A Risk Analysis Method to Support Virtual Organization Partners' Selection

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Abstract. The Virtual Organization (VO) concept has emerged as a promising form of collaboration among companies by providing a way of sharing their costs, benefits and risks when attending to demands. When manufacturing processes and physical distribution of products are involved, the process of VO creation demands the selection of both Logistic Partners and Industrial Partners. This VO composition requires several aspects to be considered to ensure the VO correct operation, synthesized in the form of risks. Proper risk analysis provides more solid means for managers to evaluate and further decide about the more suitable VO composition for a given business. This work presents an integrated and quantitative risk analysis method to support Partners' Search and Selection process within the VO creation phase. A set of algorithms have been developed to measure the risk considering a number of risk categories and performance indicators. A general example is showed and results are discussed at the end.

Keywords: virtual organization, partner's selection, risk analysis.

1 Introduction

Virtual Organization (VO) has emerged as a powerful enterprising strategy to leverage Small and Medium sized Enterprises to increase their value and better compete in the market [1]. This is possible due to its intrinsic properties, which provide a more systematic form of collaboration in dynamic business scenarios, involving autonomous, heterogeneous and geographically dispersed companies that join their efforts with the aim of attending given demands (collaboration opportunities - CO), sharing costs, benefits and risks, acting as one single enterprise [1].

One of the issues related to VOs refers to on how its members are selected. Most of works in the literature considers a VO as formed only by "industrial partners" (IP), i.e. the ones that "manufacture" the different parts of a good.

However, when the business involves manufacturing processes along a value chain, the VO composition should be *complemented* with other partners, namely logistics operators (LP). From the logistics theory point of view, by LP it is considered in this work the types 2LP and 3LP [2], responsible for the transportation, delivering and intermediate storage of goods between IPs and final customers. As such, different indicators are required for selecting LPs when compared to IPs [2].

It is assumed in this paper that both LPs and IPs are members of a long-term alliance, like a Virtual organization Breeding Environment (VBE) [3], so sharing some basic and common principles of collaboration, quality and performance.

Several works in the literature have approached the problem of selecting partners via an analysis focused on members' competences, capacities and historical performance [4-6]. Alawamleh *et al.* [7, 8] have pointed the importance of enlarging these dimensions considering risk analysis. The essential rationale is that, even taking those dimensions into account, there is a risk of failure in any event or partner and hence in the VO to succeed. Besides that, partners can be good when working individually, but not well *too* when collaborating with other partners in a joint business, as in a VO [9]. These aspects are critic as a VO reflects a sharing of duties among companies and it has an intrinsic dynamic nature of relationships [7].

Literature review has showed a lack of works that considers measuring risk upon the entire VO (i.e. IP plus LP) as well as that analyzes its partners regarding their collaboration quality and intensity within an integrated framework.

In general, the problem to be tackled in this research consists in selecting which are the most suitable LPs to be joined to a VO of previously pre-selected IPs that, when seen as a whole, have the lowest risk?

In previous works, authors have conceived a method to select LPs for given VOs [6] and to analyze LPs risks [10], so without considering neither IPs (i.e. the VO as a whole) nor evaluating how good they might be when working together. Therefore, that is core contribution of the proposed method in this paper. By means of a set of quantitative analysis, involved VO managers can have better conditions to evaluate how risky every possible VO composition is. Another facet of the value proposition refers to the systematization of the risk analysis and associated decision-making processes so providing more agility and transparency when creating new VOs.

The remainder of this paper is organized as follows: Section 2 addresses the partner's search and selection problem in the context of risk analysis. Section 3 introduces the proposed method for risk analysis. Section 4 presents an example of the method. Finally, Section 5 presents some conclusions about current achievements.

2 General Background

Risk management is an important foundation to several fields of decision and control management. In brief, risk can be defined as the probability of an event to occur and that causes a negative or positive impact on the organization's goals when it takes place [11]. In the context of this research, a risk is characterized by the potential of a partner (LP or IP) - that is in principle able to be member of a VO - to do not perform correctly its assigned task regarding the associated CO's requirements and hence hazarding the VO success.

