A Methodology for Logistics Partners' Selection to Compose Virtual Organizations Based on KPI

Omir Correia Alves Junior[1], Ricardo J. Rabelo[2]

omalves@gmail.com; rabelo@das.ufsc.br
[1]Dept. of Computer Science, State University of Santa Catarina, Brazil
[2]Dept. of Automation and Systems Eng., Federal University of Santa Catarina, Brazil

Abstract. This paper presents an exploratory and qualitative work of a novel model for the selection of the most adequate logistics providers that will compose a virtual organization. It includes a performance measurement model and a supporting methodology that considers the intrinsic dynamics, autonomy and temporality of Virtual Organizations, involving both intra and inter-organizational indicators at strategic levels. The model is flexible in terms of both allowing performance indicators' weights relaxation and being adapted according to the organizations' governance model.

Keywords: virtual organization, logistics partners' selection, performance indicators, AHP method, performance measurement.

1 Introduction

The Globalization is a trend that favors the expansion of logistics partners. New markets and new products have been increasingly created all over the world and proper logistic providers should be hired. The cleverer this activity is done the greater visibility, improved customer service, better planning and cost savings will be supported [1]. When companies work in more volatile strategic networks, the difficult of selecting the most appropriate logistic providers is even higher. This works focuses on the *Virtual Organization* (VO) type of network.

Part of such difficulty is due to the intrinsic nature of a VO, which is a temporary and dynamic strategic alliance of autonomous, heterogeneous and usually geographically dispersed companies (often SMEs) created to attend to very particular business opportunities [2-4], sharing costs, benefits and risks, acting as it was one single enterprise [5, 6]. After ending all legal obligations a VO is dismissed.

Differently from traditional supply chains, logistics providers (responsible for handling material and cargo transportation) are not known in advance, as this depends on the business, on the client, on the country or region's regulations, etc. Therefore, the collaboration among involved industrial partners (who produces some part of the good) and logistic providers are crucial to be augmented [7, 8] as a way to fulfill temporal and quality requirements of this unique business opportunity as well as to differentiate in the market as long as they create value in this chain [9, 10]. Considering this tighter collaboration, logistics providers are seem as logistics *partners* (LP) and a business opportunity is as a *collaboration* opportunity (CO).

Most of the works found out in the literature tackled this problem usually calling it as *partner's search and selection*, but with the focus on the selection of *industrial* partners (IP) instead of on *logistics* partners. Besides that, the works on logistics in

VOs essentially considers performance indicators basically at operational level, neglecting the also important strategic level. Yet, they do not consider other relevant dimensions when autonomous and collaborative companies do business together, such as governance and trust. Finally, the large majority of the works try to apply an automatic approach when selecting partners. We argue that the selection of LPs in a VO scenario is so complex and full of particularities that making this automatically is perhaps unrealistic as well as it prevents involved companies' managers from properly putting in practice their experience.

This work proposes a novel model that complements other contributions about IPs' selection, supporting the suggestion of adequate *LPs* for given VO.

This paper is organized as following: section I introduced the problem; section II details the problem and contextualizes it within the collaborative networks area; section III presents the supporting methodology for LP suggestion; section IV provides an example of the model usage; and section V provides some preliminary conclusions about the model.

2   Logistic network problem

A VO is one type of a diversity of Collaborative Network Organizations (CNO). However, a key aspect when considering VOs is that all of its members come from another type of CNO, which is the so-called *Virtual organization Breeding Environment* (VBE). A VBE is a long-term alliance of companies whose ultimate goal is to be the basis for the creation of VOs. Likely VOs, VBE members are also composed of autonomous, heterogeneous and geographically dispersed companies. Regarding that they share principles and working methods, the creation of VOs from a VBE becomes much faster, more effective and less complex to manage [11, 12]. A typical VO is generally composed of LPs and IPs, creating a logistics and value chain network, as illustrated in Figure 1.
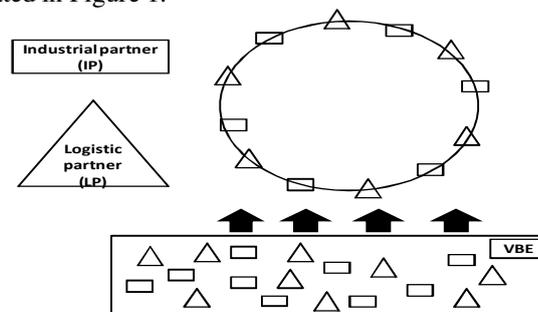

