Multi-model for planning high-complexity spectrum

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Abstract: This work intends to contribute to the planning guidelines in the field of Supply Chain Management (SCM). Thus, it develops a multi-model proposal supported by the definition of a highly complex spectrum of knowledge that considers a sequence of systematic procedures in the following phases – Phase 1: modelling the needs of information in SCM and Phase 2: determination of the critical knowledge in SCM. Several support instruments were used in the modelling elaboration in order to reduce subjectivity in the results: psychometric scales – Thurstone's law of comparative judgement, multi-criteria compromise programming, Electre III and Promethee II, artificial neural networking and neurofuzzy networks. The results produced are satisfactory, validating the proposed procedure for SCM.

Keywords: multi-model; planning; supply chain; knowledge management.

Reference to this paper should be made as follows: Oliveira, S.R.M., Cazarini, E.W. and de Oliveira, J.D. (2011) 'Multi-model for planning high-complexity spectrum', *Int. J. Services, Economics and Management*, Vol. 3, No. 2, pp.170–196.

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1 Introduction

The Supply Chain Management (SCM) has for quite some time presented challenges within a wide diversity of extremely complex events, all of which in an unsure and risky context can affect the flux of decisions and the desired levels of performance, hence frustrating expectations for stability (Khan and Burnes, 2007; Manuj and Mentzer, 2008). It must be acknowledged that risks can be brought about from different origins and scenarios. With time, this eventually leads to changes in the configuration of the chain. Consequently, it is considered one of the main challenges of SCM, which basically consists of creating integrated structures of decision making in an extensive universe containing multiple organisations. This requires an integrated and shared decision structure that involves key business processes, concerning efficient coordination of functional-temporal company-client (Power, 2005; Kim, 2006; Halldorsson et al., 2007; Svenson, 2007; Cheng et al., 2008; Blos et al., 2009; Fawcett et al., 2009; Godsell et al., 2010).

According to Holmberg (2000), the fast-moving growing interest by companies worldwide in the supply chain is due to competitive pressure and the belief that working in cooperation can create advantages. However, the integration challenge can be met by modelled management models in very wide-ranging interest areas, regarding the global optimisation of the system (Neuman and Samuels, 1996; Fabbe-Costes and Jahre, 2007; Aryee, 2008). Within this spectrum, controlling the logistic performance is crucial and should be indicated on many dimensions; that is why management instruments that capture, if not all, at least the most relevant ones, should be used (Lee et al., 2007; Trkman et al., 2007). They should be able to provide the managers a short-term as well as a long-term view of the chain performance and, especially, be able to reflect the most relevant aspects of the organisation (Chow et al, 1994; Green et al., 2008).

The characteristics of the supply chain differ a great deal (Chi et al., 2009), therefore becoming the object of analysis equally differentiated (Chi et al., 2009). The good practice recommends fulfilling a sequence of articulated actions, which consists of the following phases:

1 planning the necessities
2 institutionalisation and formation of a project team and determination of the communication procedures
3 the objectives' consolidation, results and performance's goal of the supply chain
4 study of the costs, prescriptions, flows of box
5 study of the social impacts
6 analysis, allocation and management of risks (preliminary evaluation), etc.

Many times the projects are made impracticable while still in the act of planning, hence becoming unsustainable (Min and Omega, 2002; Li et al., 2005; Hong and Jeong, 2006).

One of the aspects that deserves to be highlighted is the occurrence of errors in the management of the supply chain (Winch, 2003; Blos et al., 2009), which often results in a non-fulfilment of the established goals. It is thus imposed that the efficiency in the planning of the supply chain propitiates more efficient decisions (Cassivi, 2006; Hadaya and Cassivi, 2007; Jonsson et al., 2007), diminishing the improvisation and improvement of the involved team. Traditionally, the planning phase 'sins' when it is elaborated without support of methods and adequate techniques having prioritised the knowledge that really is essential in the management of the supply chain. In this spectrum, the perspective of the efficiency of the SCM should be standardised in methods and techniques which permit a correct planning and management upon the decisions to be made. The methods and techniques of the supply chain viability in Brazil are still found in a disadvantage situation when compared to the international experience. The scarcity of the material, technological and human subsidies make such relevant projects unsustainable to be viable.

This process should result in people with abilities, experiences and adequate knowledge to perform tasks correctly at the right place and opportune moment (Mangan and Christopher, 2005; Min et al., 2005; Sauber et al., 2008). Generally, the SCM models are commonly developed by conventional modelling techniques, including mathematical programming, simulations, heuristics and statistical and probabilistic tools. However, none of these planning and managing models listed by the literature investigated takes into consideration the priority of cognitive elements in the SCM. The present work aims to contribute to the planning guidelines in the field of SCM.

Therefore, a support system for the decision of the building up and the SCM has been developed based on the methodological support of the Knowledge Management (KM) theory. The aforementioned system considers a sequence of proceedings directed to the prioritisation ranking of knowledge objects, so as to assist managers to choose priorities regarding information and theoretical knowledge in the SCM.

This contribution focuses on the definition of knowledge priorities. On the basis of a methodological strategy explained further on, which included interviews with Brazilian specialists in SCM, the priorities have been systemised and prioritised. It is within this panorama that the methodological contribution of this supply chain gets emphasis, as there is a support to the critical priorities to be considered in the list of necessary elements for the SCM of this nature. In synthesis, this work intends to contribute to the planning guidelines in the field of SCM. Therefore, a support system for the decision of the building up and the management of supply chain has been developed based on the methodological support of the KM theory. The aforementioned system considers a sequence of proceedings directed to the prioritisation ranking of knowledge objects, so as to assist managers in choosing priorities regarding information and theoretical knowledge. Thus, it develops a multi-model proposal supported by the definition of a highly complex spectrum of knowledge that considers a sequence of systematic procedures in the following phases:

1 *Phase 1*: modelling the needs of information in three stages:
   - Stage 1: determination of the Critical Success Factors (CSF)
   - Stage 2: determination of the information areas and prioritisation of the information needs starting from the crossing of CSF
   - Stage 3: the areas of information.
2 *Phase 2*: determination of the critical knowledge in SCM in four stages:
   - Stage 1: identification and acquisition of knowledge
   - Stage 2: knowledge evaluation
   - Stage 3: determination of the effective rate of knowledge priority in decision of the supply chain
   - Stage 4: representation of knowledge in mental maps. These different stages are detailed here.

2 Modelling and discussion

The building-up and the management of a supply chain require highly complex analytical approaches, which include subjective elements. Thus, they demand the technical mastery of various technological, human, environmental, technical, legal, financial and political aspects and procedures. KM may represent a strategic tool, increasing the institutional capacity of the entrepreneurs in their assignments of formulation, evaluation and execution of such projects (Fletcher et al., 2007; Nelson and McCann, 2008; Hanisch et al., 2009; Kannabiran, 2009; Koskinen and Pihlanto, 2009; Kayakutlu and Buyukozkan, 2010; Oluikp et al., 2010). The KM would work as a facilitator instrument of improvement, contributing for the quality of services and the enhancement of the agility to decide.