A number of works on risk analysis have been proposed on networks (e.g. [4, 5, 10, 11, 13]), hence potentially suitable for VOs. They are important as offered some insights for devising the basics of the requirements to be supported, in more particular: partners should be analyzed both individually and collectively; all links between any two partners must be measured; there is a need to analyze all partners together when considering the interrelationships among them; such analysis should be made via some explicit and transparent performance criteria.

In that same line, there is a number of methods that can be applied to model risks and to support their analysis, as evaluated in [10]. ETA (Event Tree Analysis) [12] and

ANP (Analytic Network Process) [5] were selected regarding those requirements. As this paper also embraces another dimension, which refers to how partners are able to or have successfully worked in past partnerships, a more proper method had to be evaluated. The *Intensity Analysis* [13] approach has been selected and so combined with ETA and ANP.

In the state of the art review, some works related to risk analysis for VOs have also been found out and have provided some designing elements to the proposed methods. For example, in [7] thirteen KPIs (Key Performance Indicators) were identified as general risk sources for VOs as well the importance of each one. In [14] the advantages of AHP/ANP over the other multi-criteria decision making methods to assess VO risk sources were discussed.

All the reviewed works in the literature have proposed contributions to isolated elements of the whole problem tacked in this research. In other words, none of them have devised approaches or methods that analyze risks upon both IP and LP individually and collectively in a systemized and integrated framework, and also considering partners relationships intensity for risk analysis purposes.

3 The Proposed Method

The proposed method corresponds to an incremental research work developed on top of three previous works. Firstly, a partners' search and selection work was developed to select the most suitable IPs for given VO, strongly based on IPs' capabilities [15]. After that authors developed an equivalent work but focused on selecting LPs, based on a KPI model composed of 15 indicators [6]. Later on authors complemented this last work by adding the risk dimension when selecting LPs, using four main KPIs: trust, communication, collaboration and commitment [10]. In the work presented in this paper, risk is also applied to IPs so to the whole VO. Besides that, it adds another risk dimension, considering the relationships "quality" among pre-selected VO members (IPs + LPs). For that, and based on the studies presented in [8], three aspects were taken as the most critical ones in terms of sources of risk: trust, commitment and information sharing. They were modeled as KPIs and their values were calculated using the method developed in [6].

The fundamental rationale of this additional dimension is that a VO could be composed by the best companies from the performance point of view but that never had worked together before. The premise is that this lack of previous relations can hazard the whole VO performance, i.e. this can put the VO in risk. Regarding this, the proposed risk analysis framework has three hierarchical layers, as illustrated in Fig. 1.

The first layer is responsible to handle the aspects related with partner's search and selection, including the selection criteria and the used KPIs [6]. The second layer provides an extension of a risk analysis method to select LPs and so to compose VOs, [10], also considering an analysis upon the pre-selected IPs and the relationship intensity between all of them. This layer evaluates the pre-selected LPs (represented by triangles) and IPs (rectangles). Finally, the third layer aggregates the results from the second layer to assess the risk level of the whole VO. It applies the Analytic Network Process (ANP) [5] method over the previous analyzed partners (LPs and IPs) to measure the aspects of collaboration among them and to further generate a so-called Global Risk Level (GRL) score for the VO. Managers can then compare this afterwards for the final decision-making about the most suitable members and less risky composition for a given VO. Next subsections detail each of these layers.

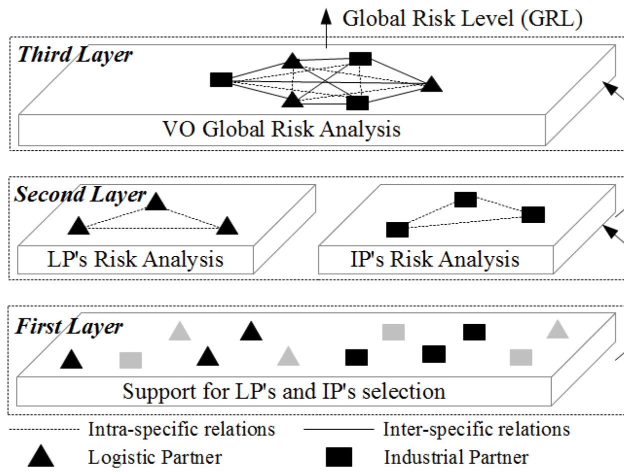

Fig. 1. General view of the proposed method.