Fig. 1: VO composed of LPs and IPs

The reference process for a VO creation consists of seven steps (Figure 2) [13]. Adopting a performance measurement approach, in [14] partners' search and selection step is extended introducing key performance indicators (KPI) as a first task to be made to filter IPs. This paper follows the same approach, adapting it to LPs and restricting the model to the *suggestion* stage. This is a complex task because LPs will work collaboratively in a VO and their selection should consider particular aspects of a VO and VBE, such as:

- LPs can only be identified after knowing the particular CO in details;
- A repeated CO will be rarely composed of the same set of VBE members;
- VO's LPs and IPs not necessarily will have worked together in previous COs;
- COs are usually unique or one-of-a-kind;
- KPI and/or their weights vary from one CO to another;
- LPs usually have different information system, semantics and performance measures;
- The final handshake among IPs and LPs should be carried out as fast as possible;
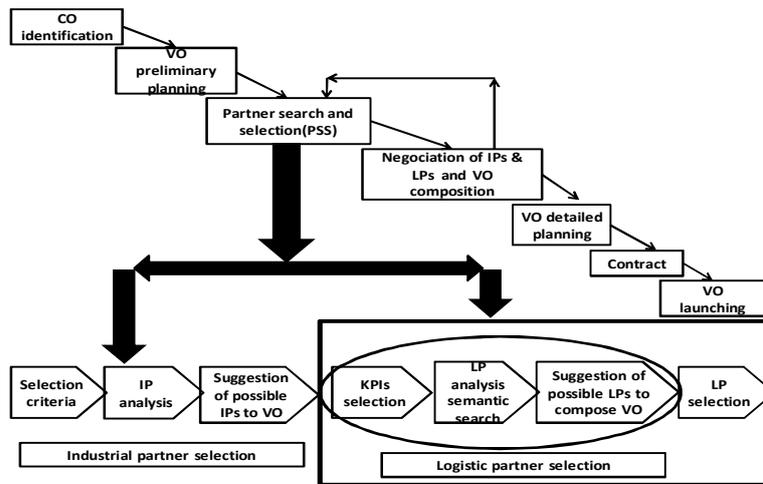- Each VBE has its particular governance model.

Fig. 2: Extended framework for the VO creation

A literature survey about this showed that there are several approaches based on performance measurement and KPIs for evaluating companies [15]. However, few of them address the problem of KPI models for LPs in VOs. For example, in [16] a generic methodology based on balanced Scorecard (BSC) indicators is proposed, but without any support for governance and trust issues. The methodology proposed by [17] assigns performance indicators for each partner but does not provide criteria for analyzing the collaboration level of partners to compose VOs. In [18] the complexity of structuring a methodology for VO partners' selection is identified and a hierarchical methodology based on multiple attribute decision making is proposed. However this work has focused only on intra-organizational performance indicators.

3   Proposed methodology

In order to tackle this issue of suggesting adequate LPs for a given VO a methodology is proposed (Figure 3). Two important assumptions are considered. Firstly, all LPs are members of a VBE. Secondly, there is a global coordinator of the process, which is called *VO Coordinator*. An additional role is taken by a logistic specialist, who permanently audits the LPs' KPI values.

A. CO identification

In this first methodology stage the CO is verified in order to identify the logistics itineraries that have to be carried out. A CO, besides other information, is composed of logistics-related data showed on section 4. This set of information was based on a VO information reference model [19] [14] and extended for this work.
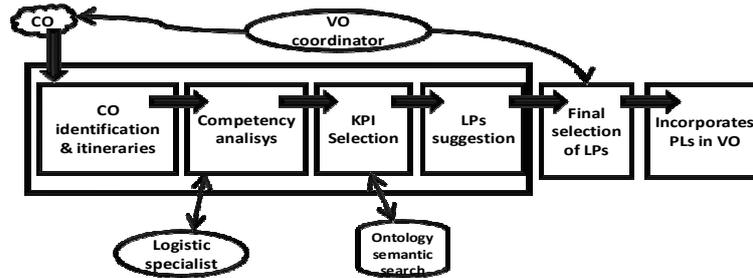

