A KPI model for logistics partners’ search and suggestion to create virtual organisations

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Abstract: This paper presents an exploratory and qualitative work of a novel model for the selection of the most adequate logistics providers to compose virtual organisations. It includes a performance measurement model and a supporting methodology that considers the intrinsic dynamics, autonomy and temporality of virtual organisations, involving both intra and inter-organisational strategic indicators. The model is flexible in terms of both allowing performance indicator weight relaxation and being adapted according to the organisation’s governance model. A software prototype was developed and interviews with specialists were carried out to evaluate the model. Results are discussed at the end.

Keywords: virtual organisation; logistics partner selection; key performance indicator; KPI; performance indicators.


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1 Introduction

Globalisation is a trend that favours the expansion of logistics partners (LPs). 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 (Mentzer and Konrad, 1991). When companies work in more volatile strategic networks, the difficulty of selecting the most appropriate logistic providers is even higher. This work focuses on the virtual organisation (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 (Mowshowitz, 1997; Katzy and Obozinski, 1999; Camarinha-Matos and Afsarmanesh, 2005), sharing costs, benefits and risks, acting as they were one single enterprise (Sandberg, 2007; Camarinha-Matos and Afsarmanesh, 2008). A VO dismisses itself after ending all legal obligations.

When involving physical distribution and distributed production, a ‘complete’ VO is composed of manufacturing partners (MPs) (the ones that produce some part of the goods) and of logistics providers (the ones responsible for handling material and cargo transportation among MPs). However, different from traditional supply chains, logistics providers are not known in advance, as this depends on the business, on the client, on the country or region’s regulations, among other aspects. Due to this composition volatility, the collaboration among involved MPs and logistic providers ascends in significance (Whipple and Russell, 2007; Skjoett-Larsen and Andresen, 2003) as a way to fulfil 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 (Esper and Williams, 2003; Rafele, 2004). Considering this tighter collaboration, in this work, logistics providers are called as LP and a business opportunity as a collaboration opportunity (CO).

Most of the works found in the literature tackled this problem usually calling it partner search and selection (PSS). However, these works are devoted to the selection of MPs and not of LPs. Besides that, such works on logistics in VOs essentially consider performance indicators basically at the operational level neglecting the equally 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 fully automatic is perhaps even unrealistic as well as preventing involved companies’ managers from properly putting in practice their experience when negotiating prices, delivery dates, strategic interests to participate in the business, etc.

In this sense, this work proposes a novel model for suggesting of adequate LPs to compose VOs, which complements other contributions about MP selection.

This paper is organised as follow Section I introduces the problem. Section 2 details the problem and contextualises it within the collaborative networks area. Section 3 presents the proposed model. Section 4 presents the supporting methodology for LP suggestion. Section 5 presents the concept of the level of collaboration (LC). Section 6 presents the process formalisation. Section 7 provides an example of the model usage.
Section 8 provides the computational prototype. Section 9 provides the evaluation process and Section 10 provides the conclusions about the model.

2 Logistic network problem

A VO is one type of a diversity of collaborative network organisations (CNO). However, a key aspect when considering VOs is that all of its members come from another type of CNO, which is called virtual organisation breeding environment (VBE). A VBE is a long-term alliance of companies (MPs, LPs, etc.) whose ultimate goal is to be the basis for the creation of VOs (Rabelo et al., 2004; Afsarmanesh and Camarinha-Matos, 2005). Like VOs, VBE members are also composed of autonomous, heterogeneous and geographically dispersed companies. Since they share principles and working methods, the creation of VOs from a VBE becomes much faster, more effective and less complex to manage (Rabelo et al., 2004; Afsarmanesh and Camarinha-Matos, 2005). A typical VO is generally composed of LPs and MPs, creating a logistics and value chain network, as illustrated in Figure 1.

Figure 1 VO composed of LPs and MPs

The reference process for a VO creation consists of seven steps (Figure 2), starting with the CO identification, passing by the PSS step, and ending with the VO launching (Camarinha-Matos et al., 2005). Adopting a performance measurement approach, in (Baldo et al., 2009) the PSS step – the focus of this work – is extended to introduce key performance indicators (KPIs) as a first task to filter potential MPs to be part of the VO. The work presented in this paper follows the same approach (within the square in Figure 2), adapting it to LPs and restricting the model to the suggestion stage (avoiding an automatic selection, as it was said before).
As the MP search and selection process has specific requirements/indicators related to, e.g., manufacturing process, shop floor control, production resources data and capacity planning, the work presented in this paper was extended to complement the model to comprise requirements devoted to LPs.