Monitoring the performance of SCM from a KM perspective requires that the appropriate monitoring procedures are in place and operational (Mangan and Christopher, 2005; Fletcher et al., 2007; Svensson, 2007; Godsell et al., 2010). These procedures will of course depend on the kind of measures taken earlier and must be tailored to them. But it is not only improvement plans that must be monitored. Generally, a keen eye must be kept on the knowledge household of SCM. Especially important is watching the external environment for new events that may have impacts on the way SCM deals with knowledge shown as ‘incoming’ arrows that will influence the execution of the KM cycle (Miguel et al., 2008; Schroeder et al., 2009).

Here, following the proposals of Bukowitz and Williams (2002), Eliufoo (2008), Sugiyama (2007) and Wu (2008), knowledge is considered as the elaborated, refined information, which is also able to self-evaluate its liability, relevance and importance (Nonaka and Takeuchi, 1995; Hunt, 2003; Samuel et al., 2008; Engberg, 2010). Knowledge is to be considered as the most important information as it includes a precise context, a concrete meaning, the respective interpretation and reflection, is added by personal discernment and considers the widest implications (Davenport and Prusak, 1998; Gelbstein, 2004). Moresi (2001) proposes a chain composed of the following elements: processed data, elaborated information, synthesis by knowledge and, finally, the intelligence (Gelbstein, 2004; Checkland and Holwell, 2006; Arif et al., 2009). The knowledge step converts by the synthesis information into knowledge. After this synthesis, the information is gathered in blocks in such a way that they can later be used by specialists who filter it and standardise it in order to apply it to a specific situation.

Moreover, KM is defined as an integrated set of intervention tools (Nonaka and Takeuchi, 1995; Rowley, 1999; Probst et al., 2002; Denkena et al., 2007; Wu and Lee, 2007), which consists of a systematic process of identifying, generating, distribution, application and creating knowledge.

The current proposal to build up a methodological support applied to the SCM happens within the following proceedings: we start by modelling the needs of information required to feed various activities developed (by the areas of information) in the build-up and the management of SCM projects, which will be developed starting from the critical factors of success, that will be identified and evaluated. The method of critical factors of success is the most used to determine the needs of information in businesses. In order to identify and to set priorities for information needs in SCM projects, following steps are foreseen: (Stage 1) determination of CSF; (Stage 2) determination of the information areas and (Stage 3) prioritisation of the information needs starting from the crossing of CSF and the areas of information. These different stages are detailed here.

2.1 Phase 1: modelling the needs of information

This phase is structured in three stages:

- *Stage 1*: determination of the CSF
- *Stage 2*: determination of the information areas
- *Stage 3*: prioritisation of the information needs starting from the crossing of CSF and the areas of information.

2.1.1 Stage 1: determination of CSF

This phase is focused on determining the CSF, and is itself structured in two stages:

1 *Identification of CSF* – the identification of CSF is based on the combination of various methods (Leidecker and Bruno, 1984):

- environmental analysis (external variable: political, economical, legislation, technology, among others)
- analysis of the industry structure (users' needs, the evolution of the demand, users' satisfaction level, their preferences and needs, technological innovations)
- meeting with specialists and decision makers
- the study of literature.

2 *Evaluation of CSF* – after their identification, the CSF is evaluated in order to establish a ranking by relevance. Here, the scale model of categorical judgements designed by Thurstone in 1927 has been adopted. This model starts form mental behaviour to explain the preference of a judge (individual) concerning a set of stimuli $\{O1, O2, \ldots, On\}$. Thus, the evaluation of the CSF is systematised in the following steps:

- Step 1: determination of the frequencies by pairs of stimuli
- Step 2: determination of the frequencies of ordinal categories
- Step 3: calculation of the matrix $[\pi ij]$ of the relative frequencies accumulated.

It is highlighted though that the results to be achieved in Step 3 reflect the probabilities of the intensity of the specialists' preferences regarding the stimuli, the critical factors of success in this work. As a result, a hierarchical structure of CSF is obtained.

Determining the CSF is the goal. According to Oliveira (2004), the CSF in SCM are (Table 1): first, the market and political factors; secondly, the technical factor; thirdly, the economical and financial factor and, fourthly, the judicial factor.

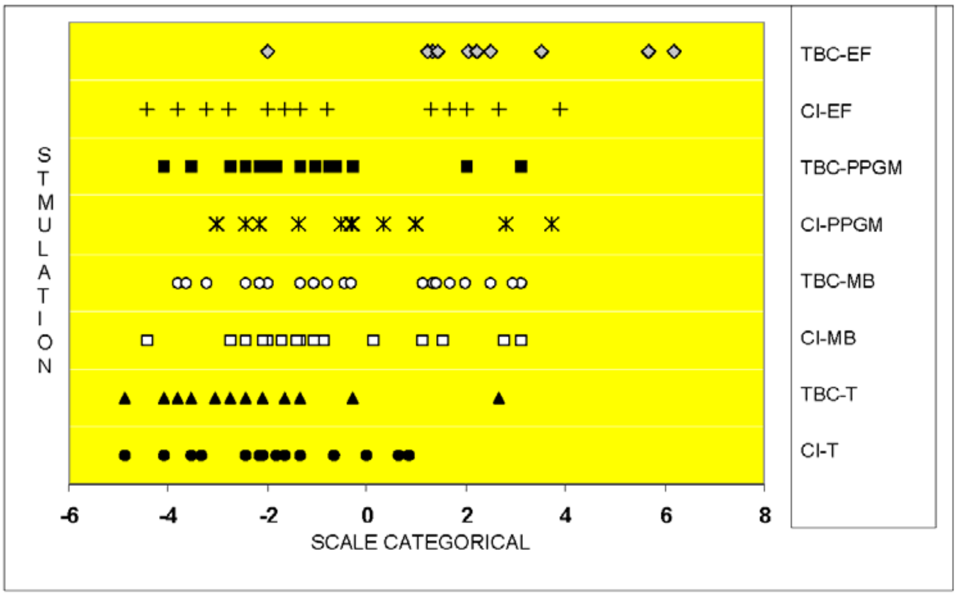
Table 1 CSF of projects – method of categorical judgement of Thurstone (1927)

Stimulations (CSF)	$\mu_i = -\left(\sum_{j=1}^{4} Zij\right) / 4$	*Classification*
Market	–3.34	1º
Political	–3.35	1º
Judicial	4.92	4º
Technical	–1.19	2º
Economical and Financial	1.36	3º

Assembling here the many dimensions of the CSFs, the results show (Figure 1) that there are predominance of political and market factors. This is seen when taking into account the relevancy of public policies for the design of SCM.

