

POMS Abstract Acceptance - 015-0348

Abstract title: **Complex Thinking in the Production Management.**

**Authors:**

Rolf Hermann Erdmann

Doctor in Production Engineering at Universidade Federal de Santa Catarina. Centro de Pós Graduação em Administração - CPGA. Centro Sócio- Econômico - CSE. Caixa Postal 476. Campus Universitário da Trindade, s/n. Universidade Federal de Santa Catarina, Florianópolis, SC, Brasil. CEP 88.040-900. Telefone: 55 48 37217082. Email: [erdmann@cse.ufsc.br](mailto:erdmann@cse.ufsc.br)

Darlan José Roman

Master in Business Administration from Universidade Federal de Santa Catarina. Centro de Pós Graduação em Administração - CPGA. NIEPC - sala 220. Centro Sócio- Econômico - CSE. Caixa Postal 476. Campus Universitário da Trindade, s/n. Universidade Federal de Santa Catarina, Florianópolis, SC, Brasil. CEP 88.040-900. Telefone: 55 48 37217082. Email: [darlanroman@yahoo.com.br](mailto:darlanroman@yahoo.com.br)

POMS 21st Annual Conference

Vancouver, Canada

May 7 to May 10, 2010

## **1. Introduction**

Since it is not possible to identify clearly the complexity in the history of business organizations, their fundamentals were certainly present in their development over time. Nowadays, it is a fact the Theory of Complexity takes on an important feature in the organizational environment, both in everyday actions and the strategic direction for future actions.

In the present competition scenario established among organizations, it is no longer possible to differentiate working with the focus "from the inside out." That is, more and more environmental variables (client, environment, economic aspects) appear as key points, often assuming a vital importance to stay in the market.

Companies usually idealize complex projects to improve the product, changing processes and operations, thus believing those changes are exactly what the customer desires. However, they may prove irrelevant in the customer's perception. Similarly, a production technology in disagreement with the environmental legislation could cause a negative impact on the company's budget and image.

Then, there is clearly a complex relation the company system establishes with its subsystems and the environment. Therefore, this article aims at analyzing how the inter-relations in a production system might be empowered and ensure better performance and competitiveness. The relations strengthening is given by factors of competitiveness, which are the link between the parties. In order to understand how to set up relations in a production system and improve the production environment from the complexity perspective, it has been established categories of analysis developed by the NIEPC (Interdisciplinary Nucleus of Studies in Production Management and Costs) from the Federal University of Santa Catarina.

Those categories have been established by the Nucleus, through the model of the Professor Chris Voss from the *London Business School*, on the best practices of Industrial Benchmarking (Hanson, Voss, 1995), in which the lean production, manufacturing systems, simultaneous engineering, total quality and the organization and culture form the base of the main components from the model. Starting from the complex approach, it is believed the strengthening of interrelations among categories may contribute greatly to increase the efficiency of a production system.

The search for competitiveness factors is under development, and it will be presented in this paper the results achieved so far. Once the factors are known, it will be possible to elaborate an organizational analysis tool based on assertions.

## **2. Complexity and Business Organizations**

Within the organizations environment, it is assumed the company is opened to the understanding of new behaviors, organizational models and their continuous adjustments, interacting with systems and its environment. Thus, it is possible to recognize a structure composed of integrated parts: management, people, tasks, and each change in one of them it will affect the other. One of the main organizational challenges is the adaptation to one environment that changes faster than the organizations. That aspect becomes even more critical in companies conducted by the mechanistic paradigm.

At some stage of capitalist development, there was a transformation in the organization concept. That transformation starts from the moment companies have become goals by themselves. As a result, it starts the use of machines as metaphors for workers and the world is molded from mechanistic principles. Therefore, the idea of human association

designed to enable the achievement of predetermined aims is distorted by the requirement of strict schedules, aggressive rationalization, repetitive tasks and severe forms of control.

We live, in the area of administrative and management models, a period of disruption. And the most common way to characterize that disruption has been exploiting the depleted model from Taylor-Ford and the emergence of flexible specialization models, based on concepts of open systems and cybernetics. The idea of complexity and environmental chaos, by imposing internal configurations also unstable and chaotic, has an irresistible appeal to the organizations hit by crisis they seek to decipher in order to survive (WOOD JÚNIOR, 2004, p. 45).