The classification of LPs is quite variable in the literature. This work follows the categorisation proposed in Jackle (2009), which classifies LPs into four types: first party logistics, second party logistics, third party logistics and fourth party logistics. A first party logistics provider (1PLP) is an enterprise performing their logistics activities on their own, e.g. a manufacturing enterprise that transports its produced products to its customers or distributors. The second party logistics (2PLP) is a ‘party that receives the products or goods from the 1PLP. They offer specific logistics services like transport, warehousing and handling services. Third party logistics provider (3PLP) are able to offer integrated and systems services. They aggregate value helping 1PLP and 2PLP in the management and coordination of different modal transportations and/or warehouse management. Fourth party logistics provider (4PLP) is an integrator of services provided by 2PLPs and 3PLPs, achieving a ‘one-point’ contact for the 1PLP manufacturer. A 4PLP does not have logistics assets and its main purpose is to ensure/coordinate that an end-to-end service is sustained and managed in a supply chain (Chu, 2004). In other words, the 4PLP has administrative competencies, building and managing a network of LSPs to provide one-source logistics services solutions to customers (Figure 3).
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According to the above definitions, the proposed model is able to cope with the three first LPs. The 4PLP case is not supported as the LPs that will be suggested/selected will be the ones in charge of doing the transportation service.

The selection of the most adequate LPs to compose VOs is a complex task because they will work collaboratively in a VO and their selection should consider particular aspects of a VO and the VBE they are a member of, such as:

- LPs can only be identified after knowing the particular CO in detail
- a repeated CO will rarely be composed of the same set of VBE members (i.e., MPs and LPs)
- VO’s LPs and MPs will not necessarily have worked together in previous COs
- COs are usually quite unique or even one-of-a-kind
- KPI and/or their weights vary from one CO to another
- LPs usually have different information systems, semantics and performance measures
- the final handshake among MPs and LPs should be carried out as fast as possible to rapidly respond to the market
- each VBE has its particular governance model.

A literature review about this problem showed that there are several approaches based on performance measurement and KPIs for evaluating companies (Seifert, 2009). However, few of them address the problem of KPI models for LPs in VOs. For example, in Westphal et al. (2007) a generic methodology based on balanced scorecard (BSC) indicators is proposed but without any support for governance and trust issues. The methodology proposed by Bititci et al. (2005) assigns performance indicators to each partner but it does not provide criteria for analysing the collaboration level of partners to compose VOs. In Sarkis et al. (2007) the complexity of structuring a methodology for VO partner selection is identified and a hierarchical methodology based on multiple attribute decision making is proposed but focusing only on intra-organisational performance indicators.
3 Proposed model

The suggestion of LPs consists of an analysis about the CO and the selection for the most appropriate ones from a given universe of operators (a VBE, in the case) that meets the required level of competence to perform a range of itineraries and hence that helps the VO to achieve the CO’s requirements.

In a VO environment, the specification of a model for partners’ suggestion is not trivial. This is essentially because: alliances between partners are temporary; they are established dynamically and only after knowing the CO’s details (technical and legal aspects); and because it is difficult to establish some formal mechanisms (e.g., contracts) to ensure the level of responsibility and quality of service of each one (Crispim and de Sousa, 2008; Mat et al., 2009).

The suggestion of LPs is made following a set of criteria, where different possibilities of VO composition can arise depending on this. The proposed model aims to ensure that the suggestion process is carried out based on previously established criteria, making a more appropriate and transparent selection, strengthening the confidence in the process itself and the trust building among partners.

The proposed model is based on performance measurement using inter and intra-organisational KPIs (Figure 4). It is composed of seven key elements:

1. A set of 15 KPIs.
2. The CO representation, which is composed of: CO id, CO description, required competencies and itineraries.
3. A performance measurement system, which provides the detailed specification (name, definition, owner, metrics value range, origin) of each the 15 KPIs.
4. The criteria for suggesting LPs for VOs, which is represented by mathematical algorithms that calculate the LC (Section 5) for each LP. This is based on historical data as proposed in Goranson (1999), i.e., on the partners’ historical performance in past VOs.
5. The criteria for selecting KPIs, which is supported by a semantic search tool. For each VO, regarding the CO description, a list of the most important KPIs to be considered is defined.
6. The VBE/VO managers, who have the following roles: they qualify the LPs to enter into the VBE, identifies the CO and launches the VO.
7. The logistics specialist, who is in charge of auditing the historical KPI metrics for each LP that belongs to the VBE.