In view of past experiences in the international and Brazilian scope, the high-level of political and market factors preferences is justified. Undoubtedly, political instability brought forth discontinuity of great and sound projects. Oftentimes, political instability has created immeasurable systematic crisis, thus planting public policies, investments, projects, programmes and State guidelines in second place.

Figure 1 Variation of preference dispersion of the decision makers (see online version for colours)



With this scenario, having defined the political factor and its components, it is possible to understand the information that is included in the macro guidelines defined by policies and the strategic decisions, among others. To sum it up, by developing this factor, it is possible to understand the information referring to:

- the guidelines for strategic planning of infra-structure development, backing up the investment policies
- the strategic objectives to be reached by PP
- the national politics of financing, within the context of other options for infra-structure financing: the institutional organisation
- the commitments of the different levels of government with the objectives, guidelines and instruments of the risks for the supply chain policy
- the assurances of effective cost and risk advantages
- the maintenance of government guidelines and space for public policies
- the process of communication and accountability
- the matters of transition and working rights in sectors predominantly operated by public servants
- the political stability guaranties of contracts
- the adequate management of social and environmental impacts.

Regarding the market factor, there is a need to perceive the need for monitoring:

- offer and demand
- consumer needs
- competition
- better practices and technological innovation
- negotiation with individuals, alliances and partners
- economic details and new market opportunities
- risk analysis
- new information technology, among others.

2.1.2 Stage 2: determination of the areas of information

The CSF having already been defined, the information areas are delimited with respect to the different CSFs. After determining the CSF, the determination of the areas of information ensues. The result has allowed defining four groups that represent the areas of information: first, the governmental area on public policies; secondly, the economical and financial area; thirdly, the technical information area and, fourthly, the market area. The goals of the areas of information define specifically what must be achieved by these areas to meet one or more objectives from the projects (business), contributing for the enhancement of the project performance as to quality, productivity and profitability.

2.1.3 Stage 3: prioritisation of the information needs starting from the crossing of CSF and the areas of information

Again, these information areas are ranked by application of the same categorical judgement method of Thurstone (1927) and put into relation with the CSF. At this moment the following tools have been adopted:

- *Multi-objective utility* – multi-attribute, in this case compromise programming™, which represent mathematically the decision makers' preference structure in situations of uncertainty
- *Selective*, taken on account for the situation, Promethee II™
- Electre III™.

These methods rendered their contributions in determining the performance in the areas of information, which led to the identification of Mercadology Area as the most important one in order to globally ensure the overall CSF. The critical knowledge for SCM is determined in the sequence.

Aiming to know which area of the SCM the decision makers must develop a 'strong management', the prioritisation of information needs takes place. The results shown by the methods compromising programming, Electre III and Promethee II have pointed out the Mercadology Area as the most relevant one to guarantee the CSF. The gathering, analysis and processing of information must be to strongly reinforce the set of activities that comprise this area, specially in what concerns the information about actions on:

- monitoring the political, economical and social environment, risks that impact directly or not the organisations
- the best choice decision as for the contractual negotiation, specially the rights and duties between partners
- the best choice of partners
- the best build-up and management of the project
- the best definition of the competition policy
- the best definition of service levels – availability, punctuality, reliability, flexibility and managing the defect recuperation system
- the best definition of the costs structure
- the best definition policies of managing holdings
- the best choice of quality and productivity for policies on the supply chain
- competitive strategy
- analysing strategic planning on defence against competition
- monitoring and control of the environment
- the best choice criteria, organisation, proceeding and monitoring of projects
- monitoring risks of the project
- attending to demands
- defining the best investment policy
- search for better innovation practices and new managing methods and models (demand and offer)
- defining better capital and finance structure
- follow-up of supply markets of input
- defining better partnerships and alliances
- defining planning policies and control social and environmental impacts and their mitigation
- the best financial engineering management; define the goals to be met, etc.

In order to do so, the data gathered from the specialists were used.

2.2 Phase 2: determination of the critical knowledge in SCM

This phase has been sub-divided as follows:

- *Stage 1* – identification and acquisition of knowledge
- *Stage 2* – knowledge evaluation using the method of categorical judgements of Thurstone (1927) and artificial neural network (ANN)

- *Stage 3* – determination of the effective rate of knowledge priority in decision of the supply chain using neurofuzzy modelling
- *Stage 4* – representation of knowledge in mental maps.

This proceeding is shown in details as to its structure.

2.2.1 Stage 1: identification and acquisition of knowledge

Initially, information topics which have been already identified will be elaborated, analysed and evaluated in order to be understood by the decision makers during the formulation and the SCM. Following this, they will be reviewed, organised and validated by SCM specialists. Afterwards, relevant theories and concepts are determined. With respect to the acquisition procedures, the different procedures of the process of acquisition represent the acquisition of the necessary knowledge, abilities and experiences to create and maintain the essential experiences and areas of information selected and mapped out (Thiel, 2002; Douligeris and Tilipakis, 2006; Miguel et al., 2008; Wu, 2008).

Acquiring the knowledge (from specialists) implies, according to Buchanan (2002), Eliufoo (2008) and Fletcher et al. (2007), the obtaining of information from specialists and/or from documented sources, classifying it in a declarative and procedural fashion, codifying it in a format used by the system and validating the consistence of the codified knowledge with the existent one in the system. Therefore, at first, the way the conversion from information into knowledge (Herschel et al., 2001) is dealt with, which is the information to be understood by and useful for the decision making in SCM. First the information is gathered. Then the combination and internalisation is established by the explicit knowledge (information) so that it can be better understood and synthesised in order to be easily and quickly presented whenever possible (the information must be useful for the decision making and for that reason, it must be understood). In this work, we aim to elaborate the conversion of information into knowledge.

The conversion (transformation) takes place as follows: first, the comparison of how the information related to a given situation can be compared to other known situations is established; secondly, the implications brought about by the information for the decision making are analysed and evaluated; thirdly, the relation between new knowledge and that accumulated is established and, fourthly, what the decision makers expect from the information is checked. The conversion of information into knowledge is assisted by the information maps (elaborated in the previous phase by areas, through analysis and evaluation of the information). We highlight that the information taken into account is both the ones externally and internally originated. The information from external origins has as a main goal to detect, beforehand, the long-term opportunities for the project (Celis, 2000; Eliufoo, 2008; Wei et al., 2009). The internal information is important to establish the strategies, but it has to be of a broader scope than that used for operational management, because besides allowing the evaluation of the performance it also identifies its strengths and weaknesses.