The Paradigm of Complexity is complemented by the Theories of Chaos and Ssystems. The three approaches include a unique way of looking at the complex systems. Although they are not waterproof fields, those approaches have unclear borders and major interfaces, which make up a new set of ideas to the study of systems and organizations (WOOD JUNIOR, 2004).

Conventionally, an organization is defined as a group of people with a common goal. A distinct entity separated from its environment. There is a clear boundary separating it from its environment. "The needs for changes are growing outside the organization. That change is planned, so the organization reacts or gets adapted "(Stacey, 1995, p. 528). The middle is full of possibilities and the organization, in order to remain in operation, establishes mechanisms allowing the selection of the best alternatives. With the example of a tapestry, Edgar Morin explains the complexity in the organizational environment:

Let us take a contemporary tapestry. It holds flax, silk, cotton and wool in various colors. In order to know that tapestry, it would be interesting to know the laws and principles in relation to each one of those thread types. However, the sum of knowledge about each of those threads types components of the tapestry is insufficient to meet that new reality which is the fabric, that is, the qualities and own properties of that texture are unable to help us know its shape and configuration (MORIN, 2007, p. 85).

In that tapestry, the threads are not organized by chance. They are organized according to a script, a synthetic unity where each part contributes to the whole. The tapestry itself is an observable and knowable phenomenon that is driven by the complexity of functions and interactions, and it can not be explained by any simple law (MORIN, 2007).

The constant changing situations have increasingly pushed the organization to incorporate feedback mechanisms, in other words, mechanisms offering adequacy conditions to the system by taking into consideration the environment complexity. Then, it is possible to visualize business organizations like mechanisms that reduce complexity.

It is realized "the complexity of socioeconomic structures and the resulting complexity from the markets in which organizations interact, virtually compel the organizations to adopt a broader view of their structures and management methods" (CARDOSO; SERRALVO, 2009, p. 61) . In more and more turbulent markets, the organizations management should seek integration between the rational (efficiency, productivity, goals) and irrational (human factor).

Agostinho (2003) describes the organizations like Complex Adaptive Systems (CAS), because they exhibit the ability of responding to the pressures without being

prescribed the action of each member by an authority, that is, the system owns the capacity to self-organize . The complex adaptive system, therefore, detects interconnected subsystems that feed back (feedback mechanisms), and the modification in one of them affects the other, besides the external modifications in the environment. The organization should not be considered in separated parts, nor seen as a whole and ignoring the parts (MORIN, 2007).

Complex adaptive systems are organizations in networks formed by countless agents, which are autonomous and active elements, whose behavior is determined by a set of rules and changes regarding their performance and conditions of the immediate environment. Those agents learn and adapt their behavior from the present selection pressures. The system global behavior emerges, then, like an effect of interactions combination (non linear) among several components (AGOSTINHO, 2003, p. 28).

Self-organization "is the process in which components communicate with each other spontaneously and cooperate suddenly in a common, coordinated and concerted behavior" (Stacey, 1995, p. 545-546). In the business world, that means the spontaneous formation of interest groups and coalitions around certain issues, and besides the communication about those problems, there is cooperation, formation of consensus and endeavors for the answer of those problems.

A business organization is part of a market. It produces objects or services, things that become external to it and enter in the consumption world. By producing things and services, the company at the same time, self-produces. That means it

produces all the necessary elements for its own survival and organization. By organizing the production of objects and services, it self-organizes, self-entertains and, if necessary, self-repairs. If things go well, it self-develops when developing its production (MORIN, 2007, p. 86).

The internal complexity of the organization impacts decisively on its performance. That complexity is defined by the interdependence among its constituents. Thus, the behavior of the whole is directly related to the conduct of the parts, the relations between the parts. From those relations follow the ability to the self-organization of adaptative complex systems, making the system flexible, and so, in better conditions to cope with external disturbances.

The adaptative complex systems capability of responding to the environment pressures is due largely to the autonomy of their members. Although that fact, to some extent, is in conflict with the idea that "order" can be built, overall results surprisingly ordered emerge from interactions among autonomous individuals. "Organizations viewed as adaptative complex systems must show the capacity of responding to the pressures without being prescribed by an authority the action of each member, that is, they must be able to self-organize" (AGOSTINHO, 2003, p. 10).

The Complexity Theory is responsible for disseminating the importance of promoting a proper interaction among various parts of an enterprise, "in order to set goals that meet the basic needs of the parts, leverage their efforts and lead to a better achievement of the proposed targets. (CARDOSO; SERRALVO, 2009, p. 61-62). Then, the relations strengthening among various parts of the organization emerge as a key point to be considered when it comes to productivity, competitiveness and profitability.