The most important element of this work is the KPI model with its 15 indicators. It was devised based on the literature review (Rafele, 2004; Baldo et al., 2009; Mat et al., 2009; Mezgar, 2006) in particular and observed trends (e.g., environmental aspects) as well as on interviews close to some logistics operators. The conception of this model was motivated by the fact that none of the KPI models revised in the literature, e.g., Chu (2004), Seifert (2009), Westphal (2007), Bititci et al. (2005) and Sarkis et al. (2007) were devoted to logistics in dynamic alliances (like VOs) not comprehensive enough to cope with CNO requirements (already mentioned).
Besides coping with the CNO requirements, the model’s rationale considers two main and general aspects. Firstly, the set of KPIs should consider both intra and inter-organisational perspectives, i.e., issues not only related to the companies themselves, internally, but also, complementary, with issues at the network level (VO and VBE, to some extent), externally. Secondly, they should also consider indicators at the strategic level. From the tactical and operational standpoints, each LP can keep using their own (if any) performance measurement system. However, they should certify that the necessary data to feed the agreed KPIs can be provided. This assumption is considered valid as members belonging to a VBE should share common principles and practices referring to common reference KPI models for performance management (e.g., for internal benchmarking purposes) (Afsarmanesh and Camarinha-Matos, 2005). In resume, the 15 KPIs of the proposed model are:

1. **Commitment**: measures the level of commitment between the LPs;
2. **Collaboration**: measures the LP’s level of collaboration;
3. **Cost control**: controls the cost reduction of LPs;
4. **ROE** (return-on-equity): The amount of net income returned as a percentage of shareholders equity;
5. **Environmental performance**: measures how the LP copes with environmental practices;
6. **Customer satisfaction**: measures the customer perception related to delivered services;
7. **Communication**: measures the level of effective communication among LPs members;
8. **IT maturity**: measures if the LP’s IT objectives are aligned to its business strategies;
9. **Governance**: measures the code of conduct and cultural issues of each LPs;
10. **Flexibility**: measures the LP flexibility to adapt to changes along during the VO operation;
11. **Availability**: measures the level of LP availability;
12. **Trust**: measures the level of trust between the LPs;
13. **Susceptibility**: the elapsed time between customer purchase order and product delivery;
14. **Effectiveness**: measures if resources (e.g., labour) are properly allocated;
15. **Cash flow**: focusing on the cash being generated related to how much is being generated and the safety net it provides to the LP;
Collaboration, trust, communication, commitment, flexibility and governance represent inter-organisational KPIs (Clarke, 1998; Gunasekaran et al., 2001; Gibson et al., 2002; De Haes and Grembergen, 2004; Luftman, 2004; Mezgar, 2006; Naim et al., 2006; Simonsson and Johnson, 2006; Provan et al., 2007; Romero et al., 2007, 2008, Simonsson and Ekstedt, 2007; Jansson et al., 2008; Parung and Bititci, 2008; Westphal et al., 2008; Zhao, 2008; Msanjila, 2009; Romero et al., 2010), whereas the other are considered as intra-organisational ones.

Each KPI is seen as at a strategic dimension, which is divided into a subset of individual and lower-level performance indicators (PIs) at operational dimension. When computed as a whole, they provide the value of the KPI itself. For example, KPI cost control is calculated considering the (operational) indicators cost of warehousing, reverse cost and labour cost (Gunasekaran et al., 2001; Gibson et al., 2002; Supply-Chain Council, 2006). This proposed list of KPIs could also be considered for selecting any provider (in general) but since some KPIs are redefined.

4 Proposed methodology

In order to assist VO managers towards having a list of suggested adequate LPs for the given VO, a methodology is proposed (Figure 5). The methodology involves four main steps, and two important assumptions are considered taking the basis of theoretical foundation of CNOs (Camarinha-Matos and Afsarmanesh, 2005) into account. Firstly, all LPs are members of a VBE. Secondly, there is a global coordinator of the suggestion process, which is called coordinator. An additional role is taken by a logistics specialist, who periodically audits the LPs’ KPI values.

Figure 5 LP selection steps
The methodology itself starts after the CO identification (left side in Figure 5). A CO is gathered by the coordinator, or by the MP, depending on the given VBE policy. A Coordinator is in charge of several activities along the VBE and VO life cycle (Camarinha-Matos and Afsarmanesh, 2005). In the scope of this work, two activities are of particular interest, which are LPs selection and CO identification. After the last step, the very final selection of the LPs that will compose the given VO to attend the given CO is made, and LPs with MPs previously selected are assigned the VO. Although this proposal has taken into account the seven steps of the framework (Figure 5), the steps related to contracting and launching are out of scope of this work. The methodology’s steps are detailed in the next sections.

4.1 CO and itineraries registration

In this first methodology step, the CO is verified in order to identify the logistics itineraries that have to be dealt with. A CO, besides other information, is composed of one or more itineraries and other logistics related data (see Section 7). This set of information was devised based on a VO information reference model (Camarinha-Matos and Afsarmanesh 2003; Baldo et al., 2008) and further extended for the purpose of this work.