Following from this, the proceedings for the acquisition of theoretical background and concepts are dealt with. Such proceedings begin with the areas of information, one by one, where the concept and the theory on which is based the performance of the actions (articulations) developed in those areas that allow to guarantee the feasibility of the SCM projects are identified. In other words, knowledge and theory which are required to be known in order to ensure the success of projects on supply chain in that area are identified. Then, the analysis of surveys in institutions about the job market for these institutions takes place bearing in mind the demands of similar areas studied in this work. As for the offer, we intend to search for the level of knowledge required by the companies and other organisations in those areas, as well as what concerns technical improvement (means) for the professionals.

This stage determines the concept of knowledge to be taken into account on the development of this work. So, for the operational goals of this work, we have adopted them as the 'contextual information' and the theoretical framework and concepts.

2.2.2 *Stage 2: knowledge evaluation using method of categorical judgements of Thurstone (1927) and ANN*

After being identified and acquired, the knowledge is evaluated, with the aid of the method of categorical judgements of Thurstone (1927) and ANN.

2.2.2.1 *Evaluation for the method Categorical Judgements' Laws*

The achievement method of the research results with the specialists of SCM, who revealed their preferences for pairs of stimulation (in the case, the objects of knowledge, and these submitted the ordinal categories C1 = 5º place, C2 = 3º place and C3 = 4º place). The evaluation of objects of knowledge (LJC) happened in three stages. In the Stage 1, one determined the frequencies for pairs of stimulations, where O_i is equivalent to objects of knowledge and O_j the specialists. The data had been extracted from the preferences of the specialists in relation to objects of knowledge, attributing weights to the cognitive elements.

After that (Stage 2), the preferences of the specialists are determined in relation to the stimulations (knowledge). The results were obtained by means of the ordinal frequencies from the results of the previous stage.

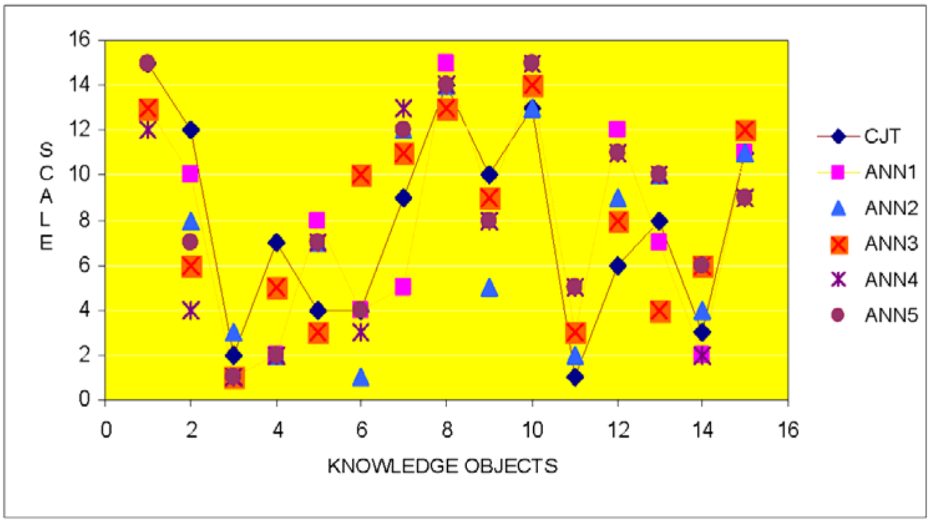
Finally (Stage 3), the accumulated relative frequencies were calculated first. The results obtained here reflect the probabilities of preferences intensity of the specialists in relation to the stimulations (theoretical bases and concepts). The result of the preferences, then, is presented in an upward order of importance. In order to demonstrate the application of the methodological proposal, the results of the objects of knowledge on the 'market area' were dealt.

Prior to the compared analysis of knowledge, it is important to mention that the results were extracted from the four categories of the following areas: Public Policies Government Management (PPGM), Economic and Financial (EF), Technical (T), Marketing/Business (MB).

First, we established a comparison of all the theoretical bases and concepts (TBC) and context information (CI), denominated as stimulus by the areas. Thus, generally we tried from this analysis to understand the behaviour of the preference intensity of the decision makers regarding stimulus. Secondly, we compared all the sets of theoretical bases, analysing the preference intensity of the specialists regarding the theories and concepts. Thirdly, we analysed the behaviour of context information, broaching the preference intensity of the decision makers with relation to the theories and concepts. Lastly, we discussed individually the categories (areas) to understand how the theories, concepts and context information behave. This procedure was performed with the support of the scale model of categorical judgements.

With all of the various dimensions of knowledge objects (theoretical basis and concepts and context information), the results show (Figure 2) that there is no great predominance of another type of knowledge, and this should be considered in SCM. However, there are those with more relevancies in the decision maker's preference. Therefore, the best decision is sought, considering the background of each supply chain category. Furthermore, one should consider that each one has its own peculiarity, hence demanding differentiated knowledge, since we are dealing with highly subjective questions. Hence, the reason why it is wise to choose those that fit best the reality of each project of the supply chain.

Figure 2 Priority of knowledge's objects – ANN and CJT (see online version for colours)



With regards to theoretical bases and concepts and context information, the 'market' category presents the following knowledge objects in an upward order of importance:

1 institutional organisation for policies on SCM

2 quality and productivity for policies on the supply chain

3 competitive strategy

4 strategic planning on defence against competition

5 administration of projects

6 monitoring and control

7 criteria, organisation, proceeding and monitoring of projects

8 engineering of the knowledge and technologies of the information

9 actors

10 risks of the project

11 attend the demand

12 civil and commercial contracts

13 productivity policy
14 investments policy
15 innovation and new managing methods
16 financing
17 follow-up of costs and of supply markets of input
18 partnerships and alliances
19 monitoring methods and techniques of the best success practices in supply chain projects
20 quality engineering – quality patterns
21 effective engineering
22 technical and human resources
23 analysis of social and environmental impacts and their mitigation
24 information technology
25 indicators used by the market
26 monitoring the competition
27 profitability of the industry and
28 new methods for forecasting and simulating the demands.

The results obtained have been satisfying, validating the proceeding proposed for assembling and the prioritisation of critical knowledge for SCM, as well as for the constitution of other elements of the intellectual capital in SCM.

2.2.2.2 Evaluation of Knowledge's Objects using the ANN

The ANN is understood to simulate the behaviour of the human brain through a number of interconnected neurons. A neuron executes weighed additions for the activations of the neurons representing non-linear relations. The ANN has the capacity to recognise and to classify standards by means of processes of learning and training. The training of the net is the phase most important for the success of the applications in neural network. The topology of the net can better be determined of subjective form, from a principle that consists of adopting the lesser intermediate number of possible layer and neurons, without compromising the precision. Thus, in this application, the layer of the entrance data possesses 15 neurons corresponding the 15 variables referring to objects of knowledge. The intermediate layer possesses seven neurons, and the exit layer possesses one corresponding neuron in a scale value determined for the ANN. The process of learning supervised based on the back propagation algorithm applying software Easy NN determines the weights between the layers of entrance and intermediate, and between the intermediate and exit automatically.