Fig. 3: LP selection steps

B. LP competency skills analysis

In a first round of analysis the methodology checks the technical LP's competences against to every single CO itinerary. If a given LP is pre-selected then it is moved to a suggested list for further VO coordinator decision. After an analysis on the logistics discipline [20], seven attributes were elicited to represent LP competences showed on section 4. The formal competency skills analysis is performed using the set theory. Two sets are considered: *R* and *M*. *R* represents the whole set of specific CO requirements *(R={1,...,r})*. *M* represents the set of LP's competencies *(M={1,..,m})*. The problem is to find a match between *R* and *M*, which will then define the pre-selected PLs for the given CO. This is provided by the function *G(i,j)*, which represents the intersection of *R* and *M* sets:

$$G(i,j) = | Ri \cap Mj |, \ \forall i \ \epsilon R \ \wedge \ \forall j \ \epsilon M \qquad (1)$$

      Where:
  i=number of PLs; j=number of COs.

C. Identification and selection of KPIs

The third step of the methodology aims at selecting the most appropriate KPIs that will be applied over every CO's itinerary to filter the pre-selected LPs. This process is aided by an *ontology*, which links the semantic of CO's attributes with the KPI model (Figure 3). It is used to provide a formal representation that can be used and reused to facilitate understanding of all involved concepts and relationships between them in a specific domain [21]. The developed KPI model comprises fifteen KPIs (see section D). More than one KPI can be applied to evaluate a given CO itinerary. LPs will be selected after this set of KPI evaluation. This strategy has been inspired from [14]. With the selected list of KPIs and LPs, the methodology determines the level of collaboration (LC) (see section G) of each pre-selected LP for each itinerary. The LP to be finally suggested is the one with the highest LC value or with the highest coefficient of regression. VO coordinators evaluate the suggested list and assign one LP to the given itinerary and then this LP becomes member of the VO. The method repeats until the end of the CO itineraries, i.e. when there is one or a set of LPs selected to link all the involved (and previously defined) VO's industrial partners.

D. KPI model

A crucial element in the methodology is the KPI model. Regarding this, two general requirements were necessary to cope with. Firstly, the set of KPIs should consider both intra and inter organizational perspectives. Secondly, they should also consider indicators at strategic level. After a literature review, several KPI models were found out (e.g. [22-25]). However, none of them were neither comprehensive enough to cope with those requirements nor were devoted to logistics in dynamic alliances (e.g. VOs). The devised KPI model has considered some existing models (e.g. SCOR [26]) and complemented with a literature overview. It is composed of fifteen KPIs:

- *ROE* (return-on-equity): The amount of net income returned as a percentage of shareholders equity;
- *Cash flow*: focusing on the cash being generated related to how much is being generated and the safety net it provides to the LP;
- *Cost Control*: controls the cost reduction of LPs;
- *Customer satisfaction*: measures the customer perception related to delivered services;
- *Susceptibility*: the elapsed time between customer purchase order and product(s) delivery;
- *Commitment*: measures the level of commitment between the LPs;
- *Collaboration*: measures the LPs level of collaboration;
- *IT maturity*: measures if the LP's IT objectives are aligned to its business strategies;
- *Governance*: measures how is the code of conduct and cultural issues of each LPs;
- *Flexibility*: measures the LP flexibility to adapt to changes along VO operation;
- *Environmental performance*: measures how the LP copes with environmental practices;
- *Availability*: measures the level of LP availability;
- *Effectiveness*: measures if resources (e.g. labor) are properly allocated;
- *Trust*: measures the level of trust between the LPs;
- *Communication*: measure the level of effective communication among LPs' members.

Each KPI is seen as a strategic dimension, which is divided into a subset of individual and operational/lower level performance indicators (PIs). When computed as a whole, they provide the value of the KPI itself. For example, KPI *Cost Control* is calculated considering the PIs *cost of warehousing, reverse cost* and *labor cost*.