4.2 Competence analysis

In the second step the methodology checks the technical LP’s competences against every single CO itinerary in order to make a preliminary selection of the ones that are technically capable for. A set of criteria is used in such analysis, which is composed of seven attributes (see Section 7). This set were elicited considering some theoretical foundations on logistics (Gunasekaran et al., 2001).

The formal competency analysis is performed using set theory. Two sets are considered: \( R \) and \( M \). \( R \) represents the whole set of specific CO requirements \( (R = \{1, \ldots, r\}) \). \( M \) represents the set of the LP’s competences \( (M = \{1, \ldots, m\}) \). The problem is then finding a match between \( R \) and \( M \), which will define the pre-selected LPs for the given CO. This is provided by the function \( G(i, j) \), which represents the intersection of sets \( R \) and \( M \):

\[
G(i, j) = |R \cap M|, \forall i \in R \quad \forall j \in M
\]

where

\( i \) number of LPs

\( j \) number of COs.

4.3 Identification and LP selection per itinerary

The third step of the methodology aims at filtering and ranking that previous list of pre-selected LPs from the performance and collaboration level perspective.
Performance is actually expressed and represented in the form of KPIs. Regarding CO’s specificities, it is important to cope with additional level of flexibility in the process, which is the selection of the most adequate KPI (out of those 15 proposed) for that as well as their respective weights of importance. This analysis is made via an ontology, which links the semantics of the CO’s attributes with the KPI model. Ontologies are used to provide a formal representation to facilitate the understanding of involved concepts and relationships between them in a specific domain (Berners-Lee et al., 2001)

This selection is a semi-automated process, where managers can manually refine the suggested KPI(s) if necessary, as in Baldo et al. (2008).

With the selected list of KPIs and LPs, the methodology calculates the so-called LC (see Section 5) of each pre-selected LP for each itinerary. The LC is an attribute that determines the readiness level of each LP to participate in the VO and it is used to finally rank the LPs per itinerary.

4.4 Suggesting LPs

The last step of the methodology is about which LPs will be suggested to compose the VO. This is done according to that ranking (section C), i.e., the first one in the ranking for each itinerary will the one with the highest LC value.

This entire process repeats until the end of the CO itineraries, having the required LPs for all VO’s itineraries, linking all involved MPs.

The involved manager evaluates the suggestions and makes the final selection. This can be done at once or at all, after having all suggestions per itinerary.

This model works based on historical data. This means that the VBE database (i.e., LPs’ KPI values) should be updated after the VO dissolution according to LPs performance. This is done by all the involved VO’s companies by means of questionnaires. Considering the natural differences among companies, the Likert scale (Linacre, 2002) was used to ‘normalise’ their answers about the performance of a given LP in the given VO. Using a scale varying from 0 to 5 (in our case), managers can say that the given LP, for example, has attended fairly the expected results (giving a value 3), the quality of its service was bad (value 0) or it has accomplished the activities above the expectations and obligations (value 5).

5 Level of collaboration

As said in the previous section, the final decision about which LPs will compose a VO is determined by a last filter, which is LC. It is represented by a vector of collaboration (VC), which is formed by the historical collaboration of each pre-selected LP in past VOs. In Figure 6, the bar graphs, for example, represent the metrics of each KPI for LP_1 including the historical of the last n VOs (in this case, 10, as this can be configured in the software – see Section 8). The two formulas in the bottom explain how the LC is calculated (VC) for LP_1.

LC is composed of a set of ‘positions’ (KPIs), where each position is calculated by multiplying the average of the historical values of each KPI minus the standard deviation for each KPI regarding its respective weight. The methodology applies the AHP method...
to assign weights to KPIs. As each CO has its particular needs it is necessary to apply some analysis criteria that differentiate the Cos, which is made attributing different weights per itinerary for each of the 15 KPIs. AHP was proposed in Saaty (1990) 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 6** Value of KPIs and LC

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

where AA_KPI_1 – represents the arithmetic average of the last N values of KPI_1, W.kpi1 – 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)

The LC calculation uses this hierarchical structure to distribute weights (i.e., their importance) to KPIs to further suggest the most suitable LPs. By default, the methodology assigns the higher weights to KPIs which make a semantics matching (via the mentioned ontology) with the CO’s description attribute (see Sections 7 and 8). The lower weight is assigned to those without matching. The coordinator is in charge of assigning weights to KPIs. If necessary, weights can be redefined along the process. The determination of the LC is applied to all LPs using the following algorithm:

- Get past KPI values (from the VBE database) from each pre-selected LP associated to their previous VOs;
- Determine the time horizon 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., participation in the last two years);
- Calculate 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 (Figure 6);
- Determine the straight line for the range of the last n LC values for each LP and its coefficient, using the regression theory, and the minimum quadratic method. The slope coefficient determines if the LP performance is ascending (positive), or if is descending (negative). Figure 7 shows two examples of bar graphs that show the historical LC for the last ten VOs, and the linear regression coefficient is calculated based on these values;

- Suggest the LP for each CO’s itinerary according to the highest LC value and/or the positive coefficient of regression of the straight line. The preference will be for the LP that has the highest positive value for the coefficient of regression. The positive coefficient means that, historically, after each VO the KPI values of a LP are increasing;

- If the LCs of a set of LPs are positioned over the level of excellence line, the LPs will be selected only considering the LC value, and the regression analysis will not be considered.