In response to new questioning provided by organizational events, the administration begins to develop special tools, which do not predict how the future of an organization is going to be, but they outline several options from which managers can develop different action alternatives.

According to Stacey (1995, p. 500), any system "constitutes the environment for other systems, which, in turn, can be one part of its environment." Thus, a change inside a system will provoke disturbances in other systems. Those disturbances occur simply because there is interaction among the systems. Therefore, the environment is not something acquired, but a consequence of the interaction among systems.

### **3. Complexity Theory Contributions to the Production Administration**

The Complexity Theory reinforces the thought that greater interaction among different areas which make up a complex organization, either processes or people, promotes the best results against competitiveness and sudden changes prompted by environmental changes. Since a complex approach also foresees the evolution of interconnected systems, the tendency for the persistence of those relationships will ultimately produce better results.

The interdisciplinary knowledge aims at overcoming the Cartesianism and functionalist view of simplification and dissection, often used like techniques in the scientific universe. In that line, different disciplines are brought together, along with exchanges and cooperation and setting into something organic. The interdisciplinary and multidimensional approaches, which are present in the complex thinking, do not ignore the principle of "separate to know", but considers it insufficient. Partial conclusions are obtained from particular perspectives. In other words, it is not possible to know the whole by studying isolated parts.

In the organizational production system, search for efficiency is constant. Environmental changes obligate the organization to adapt and innovate on products and processes. Production and manufacturing of products that may range from tools and machinery to the recreation or information, that is, from goods to services. "Production management can be defined as the management of direct resources that are needed to obtain products and services from one organization" (DAVIS; AQUILANO; CHASE, 2001, p. 24).

The production function does not exist only in the assembly plant operations, specializing in the production of goods. It is also present in other areas such as hospital-medical care, transportation, food handling and retail sales, which are geared primarily for services delivery (STEVERSON, 2001, p. 4).

The production system consists of subsystems related to each other. Those parts act under a set of rules, so, they act on the inputs by processing something and turning it into outputs, according to the goals. According to Martins, Laugeni (2005, p. 12), "Production systems have the goal of manufacturing goods, production of services or pieces of information provision".

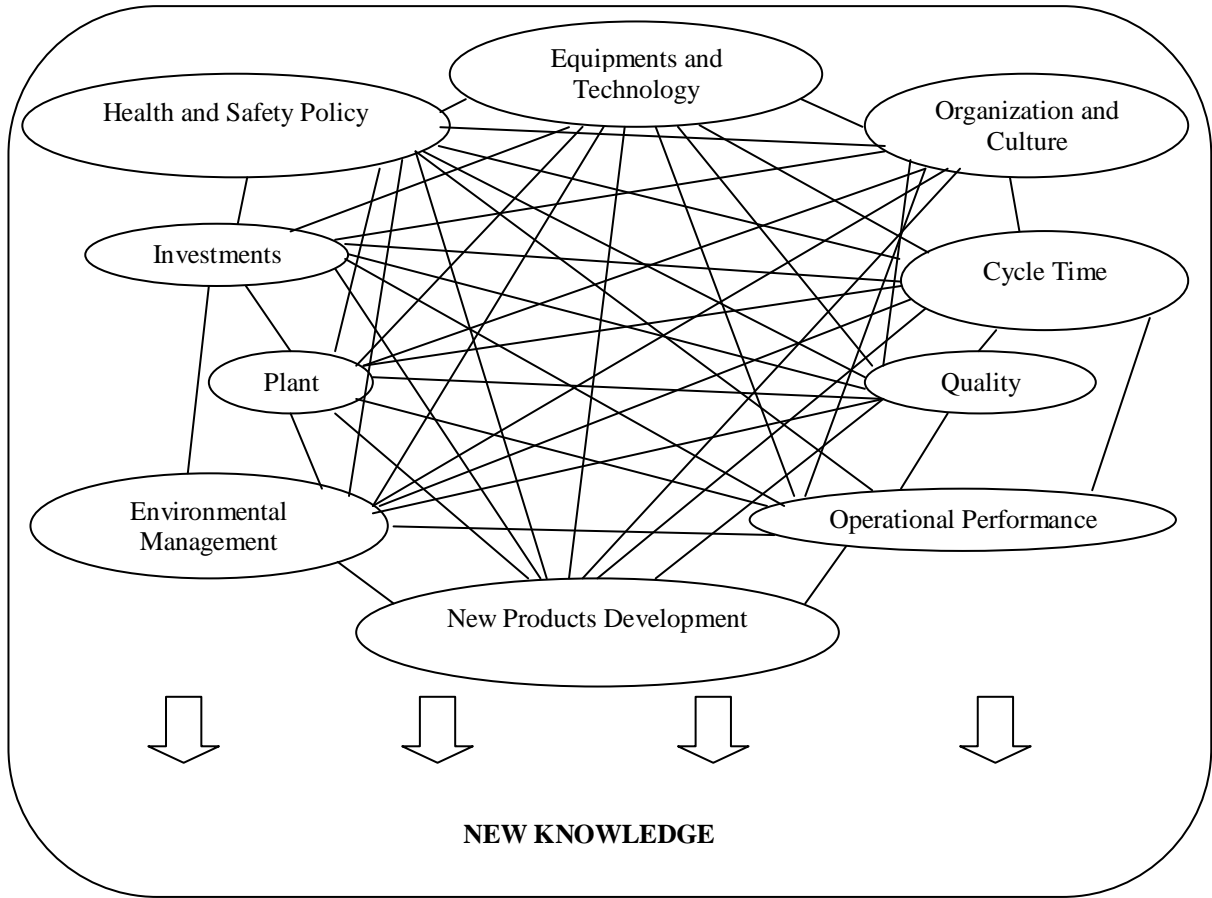
In a production system occur series of inter-relationships that trigger a range of variable processes and operations enabling the elaboration of a product (goods or services). In order to understand how the relationships in a production system are established and better explore the production environment from the perspective of complexity, the NIEPC (Nucleus of Interdisciplinary Studies on Management Production and Costs) of the Federal University of Santa Catarina has developed analyses categories. The created categories are:

Cycle Time, Quality, Plant, Equipments and Technology, Investments, Operational Performance, Environmental Management, Health and Safety Policy, New Products Development, Organization and Culture.

Those categories were established according to the model of Professor Chris Voss from the *London Business School*, about the good practices on Industrial Benchmarking (HANSON, Voss, 1995), in which lean production, manufacturing systems, simultaneous engineering, total quality, organization and culture form the basis of the main components from the model. Starting from the complex approach, it is believed the strengthening of inter-relations among categories can contribute greatly to increase the efficiency of a productive system.

Secondly, it should be considered the interdisciplinarity benefits. The loss of a global vision may result in losses and disastrous consequences. However, the complex reason seeks to establish a broad dialogue among disciplines, considering the strengthening of the "whole" by observing the specific knowledge from the "parts". In the organizational production system, the various categories must "talk" to each other.

Thus, interdisciplinarity will provide the multiplicity approach of processes and knowledge that used to be separated, until then. As a result, the fusion of knowledge from different categories of a production system will result in the configuration of a new knowledge and more capability to deal with problems. In Figure 1, it is possible to see several inter-relations that are present in a production system.



**Figure 1: Inter-relationships that are present in a production system.**

Source: Elaborated by the authors.

The strengthening of relations among the parts making up a production system will contribute to the emergence of interdisciplinary knowledge, in other words, a new knowledge. When the parts get together and discuss a particular issue, it comes up new ideas and suggestions that did not happen before. That is to say, the construction of the whole becomes greater than the sum of each one of the parts.

#### 4. Critical Factors of Competitiveness

The critical factor study is important in order to obtain the appropriate method for products development, using the best practices for costs excellence, quality, deadline and being able to capture consumers needs, so that they can be met through the offered product. The observation of critical factors is essential for the organization getting better performances, thus meeting the requirements of its mission. Chart 1 presents some definitions for critical factors of success:

Authors	Definition of Critical Factors of Success
Hofer & Schendel (1978)	CFS are variables by which management can influence, by its decision and significance, the position of each firm in an industry. Those factors vary greatly from one industry to another, but within a particular industry, they derive from the interaction of two types of variables: economic and technological characteristics of the sector and the competitive tools on which different firms have built their strategies;
Boynton & Zmud (1984)	CFS is the name of the things that must go well to ensure the success of an organization or manager, the competencies that need special and constant attention in order to achieve high <i>performance</i> ;
Leidecker & Bruno (1984)	CFS are characteristics, conditions or variables that, if properly followed, maintained and generated, could have a significant impact on the success of a firm, in a particular sector;
Bouquin (1986)	The so called CFS is all the company has to achieve its long-term goals, resist the forces of the investigated sector (the five forces of Porter's typology), to be competitive in its strategic group and without submitting to the concurrence of other groups. Or, in case of being feasible, preparing the transition to another group.