E. Assigning weights to KPIs

The methodology applies the AHP method to assign weights to the fifteen KPIs. AHP was proposed in [27] to solve multiple criteria problems in a hierarchical structure. In AHP, criteria related to the goal are distributed at lower levels from the top of the KPI weight structure (Figure 4).

   The LC calculation (see section G) uses this hierarchical structure to distribute weights (i.e. their importance) of KPIs and hence to suggest the most suitable LPs. All KPIs are weighted. By default, the methodology assigns the higher weights to KPIs with makes a semantics matching with the CO, whereas lower weights are assigned to those without matching. The VO coordinator is in charge of assignment weights to KPIs. If necessary, weights can be redefined along the process.

F. Assign values to KPIs

As the model works also based on historical data, the VBE database should be updated with the applied KPIs values after the VO dissolution. This is done by all the involved VO's companies via electronic questionnaires. Likert scale [28] is used to normalize KPI values, defining values from zero to five. These values are calculated from the set of tactical performance indicators that composes each (strategic) KPI.
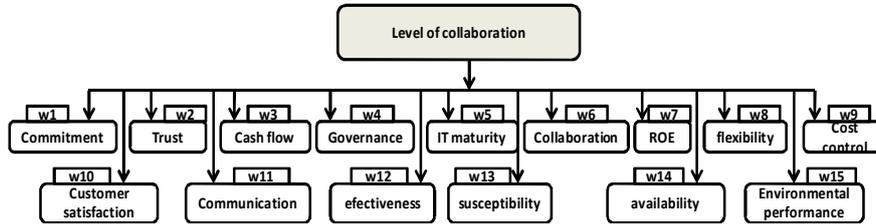
Fig. 4: Using AHP with the KPIs

G. Level of collaboration (LC)

The final decision about which LPs will compose a VO is determined by a last filter, which is LC. LC is a value calculated for each LP that was selected by the competence analysis. It is represented by a vector of collaboration (VC), which is formed by the historical collaboration of each pre-selected LP in past VOs (Figure 5).
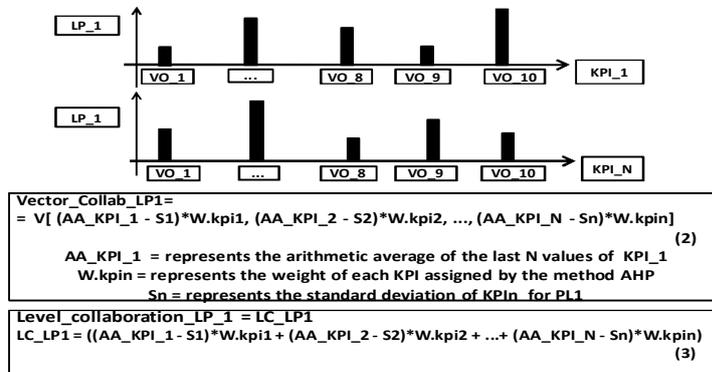

Vector_Collab_LP1=
= V[(AA_KPI_1 - S1)*W.kpi1, (AA_KPI_2 - S2)*W.kpi2, ..., (AA_KPI_N - Sn)*W.kpin]   (2)

AA_KPI_1 = represents the arithmetic average of the last N values of KPI_1
W.kpin = represents the weight of each KPI assigned by the method AHP
Sn = represents the standard deviation of KPIn for PL1

Level_collaboration_LP_1 = LC_LP1
LC_LP1 = ((AA_KPI_1 - S1)*W.kpi1 + (AA_KPI_2 - S2)*W.kpi2 + ...+ (AA_KPI_N - Sn)*W.kpin)   (3)

Fig. 5: Value of KPIs and level of collaboration formula

LC is composed of a set of "positions" (KPIs), where each position is calculated multiplying the average of the historical values of each KPI minus the standard deviation for each KPI by its respective weight. The determination of the LC is applied to all LPs, as follows:

- *Get past KPI values (from the VBE database) from each pre-selected LP associated to their previous VOs;*
- *Determine the time horizon to be applied upon the LPs. Depending on the VO or the VBE policy, this can vary from a number of past VOs (e.g. the last ten participations) or period of time (e.g. the participation in the last two years);*
- *Calculates Vector of Collaboration (VC), where each vector field is the arithmetic average of the last values minus the standard deviation multiplied by the respective KPI's weight for each KPI. The weight is represented by the variable W.idn, and it is calculated using the AHP method;*
- *Determine the total LC for each LP by the sum of the indices of the respective KPI VCs;*
- *Determine the straight line for the range of last n LC values for each LP and its coefficient, using the regression theory and the minimum quadratic method. (Figure 6);*
- *Suggests the LP for each CO's itinerary according to the highest LC and/or the positive coefficient of regression of the straight line. The positive coefficient means that, historically, after each VO the KPIs values of a LP are increasing.*

The formula for VC and LC calculation is given by:

$VC(i,j,k)=(AA\_KPI(i,j,k) - S(i,j,k))*W(i,j,k)$ (4)

   where:

i = amount of KPIs; j = number of LPs per itinerary; k = number of itineraries within a CO;

AA_KPI = arithmetic average of historical values of the KPI i, referring to PL j, which is associated with the itinerary k;

W(i,j,k) = weight assigned to KPI i by AHP;

S(i,j,k) = standard deviation of KPI i, LP j, and itinerary k;

$$LC(j,k) = \sum_{i=1}^{13} VC(i,j,k)$$ (5)

   where:

i = number of KPIs; j = number of LPs by itinerary; k = number of itineraries of the CO;

VC (i,j,k) = Vector of collaboration from KPI i to partner j, related to itinerary k;

LC (j,k) = level of collaboration of the PL j to itinerary k;

LC_a(j,k) = represents the LC of the PL j to itinerary k considering its coefficient of regression value;

LC (k) = [Max(LC(j,k)) or Max(LC_a(j,k))]   (6)

   where:

LC(k): represents the greatest value for the LC or for the LC with the highest coefficient of regression to itinerary k.
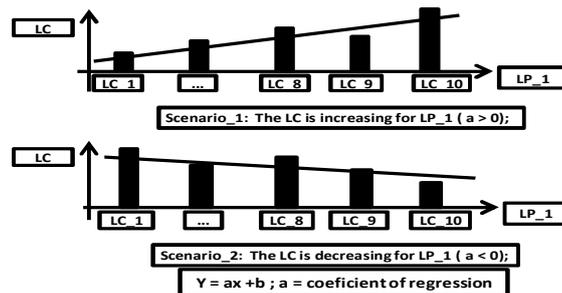

Fig. 6: Linear regression analysis for LC

4   Example of the methodology usage

Figure 7 generally illustrates an example on how the proposed model can be used. The given CO refers to a transportation of some good from the location A to B, with three legs in between: A-C, C-D and D-B. Each leg is represented by a CO's itinerary and they require up to three LPs to deliver the involved parts to the industrial partners. A LP may even get all the three itineraries, depending on its LC. CO's details are:
-        *Place of origin: A;*
-        *Place of destination: B;*
-        *Departure Date: 01-31-2011;*
-        *Delivery Date: 02-04-2011;*
-        *Service Modal: plane and train;*
-        *Cargo Type: shoes;*
-        *Quantity: 1,20 tons;*
-        *CO itinerary: itinerary_1: AC; itinerary_2: CD; itineray_3: DB;*
-        *Technical skills for itinerary_01;*
   ✓   *geographic coverage at source: A;*