- The level of excellence is a CO’s attribute that qualifies the best LPs. For all LPs located above the level of excellence zone, it means that they reached an outstanding performance.

- If the LCs for each LP are in the interval (between the minimum requested value for the CO and the minimum requested value for the zone of excellence) then the regression analysis calculation will be considered.

Figure 8 shows the LC values for a group of LPs and three different zones on the Y axis. The first one is delimited by the minimum level of LC required for a given CO; the second one is located between the LC minimum value and the level of excellence and the last one is above the level of excellence.

Figure 7  Linear regression analysis for LC

\[ Y = bx + a; \quad b = \text{coefficient of regression} \]

\[ b(j, k) = \frac{m \sum_{i=1}^{m} x(i, j, k) * y(i, j, k) - \sum_{i=1}^{m} x(i, j, k) \sum_{i=1}^{m} y(i, j, k)}{m \sum_{i=1}^{m} x(i, j, k)^2 - (\sum_{i=1}^{m} x(i, j, k))^2} \]
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Figure 8  LC and excellence zone (see online version for colours)

Notes: Zone of excellence means that LP is suggested for VO without analysing the linear regression line. In the above example the LP_N will be suggested, and the other one will not be.

The formula for the VC and LC calculation is given by:

\[
VC(i, j, k) = (AA_{KPI}(i, j, k) - S(i, j, k)) \times W(i, j, k)
\]  

(2)

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 LP \(j\), 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 \(k\).

\[
S(i, j, k) = \sqrt{\left((1 / (n-1)) \sum_{m=1}^{n} (X(m, i, j, k) - X(i, j, k))^2\right)}
\]  

(3)

where

- \(m\) quantity of VOs to be considered to calculate the standard deviation
- \(X(m, i, j, k)\) historical value related to VO \(m\), from KPI \(i\), that belongs to LP \(j\), for itinerary \(k\)
- \(X(i, j, k)\) arithmetic average of historical values of KPI \(i\), referring to LP \(j\), which is associated to itinerary \(k\).
\[ LC(j, k) = \sum_{i=1}^{15} VC(i, j, k), \quad (4) \]

where

- \( i \) number of KPIs
- \( j \) number of LPs by itinerary
- \( k \) number of itineraries of the CO

\( VC(i, j, k) \) VC from KPI \( i \) to partner \( j \), related to itinerary \( k \)

\( LC(j, k) \) LC of the LP \( j \) to itinerary \( k \)

\( LC_{-a}(j, k) \) represents the LC of the LP \( j \) to itinerary \( k \) considering its coefficient of regression value.

\[ LC(k) = \left[ \text{Max}(LC(j, k)) \text{ or Max}(b(j, k)) \right] \quad (5) \]

where

- \( LC(k) \) represents the greatest value for the LC or for the LC with the highest coefficient of regression to itinerary \( k \)
- \( b(j, k) \) represents the linear regression value (calculated by the minimum quadratic method referring to LP \( j \), which is associated to itinerary \( k \).

\[ b(j, k) = \frac{m \sum_{i=1}^{m} (x(i, j, k) \times y(i, j, k)) - \sum_{i=1}^{m} x(i, j, k) \times \sum_{i=1}^{m} y(i, j, k)}{m \times \sum_{i=1}^{m} x(i, j, k)^2 - \left( \sum_{i=1}^{m} x(i, j, k) \right)^2} \quad (6) \]

where

- \( m \) number of VOs \( i \)
- \( x(i, j, k) \) historical number of VOs where the LP \( j \) was a member, referring to itinerary \( k \)
- \( y(i, j, k) \) historical value of the LCs for each VO \( i \) of LP \( j \), referring to itinerary \( k \).