Koenig (1990)	Constitutive elements of success in a sector, during a period of its history.
Atamer & Calori (1993)	CFC are offer elements with value for the customers (users, distributors, specifiers), knowledge and/or cost advantage that are essential in a conception chain - production - and product distribution (or service), that allows to create a competitive advantage.
Stratégor (1993)	Elements on which is based primarily the competition, corresponding to the concurrences that need to be controlled, in order to get performance.

**Chart 1: Definitions from critical factors of success**

Source: VERSTRAETE, 2000

Following an analytical approach through the identification of critical factors, Agus; Amahd and Muhammad (2009) have analyzed the relations among quality management, productivity and profitability in electronics companies. From that approach, it was possible to infer that profitability and productivity are directly linked to the process of quality measurement and improvement.

Effective strategies from quality management can be one of the most important factors for success in the electronics industry. Then, the quality management has a positive impact on productivity and profitability. Similarly, some factors are strongly linked to the success of quality management implementation: quality control, focus on the employee, relations with the suppliers, benchmarking and training.

However, Agus, Amahd and Muhammad (2009) warn the company must align its quality management with customers needs, because in the end, they will drive the sales and determine profitability.

Following the same analytical focus, Nascimento and Segre (2006) have explored the influence from critical factors in the context of the automotive industry. The approach has described key factors to understand the internal and external flexibility on that sector, in Brazil. External and internal flexibilities are systemic, in other words, they can not be considered in isolation, because they are interdependent. Chart 2 presents an analysis model that integrates specific variables (factors) of external and internal flexibility.

Chart 2 – Internal and External Flexibility Variables in the Brazilian Automotive Industry.

<b>External Flexibility</b>	<b>Internal Flexibility</b>
Context in the work relations	Organization form of production systems
Union action	Labor management forms
Physical conditions for the location of plants	Labor organization forms

Source: Nascimento and Segre, 2006

The factors related to external flexibility, when they integrate with internal flexibility aspects, propose significant terms of flexibility and competitiveness for companies in the automotive sector (NASCIMENTO AND SEGRE, 2006).

The critical factors of competitiveness are not a standard set of measures and sometimes called "key indicators", they can be applied in all divisions of the company. Instead, critical factors are very important areas for a particular division of the company in a given period in time.

QUINTELA et al (2005) associate critical factors of success to temporal factors, which are driven by economic, political and social changes or competitive conditions as a whole. For example:

- Style used to be a critical factor of success in the early 1960 for any company in the automotive industry;

- The direct automakers representatives with customers have always been the car dealers. Not only the initial sale depended heavily on the quality, but also the following contacts via services in a constant relation reinforcement, affecting the future car purchases of the customers;

- In 1976/77, the adequacy to the regulation of energy consumption became a critical factor in the industry, due to government standards imposed for pollution control;

- After the initial impact of the oil crisis in 1973/74, the American consumer was attracted again by large automobiles;

- In 1978, it happened the second oil crisis, leading most of the consumers to consider their cars as efficient means of transportation and not like something that projected, through the style, the personality of the owner;