The training process was finished when the weights between the connections had allowed minimising the error of learning. For this, it was necessary to identify which configuration that would present the best resulted varying the taxes of learning and moment. After diverse configurations have been tested, the net of that presented better resulted with tax of an equal learning 0.30 and equal moment 0.80. The data had been divided in two groups, where to each period of training one-third of the data are used for training of net and the remaining are applied for verification of the results.

After some topologies of net, and parameters got the network that better resulted had presented. The net was trained for attainment of two results' group for comparison of the best-determined scale for the networks. In the first test the total of the judgement of the agents was adopted, however, only in as test was gotten better scales, next of represented for method of the categorical judgements. With this, the last stage of the modelling in ANN consisted of testing the data of sequential entrance or random form; this process presented more satisfactory results. The reached results had revealed satisfactory, emphasising the subjective importance of scale's methods to treat questions that involve high degree of subjectivity and complexity. How much to the topologies of used networks, the results gotten of some configurations of the ANN and compared with the CJT, were observed that ANN 1 is the one that better if approached to the classification gotten for the CJT.

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The reached results proved satisfactory, emphasising the subjective importance of the scale methods to treat questions that involve high degree of subjectivity and complexity. With regards to the topologies of the used networks, the results obtained some configurations of the ANN and compared with the CJT, it was observed that ANN 1, is the one that best approached the classification obtained for the CJT. Thus, even other topologies do not Tenaha been the best ones, it had been come however close in some objects of knowledge of the CJT. The results can be observed in Figure 2 that follows.

The prioritised objects for the tool proposals were for SCM knowledge. ANN, as well as psychometric (CJT), was restricted only to the specialists' decisions in projects of raised subjectivity and complexity, needing other elements that consider the learning of new knowledge. However, it is interesting to highlight that the CJT method, as it considers a variable involving a high degree of subjective and complexity and because it works with probabilities in the intensity of preferences, considers the learning of new elements of knowledge. Thus, it can be said that for typology of application, as presented here, it is sufficiently indicated. Tenaha, being the best ones, had been come however close in some objects of knowledge of the CJT.

2.2.3 Stage 3: determination of the effective rate of knowledge priority in decision of the supply chain using neurofuzzy modelling

This stage focuses on determining the Rate of Decision Effectivity (RDE) on knowledge in supply chain managing, with regards to using the neurofuzzy modelling. Seeing that it is a process whose attributes mostly have characteristics of subjectivity and the experience of the decision-maker is quite significant, there is a need for a tool that allows the association of quantitative and qualitative variables converged to a single evaluation parameter (Von Altrock, 1997; Cury; 1999; Oliveira, 2004). This model adds the technology of neural networks to the fuzzy logic (neurofuzzy technology). Here, this model supports the chain supply managing and is adapted from the model of Oliveira and Cury (1999).

In such neurofuzzy, the entry data can be quantitative and qualitative and are grouped to determine the comparison parameters between the alternatives. Since the exact models suitable for this type of calculation have a complex application, the neurofuzzy methodology enables and simplifies the human decision of reproducing the process. This methodology is structured from a combination of all of the attributes in blocks of inference that use base fuzzy rules and linguistic expressions, so that the preference for each alternative of knowledge priority decision, in terms of benefits in supply chain, can be expressed by means of a 'grade' varying from 0 to 10.

Within this spectrum, this stage presents a modelling to evaluate objects of knowledge to provide support to the supply chain performance, based on quantitative information and also on the specialist's qualitative information, using the neurofuzzy technology. The qualitative parameters are difficult to measure and may indicate high levels of subjectivity, hence justifying the application of methods that allow the convergence of these parameters to a single coefficient, therefore enabling the decision-making taking into account all of the relevant attributes. The stages of the model are described to follow:

2.2.3.1 Stage 3.1: determination of the entry variables and linguistic terms

It focuses on determining the Entry Variables (EV). These variables are categorised according to the quantitative or qualitative types. Also, the linguistic terms attributed to each EV are presented: high, medium and low. Thus, the EVs shown in the model are guidelines of: investments; fiscal; environmental; risks; regulations – legislation; client service/quality; quality; productivity; costs structure; financial return; liquidity; debt level; financial risk managing, investments and financing assessment; assets managing; capital structure; best quality engineering and SCM productivity practices, competitive strategy; criteria, organisation, proceeding and monitoring of projects; actors; negotiation, partnerships and alliances; economy; risks of the project; meet demand; competition; innovation and new managing methods (demand and offer); follow-up of supply markets of input; offer and demand of human resources; effective engineering; technical and human resources (offer and demand); analysis of social and environmental impacts and their mitigation; information technology (best practices); indicators practiced by the market and monitoring the competition.

2.2.3.2 Stage 3.2: determination of the intermediary variables and linguistic terms

The EV go through the process of fuzzy inference, resulting in linguistic terms of Intermediary Variables (IV). Thus, the linguistic terms attributed to the IV were low, medium and high, including some variables: slow, moderate, fast – bad, regular and good. The extracted IV were political performance, economic and financial performance, market performance and technical performance (Configuration Technical – Mercadology Benefit – RDE). The proposed design is made up of seven configurations of fuzzy specialist systems, two EV that go through the fuzzy process and through the inference block, therefore producing an exit variable (EXV), designated intermediary variable (DV). In turn, such DV joins with another DV, hence forming a set of new EVs, consequently configuring a sequence until the last layer of the network. In the last layer, the definite variable EXV of the neurofuzzy network is produced. This EXV then undergoes a de-fuzzing process to achieve the final result: the supply chain decision (RDE).

2.2.3.3 Stage 3.3: determination of the exit variable – effective rate of knowledge priority in decision and performance of the supply chain

The EXV of the neurofuzzy model proposed was denominated effective rate of decisions in supply chain performance, resulting in the following processes.