6 Methodology formalisation

The formalisation of the proposed methodology has used the IDEF0 method (Presley and Liles, 1995), which is used to model processes. It is composed of diagrams that hierarchically decompose the activities of the methodology. The diagram at the top of the hierarchy (level A0) describes the given activity \( A_i \) at the most abstract level. The arrows at the left side of an IDEF0 diagram represent all the inputs to the activity. The arrows at the right side represent all the outputs of the activity. The arrows in the bottom represent all the means required to execute the activity. The arrows on the top represent all the controls that enact the activity.
Figure 9 shows the IDEF0 level A0 of the methodology:

- activity: LPs suggestion
- inputs: CO IDs, CO models, type of CO related to the VBE, KPI list, competence list, CO description, itineraries, KPI metrics, criteria for assigning weights to KPIs, criteria for determination of the LC, competencies criteria, LPs suggesting criteria
- controls: VO coordinator, logistics specialist
- tools: ontology creation, semantic notation, information recovery, selecting LP by competence, selecting LP per itinerary, calculating the LC, assigning weights to KPIs, linear regression calculation.

Figure 9  IDEF0 diagram for level A0
The A0 activity (Figure 9) generally shows the whole process. It is decomposed into two other activities: A1 and A2 (Figure 10). A1 represents the CO registration/competence analysis activity and A2 represents the Identification and LP selection per itinerary.

Figure 10  IDEF0 diagram for level A1-A2
According to the competences listed in the OC the A1 activity encompasses all steps in order to query the VBE database and to identify, per itinerary, what are the LPs that will participate in the selection process to compose the OV. The A2 activity is in charge of carrying out the selection of relevant KPIs to the given CO as well as to determine the vectors of collaboration, the linear regression calculations and the PLs’ LC. Figure 11 shows the decomposition of A2 activity: Selection of KPIs (A2.1) and Calculates the LC (A2.2).

Figure 11  IDEF0 diagram for level A2.1-A2.2
The A2.1 activity selects the KPIs that have the greatest weight for calculating the LC. This is supported by the indicators’ knowledge base, an ontology (both set in the
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preparatory activity) considering the OC description. The A2.2 activity provides their respective vectors and levels of collaboration for the pre-selected LPs, and considers the distribution of weights that is accomplished through the AHP method. The supervision of this activity is performed by a logistics specialist and performance measurement. The decomposition A2.2 activity (Figure 12) calculates: the KPI arithmetic average for each LP (A2.2.1); the VC (A2.2.2), and Suggests the LPs (A2.2.3).

After the KPI selection it is needed to raise the historical values related to the participation of each of the LPs in previous VOs. The A2.2.1 activity uses these values (available in a database) and calculates the arithmetic mean values for the KPIs for all LPs previously selected. This activity is supervised by an expert in logistics and performance measurement. The A2.2.2 activity calculates the VCs for each LP. The calculation considers the values of the arithmetic means relating to each KPI, the criteria used for assigning weights to KPIs and description of the OC. The determination of the weight for each KPI is performed based on the AHP method.

The A2.2.3 activity, based on the VC, calculates the LC for the previously selected LPs and checks its level of excellence (LE). If the LPs’ LCs are positioned over the level of excellence line, the LPs will be selected only considering the LC value and the regression analysis will not be considered. Otherwise, this activity calculates the straight line for the range of the last n LC values for each LP and its coefficient using the regression theory and the minimum quadratic method.

Figure 13 Example of LP selection (see online version for colours)
7 Example of the methodology usage

Figure 13 generally illustrates an example of how the proposed model can be used. The given CO refers to the transportation of some good from the location A to location D, with three legs in between: A-B, B-C and C-D. Each leg is represented by a CO’s itinerary and they require up to three LPs to deliver the involved parts to the MPs. A LP may even get all the three itineraries, depending on its LC. CO’s details of this example are:

1. place of origin: A
2. place of destination: D
3. departure date: 01-31-2011
4. delivery date: 02-04-2011
5. service modal: plane and train
6. cargo type: shoes
7. quantity: 1.2 tons
8. CO itinerary: itinerary_1: AB; itinerary_2: BC; itinerary_3: CD
9. technical skills for itinerary_01
   • geographic coverage at the source: A
   • geographic coverage at the destination: B
   • transportation of different types of loads: nil
   • modal: plane
   • realisation consolidated shipments: mandatory
   • response time: 12 hours
   • cost: $1,200 dollars.
10. technical skills for itinerary_02
   • geographic coverage at source: B
   • geographic coverage at the destination: C
   • transportation of different types of loads: nil
   • modal: plane
   • realisation consolidated shipments: mandatory
   • response time: one day
   • cost: $1,500 dollars.
11. technical skills for itinerary_03
   • geographic coverage at the source: C
   • geographic coverage at the destination: D
   • transportation of different types of loads: mandatory
   • modal: train
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- realisation consolidated shipments: mandatory
- response time: one day
- cost: $1,800 dollars.

