like scientific thinking and strategy emerged on the second interview. Systemic concepts, wastes and performance measurements again were not concerned. On the other hand, companies in B perceive clearly the management as a scientific process, understanding the need of performance measurements and systemic approaches. Even without explicitly mentioning wastes, group B showed maturity enough to undertake a structured approach, reacting to formal training: the concept of waste arose in the second interview. Both companies prefer inductive learning methods, like benchmarking with other industries.

Interviews C and D have shown that the industry as a whole perceives management as a scientific process, with feedback by performance measurements. Although some difficulties remains in focusing on results and understanding his wastes, the industry is mature enough to introduce a structured approach, so that it does not need to learn only by inductive methods.

5. Discussion

Discussion will be led regarding two perspectives: statistical and managerial issues.

About statistical issues, a difficult arose in constructing table 2: how to guarantee total mutual exclusivity between variables. According to Hogart [25], in a scientific approach, it is hard to find constructs totally mutually exclusive. Saaty [26] also states that in human comprehension of nature there is ever some inconsistency, reflected in some loss of exclusivity in the constructs. So some shadow zone may be found between the assigned variables, provided it do not dominates the overall analysis. Provided this assumptions, the use of categorical variables, the questionnaire and Likert's scale has been satisfactory in representing manifest variables. The Crombach's alpha reliability test identified the constructs with greater and lower reliability and the doubtful meaning questions. The values of 0.64 and 0.67 do not seem to impair the investigation, since they are close to limit values pointed out in [23]. The role of theory was decisive in developing the model, since, without it, expert's knowledge would be required in the constructs level as it was in the variables level. The manifest variables succeeded in discriminating respondents in a range from 37% to 88%. It was not possible to reject the hypothesis that the fifteen values came from a normal distribution with mean of 66.54% and standard deviation of 14.47. The lowest level of significance obtained in the tests was 0.25 (chi square test, source: software Proconf 98). The clusters analysis only succeeded in sorting respondents into strong, medium and low comprehension groups by the constructs, not by questions, which do not impair the analysis, since constructs are the real basis of the theory.

The managerial issues are extracted from the case studies. Company A, from the lowest score group, seems to be more fragile than company B. Groups C and D have shown that the industry is robust enough to support the research undertaken, since they have proved that actions leading to lean thinking are feasible. After suitable stimulus, both companies tried a transition from intuitive to scientific knowledge, but only the strong profile company translated from tacit to explicit knowledge. All the groups referred preferences by experiential methods of learning, refusing deductive methods, although do not refuse academic activities in promoting organizational learning. Some conclusions are stated: (i) a learning approach based in benchmarking practices would have a better acceptance; (ii) the industry can succeed in scientific approaches and explicit knowledge, but only when scientific management is present; and (iii) the industry as a whole is conscious of the required changes, but do not pinpoints clearly neither to what to change nor how to work this change out.

6. Conclusion and suggestions for future works

The research attempted to employ knowledge from the measurements theory, supported by multivariate statistics, in deriving an approach to an specific objective: introducing lean practices in a public passengers industry, without raising strong resistance or wasting excessive effort. This is the first step of a three part research. Next steps are to build a lean performance measure system and an specific approach to transpose the five principles to the variables from Table 2.

Regarding the results, one can conclude that the first objective has been attained. A satisfactory classification and a representative scaling and distribution between respondents have been reached, according to their comprehension of the lean thinking principles. Furthermore, the case study has been conclusive, confirming the former analysis and pinpointing that the industry would succeed in scientific practices for learning, that scientific management is a prior condition to manage the explicit knowledge needed for introducing lean practices and that benchmarking methods of learning are to be more accepted then others in the industry.

As a result, the methodology presented is retained able to assess the degree of promptness, in the sense of its responsivity, of the industry to adopt practices based on lean thinking.

There are threads for the sake of continuity. In further applications, corrections are required in the questions that raised doubts. A formal inclusion of a performance measurements and explicit knowledge discussion in the focused groups is also suggested. Next steps of the overall research include employing multicriterial decision methods, such as AHP, in building a lean performance measurement system to feedback the lean principles, and the use of binary programming, subjected to organizational constraints, concerning to priorities related to influential indicators.

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