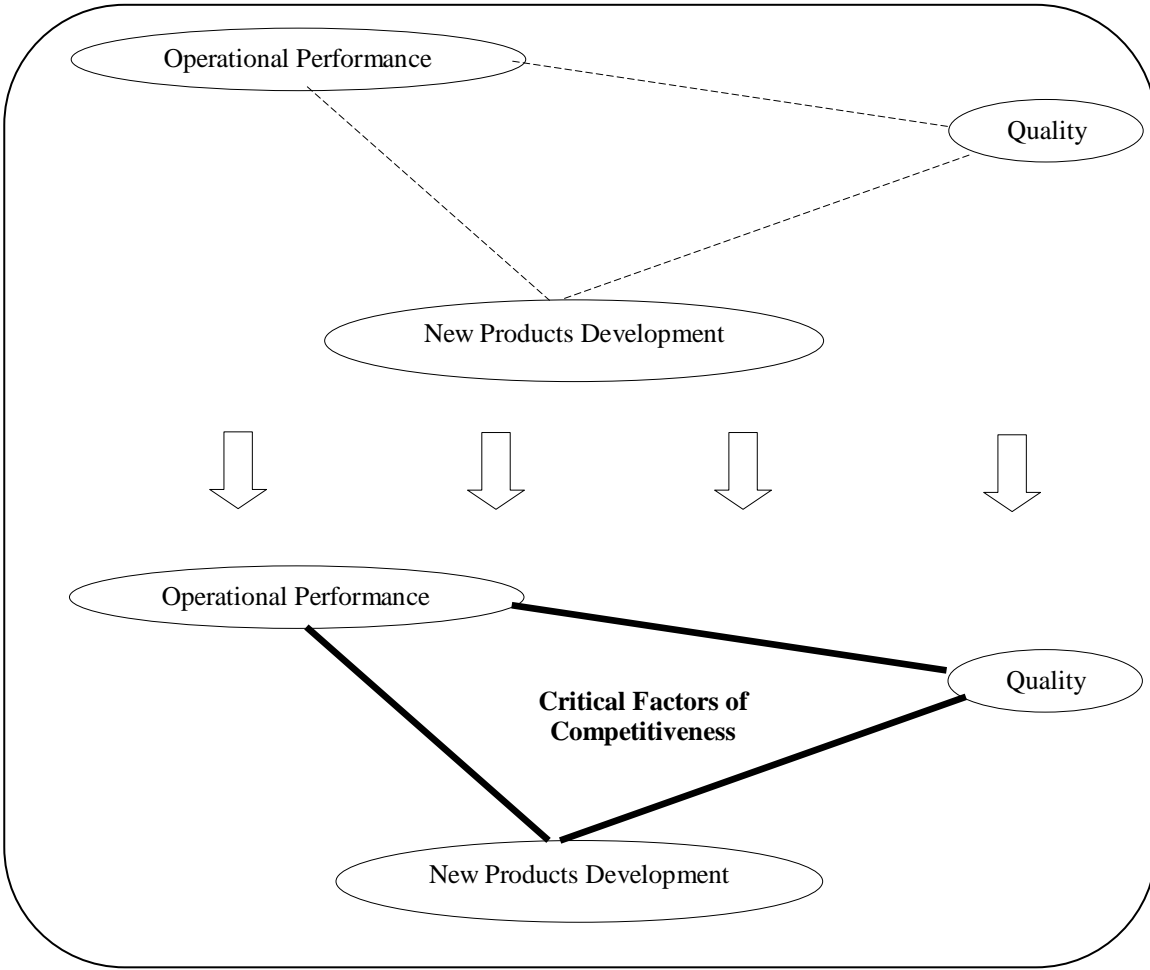
- From the 1980s, "image" has replaced "style" as a critical factor in the American auto industry: trying to maintain and strengthen the images of quality and fuel efficiency, U.S. manufacturers started also to pass the images of efficiency and reliability, which were perceived by consumers only in imported vehicles (Quintela et al, 2005);

From the notion of critical factors of competitiveness, it is possible to realize the close relation they assume with the results of one organization. Competitive factors knowledge will enable the organization to work in synchrony with environmental requirements, get internally structured, reduce levels of uncertainty and improve the performance.

## **5. Identification, Characterization and Validity of the Competitive Factors**

The Complexity Theory reinforces the thought that the greatest interaction among different areas making up a complex organization, either processes or people, promotes the best results against competitiveness and sudden changes prompted by environmental variations. In a production system occurs a series of interrelations that trigger a range of variable processes and operations enabling a product development (goods or services).

In this work, it is developed the idea that interrelations strengthening from a production system can contribute greatly to the improvement of the results. The strengthening of those interrelations is related to the existence of competitive business factors. Figure 2 shows how the competitive factor influences the relation among parts of a production system.



**Figure 2: How the competitive factor influences the relation among parts of a production system.**

Source: Elaborated by the authors.

Identification, characterization and validation of the competitiveness factors will be given from the current literature, more specifically, through the content featured in journals available at the Portal of Capes (Improvement Coordination for Higher Education Personnel). Following that work, it will be interviewed researchers in the field of Production Management from the programs of master's degree and doctorate in the areas of Management and Production Engineering, recognized by Capes. In order to finish the

search for competitiveness factors, it will be performed a field research with professionals from the production area.