12 LC: 1.5
13 Level of excellence = 4.5.

As explained in Section 4, the selection of the set of LPs to be suggested for the VO coordinator to compose the VO related to the given CO is carried out along in four phases:

- Phase 1: the user who gets the CO checks the associated itineraries.
- 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. The semantic search process selects KPIs which are related to the CO and weights are assigned to them (using AHP method).
- Phase 3: Calculation of:
  - the arithmetic average for each KPI
  - the standard deviation for each KPI (in this example, $S_n = 0$, and so $a = 0$)
  - the VC for each LP
  - the final LC for all LPs previously selected.
- Phase 4: 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 2.95.

The semantic search selected KPI_1 and KPI_3, and based on the AHP method the methodology assigned different weights $w$: 0.3 ($w_1$) for KPI_1 and for KPI_3; and 0.03 ($w_2$) for the other KPIs.

The process is repeated for all CO’s itineraries (2 and 3 in this case). In the case of problems during the VO execution (or before its 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 to which extent some relaxations (e.g., in the delivery time) are possible. Otherwise the VO should be cancelled.

8 Software prototype

A prototype has been developed to evaluate the proposed KPI model and the methodology. It was implemented as a software service, invoked by portals or other services. Web services technology and Java programming language were used. The prototype supports seven basic functionalities (Figure 14): CO creation, selection of CO competencies, selection of CO KPIs, selection of itineraries, calculation and suggestion of the best LP per itinerary, support for the historical analysis per LP/VO, and assignment of values to KPIs per LP after each VO has ended. The other elements of the architecture
refer to auxiliary software modules and tools, very much related to the implementation itself. The software prototype was developed to be a software service, using web services technology, under the software-oriented architecture paradigm (Josuttis, 2007). As such, it can be invoked by other services or by some wider VO management portal (which is the case) and can invoke other services. Two services are basically invoked by the prototype: one related to support semantics annotation and ontology management (on top of KIM platform (Kiryakov et al., 2004) and Protegé tool (Noy et al., 2001; Tramontin et al., 2010), and another one to search through an ontology for finding KPIs (Baldo et al., 2009).

Figure 14  Prototype architecture

These functionalities are available from a web user interface (Figure 15), that is the main prototype interface. Its main purpose is to allow the data input of the CO registration plus its competence attributes and itineraries. After this it is possible to request the calculation of the levels of collaboration with the suggested LP from the web interface. The upper side of the interface shows the CO description and the competence’s fields:

- CO name: the name of the opportunity for collaboration (Opportunity_10).
- Origin and destination: the information about the start and final place of the CO. In this example, from Joinville City to Celso Ramos City.
- CO description: The text inserted in this box will be used by the semantic search for selecting the KPIs. In this example, cost control and trust KPIs will be selected based on the words cost and trust that were found out in the text and assigned to the KPIs thanks an ontology and semantics annotations. Still related to this example, two very logical words were used to easy readers understanding. In a more real case, the description could use terms like cheap or less expensive (and then the ontology would deduce they would be related to cost control KPI) and confidence or responsiveness (which would link to trust KPI).
• Departure and delivery date: the start and end date of the CO.
• Departure time: time that the products to be transported should be carried out by the LP.
• Weight: the total weight of the product(s) to be transported.
• Fractionated freight: it requires that LPs provide fractionated freight, i.e., LPs can share the truck load space with other customers, and probably getting a cost reduction benefit.
• Transportation of different types of goods: There are some LPs that are specialised in providing transportation for specific kind of product(s). However, most of the time these LPs are more expensive than the other ones. If in the CO it is required that LPs should provide the transportation of different types of goods, it means that it is looking for a not specialised provider, and probably will offer best prices.
• LC: minimum LC requested for this CO. This level indicates the minimum LC value requested for each LP to compose the VO. Otherwise, the LP will be excluded for the selection process.
• Level of excellence: maximum value requested for selecting LPs based on linear regression analysis (Figures 7 and 8).
• Cost per ton: maximum value to be paid by the customer per ton.
• Historical CO: range of historical of past VOs to be considered for historical analysis.

Figure 15  Prototype main interface (see online version for colours)
The right side of the interface shows the 15 KPIs. For those KPIs selected for a specific CO, the mathematical algorithm will assign different weights for calculating the LC applying the AHP method.

In the middle of the interface it is possible to assign one or more itineraries for the CO. Each itinerary has the following attributes: name; departure and delivery dates; time spent for transportation; origin and destination and service modal. The last field is the service modal that selects the type of modal to be used for this specific itinerary (train, plane, truck, etc.). After the registration process of the CO and itineraries registration, the user can choose in the web interface the function to calculate the levels of collaboration and suggests the LPs to compose the VO. The fields that are shown with the results in the web interface are: itinerary name; LP name and its LC. The prototype allows the simulation of different scenarios for the same CO. This means that for the same CO id the prototype supports creating different scenarios based on different attributes, upon which the user can choose one of them.