    ✓ *geographic coverage at the destination: C;*
    ✓ *transportation of different types of loads: nill;*
    ✓ *modal: plane;*
    ✓ *realization consolidated shipments: mandatory;*
    ✓ *response time: 12 hours;*
    ✓ *cost: 1,200 dollars;*
-    *Technical skills for itnerary_02;*
    ✓ *geographic coverage at source: C;*
    ✓ *geographic coverage at the destination: D;*
    ✓ *transportation of different types of loads: nill;*
    ✓ *modal: plane;*
    ✓ *realization consolidated shipments: mandatory;*
    ✓ *response time: 1day;*
    ✓ *cost: 1,500 dollars;*
-    *Technical skills for itinerary_03;*
    ✓ *geographic coverage at source: D;*
    ✓ *geographic coverage at the destination: B;*
    ✓ *transportation of different types of loads: mandatory;*
    ✓ *modal: train;*
    ✓ *realization consolidated shipments: mandatory;*
    ✓ *response time: 1 day;*
    ✓ *cost: 1,800 dollars;*
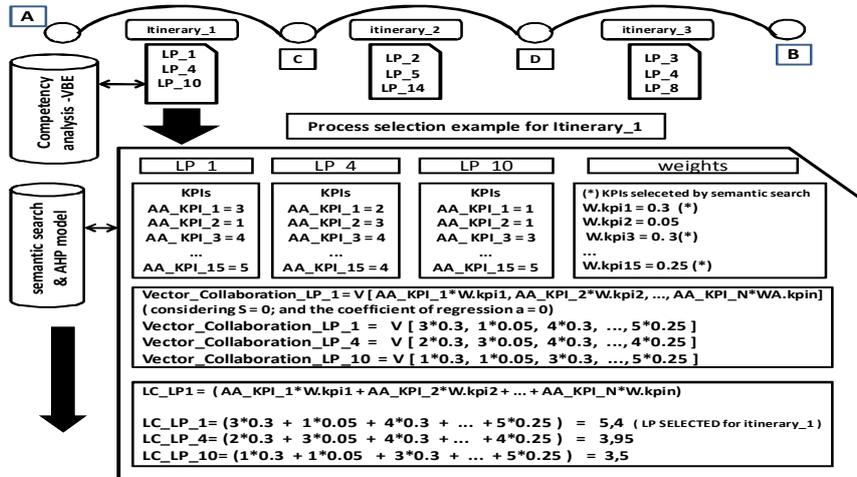-   *Level of Collaboration (LC): 5,1.*

Fig. 7: Example of LP selection

As explained in Section 3, the selection of the set of LPs to be suggested to VO coordinator to compose VO related to the given CO is carried out along five phases:
- Phase 1: the actor who gets the CO (e.g. the VO coordinator, a VBE broker or the industrial partner who was directly contacted by the customer, depending on the VBE operating rules checks the itineraries associated with the CO;
- Phase 2: for each CO's itinerary the VBE database is consulted and LPs are pre-selected based on their competencies. In the example, *LP_1, LP_4* and *LP_10* would be pre-selected for *itinerary_1*;

- Phase 3: Semantic search selects KPIs which are related to the OC, and weights are assigned to them (using AHP method);
- Phase 4: calculation of: i) the arithmetic average for each KPI; ii) the standard deviation for each KPI (in this example, $Sn = 0$, and so $a = 0$); iii.) the VC for each LP; iv) the final LC for all LPs previously selected;
- Phase 5: For each itinerary the LP with the highest LC is suggested to compose the VO. For example, *LP_1* would be selected for *itinerary_1* with the score *5.4*;

The process repeats for all OC's itineraries (*2* and *3* in this case). In the case of problems during the VO execution (or before its effective starting) that cause the need for a LP replacement, the second (and so forth) LP of the list is contacted to see if it is still available. If none of them is available or the VO coordinator considers that they are no longer useful, the methodology is started again from the competence analysis phase on. In the worst case, if none LP is found out, the client should be contacted to see at which extent some relaxations (e.g. in the delivery time) are allowed. Otherwise the VO should be cancelled.

5   Conclusions

This paper has presented a novel model and supporting methodology for the selection of the most adequate logistics partners to compose a Virtual Organization (VO). It corresponds to an ongoing and essentially exploratory and qualitative work. The complexity of the problem refers to the intrinsic dynamics, temporality and autonomy of VO, whose partners (including logistics ones) can only be identified when the business opportunity is got. Therefore, it is of extreme importance to not only make this process faster but also with more quality and confidence.

A new performance model has been presented and it is devoted to cope with the singularities of VO. It is composed of 15 KPIs and it is used to compare companies' competences, which can be flexibly assigned via AHP method. A formal ontology to establish the relation among requirements, KPIs and competences was specially conceived so mitigating semantic problems. The set of logistics partners are selected based on their level of collaboration, also considering their past performance.

So far the model has been verified in a controlled environment and close to a small group of logistics operators in the form of general questionnaires. Next main steps include the development of a decision support system prototype that implements the whole model's environment, and testing it in near real scenarios.

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