1 *Fuzzyfication*: This process includes determining the functions for each of the EV. If the entry data, the calculation results and observations are precise values, then it is necessary to perform the structuring of the fuzzy arrangement for the EV, which consists of the fuzzyfication process. In case the EV are obtained in linguistic values then the fuzzification process is not necessary (Cury, 1999). The fuzzy arrangements can be characterised as a generalisation of the Boolean sets, where the pertinency function can assume values at fixed intervals. Usually, the interval [0,1] is considered, when it is not correct to assume that an element belongs to a specified set, but that it does indeed present a certain degree of pertinency. Therefore, a fuzzy set, besides an X universe, is a set of orderly pairs represented by equation (1):

$$\mathrm{A} = \{\mu\mathrm{A}(x), x \mid x \in X\} \quad (1)$$

where $\mu A(x)$ is a function of pertinency (or degree of pertinency) of *x* in A and is defined as the mapping of *X* in the closed interval [0,1], in agreement with an equation (2) (Pedrycz and Gomide, 1998):

$$\mu A(x) : X \rightarrow [0,1] \tag{2}$$

2 *Fuzzy inference*: The ground rules of fuzzy inference are made up of the *if-then* type, which are responsible for the association of the EV and the generation of the EXV in linguistic terms, with their respective pertinency functions. The fuzzy inference is structured by two components – (a) aggregation, which means the computing from the SE of the rules and (b) composition, regarding the *then* part of the rules. The Degrees of Certainty (DoC) that determine the linguistic vectors resulting from the processes of aggregation and composition are defined by equation (3):

$$\begin{aligned} \mathrm{DoC_S} &:: \max[\mathrm{FoC_1} \cdot \min\{\mathrm{DoC_{A11}}, \mathrm{DoC_{A12}}, \ldots \mathrm{DoC_{1m}}\}, \ldots, \mathrm{FoC_n} \cdot \min\{\mathrm{DoC_{An1}}, \\ &\mathrm{DoC_{An2}}, \ldots, \mathrm{DoC_{Amn}}\}] \end{aligned} \tag{3}$$

where

DoC: Degree of Certainty

FoC: Factor of Certainty

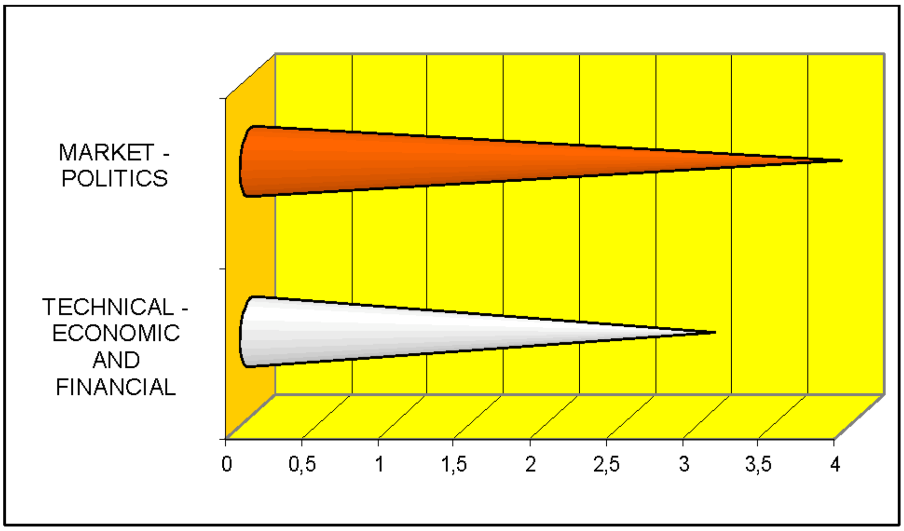
3 *De-fuzzification*: In some applications the interpretation of a result is enough, as for instance, when a qualitative or verbal response is desired. However, in other applications, a numeric value as a result from the system is deemed as necessary (as for instance, arrangement and comparison). In these cases, after the fuzzy inference, a de-fuzzification process is necessary, that is transform the linguistic values from their pertinency (Von Altrock, 1997) functions. Usually, the Maximum Centre method to determine an exact value for the EXV linguistic vector is used. From this method, the certainty degrees of the linguistic degrees are defined as 'weights', associated to each of these values. The exact Resolved Value (RV) is determined by considering the weights in relation to the typical values (maximum values of the pertinency functions), in agreement with the definition of the equation (4) (Von Altrock, 1997):

$$\mathrm{RV} = \frac{\sum_{i=1}^{n} \mathrm{DoC_i} \cdot \mathrm{X_i}}{\sum_{i=1}^{n} \mathrm{DoC_i}} \tag{4}$$

where DoC represent the DoC of the linguistic terms of the final EXV and *X* indicates the typical values for the linguistic terms that correspond to the maximums of the fuzzy sets, which define the final EXV.

The results can be seen in Figure 3, extracted from the neurofuzzy model, which associates the EVs with its intermediary and exit layers, by means of inference blocks, where the inference rules for each pair of the considered variables are contained. The result of each implementation is the RDE, defined between 0 and 10, in an increasing scale according to the adequate decision-making on knowledge in the supply chain managing, regarding benefits for performance. The RDE indicates choosing the best alternative to concentrate the endeavours on the supply chain managing. Meaning, that at first sight, it is vital to focus on monitoring the external ambient (market and politics), afterwards, the technical and economic and financial issues (external ambient). It should be taken into account that comparison among variables should take place permanently and recurrently.

Figure 3 GEDSC – degree of effectivity of knowledge priority decision in supply chain (see online version for colours)



Comparatively, the market alternative demonstrated greater effectivity in the priority decisions of knowledge for performance in supply chain managing. With regards to the market and politics variables, special attention must be given to SCM external variables. Allied to this, a space opens up to define the new managing strategies, while seeking to make the decision spectrum more intelligent. For decision choosing, the neurofuzzy model is a more efficient instrument to compare options. From the association of intervening objective and subjective variables in the decision choosing process, through a hierarchic neural network using a fuzzy inference process to convert information, it is possible to generate a numeric value denominated RDE. The greater the RDE, the more effective the chosen alternative for decision making for the situation hereby presented.

2.2.4 Stage 4: mental representation of the objects of knowledge in cognitive maps

After prioritising the objects of knowledge, the build-up of cognitive maps takes place (market area), assisted by the software Statistica. In order to create maps, the denominations of the objects of knowledge have been abbreviated. The results of the decision makers' intensity about the objects of knowledge can be seen in Figures 4 and 5.