After the VO ending, the involved LPs’ KPIs need to be evaluated. *Customer grade* and *LP grade* fields allow the evaluation of these KPIs for their further updating in the VBE database.

**Figure 16** Dashboard for LPs comparison (see online version for colours)

The prototype provides a dashboard interface available to its users (VO coordinator, LPs that are members of the VBE, and MPs). In this interface (Figure 16) users can check the LPs’ historical performance. In the upper side of the interface the user can select the type of visualisation: *partners or COs*. If the option selected is *partners*, the interface shows:
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1. The list of LPs that are members of the VBE. For each LP (one per line) the following attributes are shown.
   - Id and name: the identification and name of the LP.
   - Available: shows the condition of the LP in the VBE. A LP may be available (true) or not (false). If the LP is currently not available it is considered by the methodology, i.e., it will not be searched during the process to compose VOs.
   - Linear regression: contains the coefficient of linear regression for that LP. The coefficient may be positive (ascending line) or negative (descending line).

2. The graph on the left side: the bar graph shows, for each KPI selected (above the graphic), its historical value for one or more LPs simultaneously. For example, Figure 16 shows the historical values of the governance KPI for three LPs selected above (LP1, LP3, and LP5). The user can then analyse and compare LPs’ performance.

3. The graph on the right side: This bar graphic shows the linear regression line for each LP selected, considering a history of the past ten VOs. Based on that information the user can verify if the performance of a particular LP is ascending or descending over the time and compare with others LPs’ performance.

9. Methodology evaluation

Besides the implementation a the software prototype to verify the proposed new KPI model and LP suggestion methodology, this work was also evaluated by 11 specialists (four from the academia and seven from logistics companies) in the three core areas of the work: logistics, performance measurement and VOs. The expert panel technique (Beecham et al., 2005) was used for that by means of a questionnaire filled up after they had been introduced to the model and the software prototype. This questionnaire covered three aspects, having several questions related to each one:

1. questions about KPI model and its 15 indicators
2. about the methodology
3. about the software prototype.

The main results came up from the questionnaires were:

- 91% of the specialists agreed about the problem relevance and the adequacy of the approach and of its originality.
- 100% of the specialists agreed that the proposed model has the potential to increase the agility of the VO creation process, to increase the transparency in the selection process, to increase the quality of the suggested/selected team of companies, and to decrease the risk of failure in the VO operation.
- 100% of the specialists agreed about the approach adequacy in considering the competency analysis and the historic values of the LC for each LP.
100% of the specialists agreed that the 15 KPIs were suitable to cope with CNO requirements in a scenario of LPs’ selection.

100% of the specialists agreed that the proposed model can help improving the KPIs of each LP as long as they are forced to become better and better in order to be selected to enter in a VO as well as they can know in a more precise way which are the most adequate PIs that they should focus on to improve.

100% of the specialists agreed that the prototype worked in accordance to the specification and methodology. Yet, that its functionalities help users in selecting LPs and managing VOs through the information related to historical performance and competencies.

91% of the specialists agreed that the work as a whole has the potential to be used in the future by SMEs (belonging to a VBE) to form VOs.

10 Conclusions

This paper has presented a novel model and supporting methodology for the selection of the most adequate LPs to compose VOs. The complexity of the problem refers to the intrinsic dynamics, temporality and autonomy of VOs, whose partners (including logistics ones) can only be identified when the collaboration business opportunity arrives and it is identified what it is about. Therefore, it is of extreme importance to not only making this process of selecting VO partners faster but also with more quality and confidence.

A new performance model has been presented and it is devoted to cope with those singularities of VOs. It is composed of 15 KPIs and it is used to compare companies’ competences and general performance. This comparison can be tuned to each business regarding its particularities and hence the level of importance of the KPIs. The set of LPs that will form a VO is selected based on their LC, also considering their past performance.

An ontology was devised to establish the relation among business requirements, KPIs and competences. Thanks to a set of semantic annotations and ontology population, it was possible to reason about the collaboration business opportunity’s description and hence to identify which were the most possible suitable KPIs under which LPs would be selected.

Compared with the state of the art in the literature, it can be said that the main contributions of this work are: the specification of a KPI model devoted to VO and logistics; the supporting methodology for that; and the concept of LC as an indicator to measure the level of general readiness of a LP to compose a VO.

The model, methodology and software prototype were, however, not validated in real cases. Being a partially exploratory work, it could only be tested in a controlled environment and analysed by a small group of specialists.

Main next steps of this work refer to the introduction of risk analysis as an additional perspective of partner’s suggestion, the extension of the methodology to include a learning process after VO finalisations, and the possibility of selecting more than one LP per itinerary.
References


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