The first step consisted of identifying organizational competitiveness factors through the collection of articles from Capes website. In order to organize the search for articles that actually treat the subject of interest, it was used the criterion of search based on keywords. The keywords were: Competitiveness, Productivity, Efficiency and Organizational Performance.

Following that direction, 486 scientific papers were identified in English and Portuguese languages, mainly in English. In possession of the articles, it followed the reading and identification of fragments from the text where it was explicit the mention of some organizational competitiveness factors. At this stage of the process, some articles were discarded because they do not make explicit the connection between the mentioned factor and organizational performance.

Therefore, there were identified 198 terms that used to be explored in the texts as factors capable of influence the organizational performance. Due to the similarity of some terms, it was decided to group them. As a result, 15 groups were established and each one of them was represented by the word considered as the competitiveness factor. Chart 3 shows the groups formed to the Human Capital and ICT factors (Information and Communication Technology).

Human Capital	Development of technical skills and reinforcements, continuous investment in human capital development, management ability improvement, future planning of leadership and succession, skills development, staff development, technical skills, human resources management, force diversity and workplace, quality of life at the workplace, talent management, basic skills, technical and managerial skills, harmony in labor relations, lifelong employment, education and training, highly skilled human resources, labor health, people selection, work specialization, well-trained and motivated workers, training, human resources, ethics, ethical behavior, teamwork, mode of action from the senior executives team, competences.
ICT	ICT implementation and adaptation to improve the efficiency of daily operations, Web sites development, open channels of communication, e-business, technology strategies, internationalization through e-business, communication, information systems, interorganizational information systems, information technology for communication, technology management, appropriate technologies.

**Chart 3: Competitiveness Factors Cluster**

Source: Elaborated by the authors.

Following that procedure, 15 factors of competitiveness were identified, through the analysis of scientific articles available at the Capes Portal, and dealing with the organizational performance topic. The factors identified were: Knowledge, Control Systems, Cultural Factors, Innovation, Production Techniques, Cost, Human Capital, Speed, Flexibility, Strategic Alliances, ICT, Quality, Customer; Reliability; Social Responsibility.

The next step is configured through the validation of the factors that were found. The validation will be given through interviews with researchers of the Post Graduate *Strictu Sensu* Programs on Management and Production Engineering recognized by Capes (Coordination for the Improvement of Higher Education Personnel).

In all, 198 researchers have been identified. 120 in the Administration area and 78 in the Production Engineering area. In order to enable researchers to have some links of knowledge with the proposed topic, it was followed some criteria during the searching process. Initially, the search took place through the identification of courses accredited by Capes.

Next, the procedure was to access the home page of each course, being possible to know the respective faculty. At that moment, it began the filtering work, which means that only the components of the faculty who had some relation with the topic of interest were selected. The filtering was performed by taking into consideration the following keywords: production administration, production management, organizational performance, organizational competitiveness, production systems; operational efficiency.

With the support from those keywords, the following process was to observe research lines and expertise areas of each investigator. Pieces of information related to the research line and practice area, in some cases, are available in the *home page* of the course. However, in cases with lack of that information, the procedure was to access researcher Lattes Curriculum and observe the acting area and research lines.

The last step of the validation from the 15 found factors will be performed through interviews with professionals of the production area. In this sense, it will be identified prominent companies in the respective acting area. With the information from researchers

and professionals, it will be possible to establish what the factors of organizational competitiveness are.

## **6. Final Considerations**

The aim of this paper was to discuss on the Complexity Theory contributions in business organizations. It has been developed the idea that relations strengthening among parts of a production system may help increase the performance and improve the competitiveness on a global basis. The relations strengthening will be achieved through competitiveness factors, and they are linking mechanisms among the categories of a production system.

This article is part of a larger study developed by NIEPC (Nucleus of Interdisciplinary Studies in Production Management and Costs) of the Federal University of Santa Catarina. The objective from this nucleus of studies is to develop a diagnostic tool in production systems. The instrument is based on assertions, considering the analysis categories of a production system and competitiveness factors.

However, the analysis focus of this approach consists of describing, characterizing and validating the competitiveness factors. Through information from the literature on competitiveness and organizational performance, 15 factors of competitiveness have been described. Next steps involve the validation of those factors. That process will occur through interviews with researchers (universities) and professionals (companies) from the Production Administration area.

The process of factors validation is under development. Thus, the results presented in this article are partial. After factors validation, it will be possible the construction of

assertions that will compose the instrument of analysis in production systems. That analysis tool is based on existent complex relations.

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