Figure 4 Mental representation of the objects of knowledge in cognitive maps – segregation basis, theories and Mercadology concepts – business (see online version for colours)

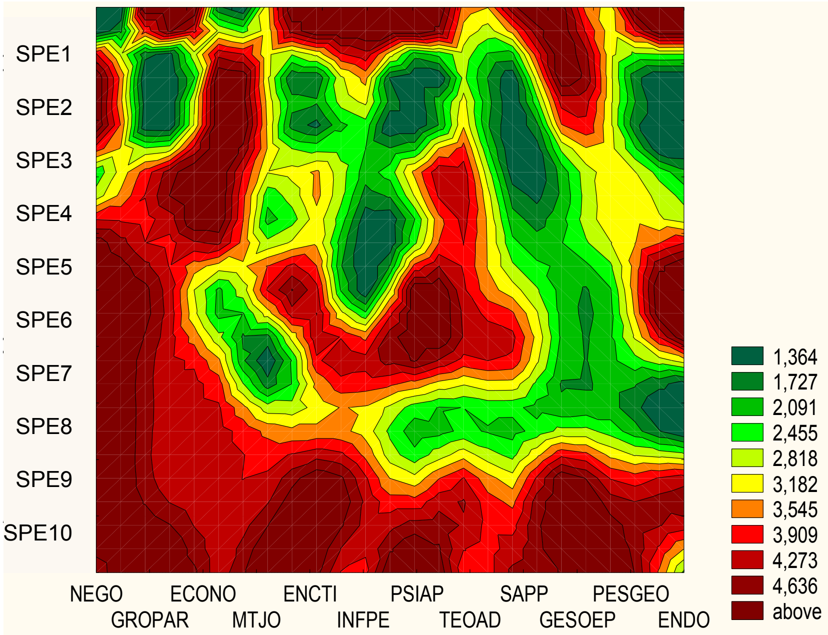
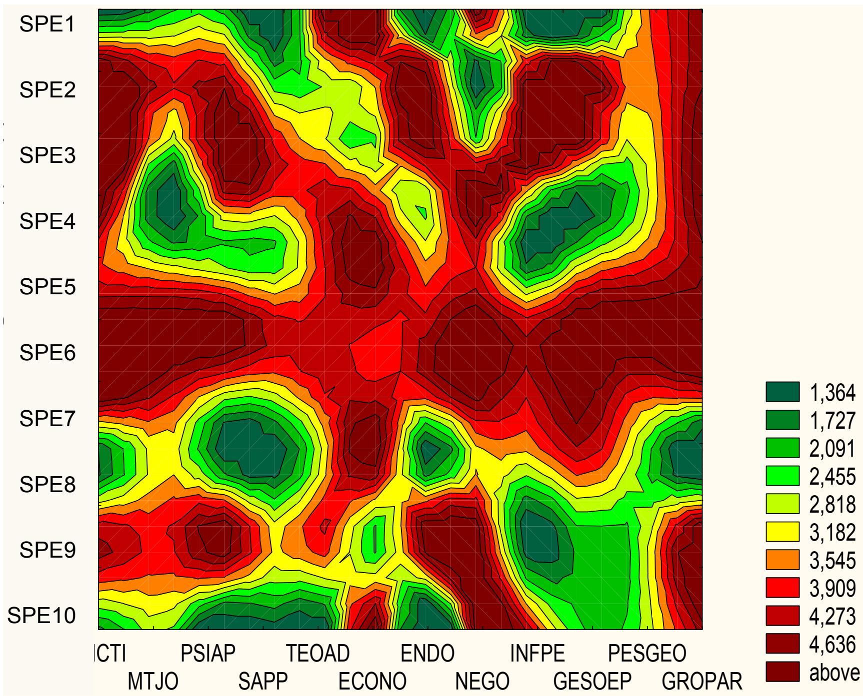


Figure 5 Mental representation of the objects of knowledge in cognitive maps – segregation basis, theories and Mercadology concepts – business (see online version for colours)



Before anything else, it is worth emphasising that the logistic managing is viewed from a strategic perspective, planning and coordinating the necessary activities, in order to meet the desired levels of services and quality at the lowest possible costs. By assembling the vast dimensions of knowledge, there is a prevalence of 'the best managing practices of supply chain projects' (NEGO), 'economy' (ECONO) and 'risk managing' (GROPAR) (Figure 5). Unified to this there is the know-how of partnerships and alliances, quality and productivity. The challenge that appears in the supply chain managing is the result of a good practice:

- shorten the logistic flux
- improve view of the logistic flux
- consider logistic managing as a system.

Such practices direct towards planning, managing and control of the logistic operations by means of monitoring the documented performance of the logistic system, which includes:

- service levels and the components of logistic costs
- control strategies that continuously follow the performance and are used to upgrade the logistic process to place it in conformity when it exceeds control patterns
- control routing that are projected to motivate employees, including additional payment practices for productivity.

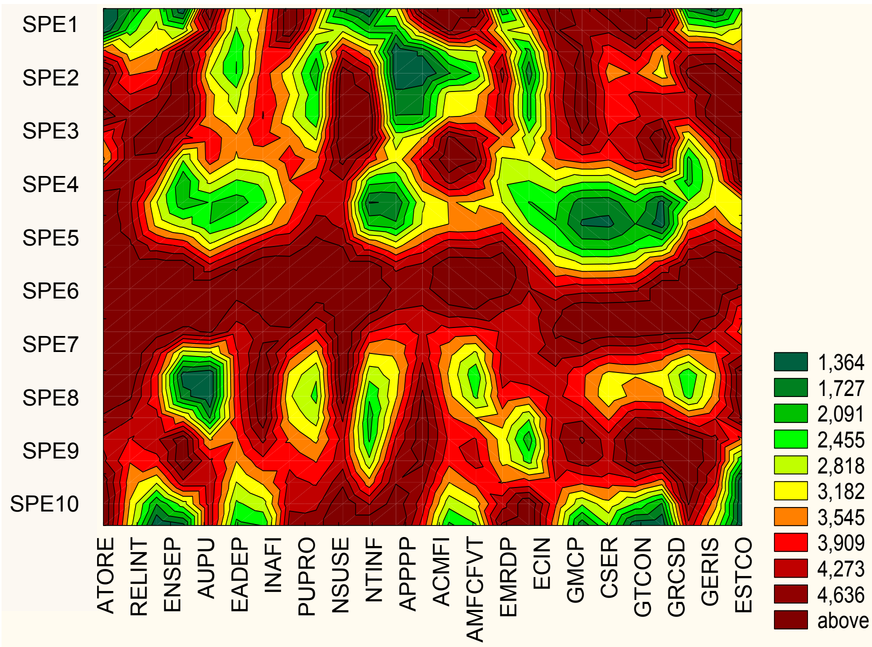
Also emphasised is that efficient supply chain managing perceives, first of all, allying costs and adequate service levels to clients, assurance of compensatory policies on losses and benefits, establish a rational stock policy and appropriate modals in agreement with costs availability, storing (deposits), productive plants and productive capacity, automated production system or not, and distribution centres. In all, good managing practices are grounded on monitoring guidelines related to storing types and location, sources and levels of stock, purchasing principles, transport requirements, methods for handling material and basic methods for processing orders.

With regards to risk management, this work considers as information the methods and organised processes to reduce losses and increase benefits in order to substantiate the strategic objectives. This requires identifying the risks, quantifying risks, selecting risks, deciding (avoid or transfer) risks, informing and communicating and following up risks completely, exactly, updated and well-timed. With regards to the processes, here are some of the risks:

- *on efficiency*, to meet or not efficiency – to have, or not, the quality and integrity, as for instance incomplete information and processes
- *risks related to the scale capacity and economy*, as for instance, idle machine capacity, company equipment and sectors
- *risks related to standardisation, concentration or diversification*, for example products are distributed nationwide (costs may reduce) or can be diversified regionally (costs are higher with additional expenses), future cash flow placed under liabilities due to exchange rate variation
- *risks related to bottleneck, redundancies, discontinuity and looping*, for instance greater entries than processing capacity, data bank creation with incomplete information and limits, e.g. minimum risk limits: stocks and processing.

With regards to economical aspects, it is worth emphasising the econometric models, which have been used very much lately in situations including parameters estimations that pertain to relations constructed by the economical theory, as well as hypotheses formulations regarding the behaviour of reality as instruments. In another level, the role of the macro and micro economics is highlighted regarding decisions, as the inflation levels, interest rates, economic guidelines, fiscal policy, investment policies, exchange rate, population consumption, employment and income rate. These variables exert an influential cost impact, average, marginal, fixed, variable, direct and indirect, and influence the quantity of product offers given the demanded quantity, in agreement with the market structure (monopoly, oligopoly and optimum competition), besides the decisions on optimum capital structure, keeping in mind the interest rates paid by the market. Lastly, decisions about financing and investing, exporting and importing, considering the exchange rate regarding the investment levels and financing rates, decisions about exporting and importing, considering the exchange rate and taxes. Figure 6 depicts the results of the context information from the Mercadology area.

Figure 6 Mental representation of the objects of knowledge in cognitive maps – context Mercadology information – business (see online version for colours)



It is relevant to emphasise the knowledge dimensions about the 'actors in the SCM projects sector' (ATORE) and 'international relations' (Figure 6). The role of the economic questions stands out (macro and micro), fiscal, investments, interest, financing, costs structure, product price, competition, among others that exert direct or indirect repercussions in the supply chain decisions (ECONO). Also recognised is the importance of 'managing the relationship of partners and alliances' (GROPAR). There is a subtle homogeneousness of these cognitive elements in the SCM (Figure 6). Time, delivery time, technical assistance and prompt delivery become fundamental. These elements are a priority given that to reach new markets and improvement in geographic integration, managing goes beyond the traditional economic activities; which takes place through partnerships with potential clients, suppliers, competitors, knowledge and technology, raw materials, innovations and the pursuit for better practices. Moreover, the current market complexity demands that the managing efficacy of product flux surpass the limits from local to global. Within this spectrum, logistics is viewed as a strategic area that enables companies to expand their relationships in the international market, transposing geographic and economic hurdles. Aiming at an integrated global economy, companies are under pressure to think of products from a global stance and to rationalise their productive processes to maximise corporative resources. This challenge is imperative and looking ahead to expand and/or sustain such participation, the need arises to develop international transport, the capacity to deal with cultural diversity, multilingual skills and widening the supply chains, among others.

3 Final words: lessons to learn

The demand for information and knowledge is vast. Capacitation is a systematic and continuous evaluation process for the future requisites of human resources. The outcome of such process should be skilled, experienced and adequately prepared individuals who can perform skills accurately at the right time and place. Within this perspective, the efficacy of the supply chain managing ought to be sedimented by managing methods and techniques leading the way for future decision-making.

The present work about SCM comes to an end, and hopes to have contributed for methodological discussions that need further investigation. Moreover, there is a need to understand SCM regarding social demands that are created within their appropriate social, economic and political context. And evidently many questions remain to be untangled in future studies of this type, specifically of planning in highly complex spectrum of, as the SCM.

The proposed methodology developed in this work differentiates from other decision support methods, by extracting the tacit knowledge and converting it into explicit knowledge of managers in SCM. In developing the proposed methodology a number of methods was used, such as the critical factors of success, multi-objectives methods, categorical judgements (scaled) of psychometrics and mental maps to represent the objects of knowledge, hence establishing a prioritisation. It is underscored that the present approach sought to make the spectrum of decision more intelligent by providing knowledge on the development and management of SCM.

In light of KM and its techniques listed here, it was possible to develop a methodology proposal and contribute to the allocation guidelines of resources, to build the intellectual capital in the field of SCM. Therefore, it is essential to guide such strategic elements of knowledge.

A general introduction to KM and knowledge maps (graphical representations of knowledge objects, bearers, structures and processes) leads to a list of typical steps to knowledge map development, and a list of typical knowledge map applications. Finally, it leads to ideas for the implementation of knowledge SCM.

By basing on the KM and its techniques, we have developed the proposal of a methodology that is focused on contributing to patterns of resource allocation to build-up intellectual capital on SCM. Also, it is underscored the importance of the neurofuzzy technology acknowledged as an additional managing instrument at the hands of administrators, especially so for the matter at hand, which enabled to identify the degree of effectivity of knowledge priority decision in supply chain. This requires a more attentive outlook to questions involving the external ambient. Neurofuzzy technology has been applied to support the decision making process in problems that involve subjective and objective attributes. A neurofuzzy model was structured and the result was named degree of mode effectiveness, representing the level of adequacy of the mode option to the manager's needs. The results obtained with the application of the proposed model show that this technology is adequate for supporting decision-making, due mainly to its low level of complexity and to its flexibility, that allows the input and output of variables.

Through this method a more pragmatic and efficient guidance is sought, assisting the guidelines for long-term supply chain managing, hence assuring this segment's competitiveness. Extensive and systematic procedures should be pursued that are capable of uniting the most diverse dimensions of SCM, surpassing the non-scientific practice often pervading some of the works.

This proposal focuses on highlighting unexplored questions in this complex design. However, it evidently does not intend to be a 'forced' methodology, but intends to render some contribution, even through independent course of actions.

This paper is aimed at an important area for Brazil where there is a new commitment to SCM as a way of funding logistics. To be successful, SCM must be introduced with an appropriate organisational structure and within an appropriate environment. Brazil is still in a disadvantageous position when compared to other international experiences: it lacks material, technological and human resources, rendering impossible the feasibility of projects of such greatness. Knowledge is insufficient and the intellectual capital is unprepared. In this scenario, our methodological contribution is highlighted, because it provides with support for the critical priorities for the implementation of this project and is directed to building up of the intellectual capital as a key element for the development of SCM. We are looking forward here to a more practical and efficient orientation supporting its long-term goals and assuring the national competitiveness concerning the category of priorities.

By gathering the cognitive elements, it can be seen that this strategy requires a priority dynamics, which is dependent on the initial state of training, on the concrete characteristics of the projects and cognitive problems that emerge during the practice, always putting in view new contents. In the near future, we aim to demonstrate the suitability and feasibility of the proposed modelling framework; priority researches must be permanently and recurrently applied.

This methodological support does not intend to be complete, but it is our intent to make it a generator of strategical elements for the development of supply chain projects. It is here where the KM is important, being a key instrument to develop projects in such a complex issue as it is the case of supply chain.

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