3.1 First Layer

The first layer provides the support for primary partner's search and selection (LPs and IPs). As already mentioned, this is made by means of a 15 KPI-based method that considers both intra- and inter-organizational indicators [6], which in turn takes into account technical competence, temporal availability, CO's requirements, and historical performance in past VOs [6, 16]. A KPI vector with 15 positions is created for each partner and this vector is further transformed into a normalized value called "level of collaboration". Decision-makers can then compare partners via their level of collaboration, including the possibility of weighting some priority KPIs according to the business requirements.

3.2 Second Layer

The second layer performs the risk analysis itself both for the group of IPs and for the group of LPs pre-selected in the first layer. This division into two subgroups is due to the fact that (mainly) IPs use to have some more strict relations with each other.

Formally, it is assumed that a VO is represented by a graph $G = (V, E)$, where V corresponds to a set with LPs and IPs, and E the relations between them. In order to handle the two different groups of partners, the graph G is split into two sub-graphs: $G' = (V', E')$ and $G'' = (V'', E'')$, where V' and V'' represents the set of LPs and IPs, respectively, and E' and E'' represent the relations among them. Besides that, there are two types of relations among the partners: *intra-specific relations*, which occur between

IPs *or* LPs; and *inter-specific relations*, which consider the relations between LPs *and* IPs. Only intra-specific relations are considered in this second layer.

The process of analyzing the individual G' and G'' risks and the further collective analysis is showed in Fig. 2. It corresponds to an extension of the previous work [10] by adding the following three main modifications:

- automation of the previous method, removing the human mediation of the VO manager from the two stages of the method;
- enlargement of the types / sources of risks upon IPs and LPs but respecting the particularities of the two types of 'services' and hence the way they are analyzed for each of these two cases.
- modification of the collective analysis algorithm by considering the intensity of intra-specific relations, so a basis for calculating the risk of G' and G''.

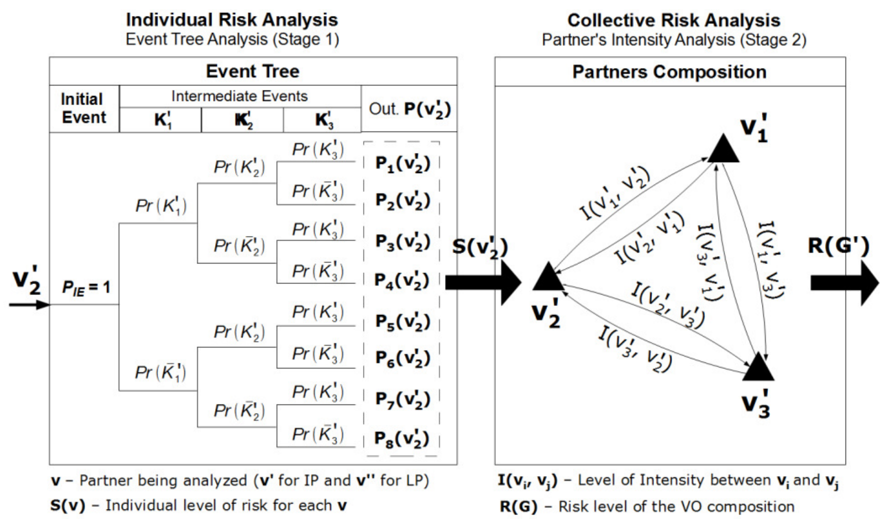

Fig. 2. The second layer of proposed method

For the sake of simplicity, the formalization procedures will just consider the operations for one of the two group of partners (G' and G'') since these operations are equally performed for the two groups. It can be formalized as follows:

Let $G' = (V', E')$ be a G sub-graph (as previously mentioned), where $V' = (v'_1, v'_2, \cdots, v'_n)$ represents the set of n LPs. Let $K' = (K'_1, K'_2, K'_3)$ be the set of three KPI (trust, commitment and information sharing) associated to each v'_n. Applying ETA method upon each element of V' it will result $P(v'_i) = (P_1(v'_i), P_2(v'_i), \cdots, P_8(v'_i))$, as the set of all possible outcomes from the 2^K event combinations in the ETA event tree (where 2^K represents the number of elements in K). The detailed procedures for obtaining $P(v'_i)$ are in [10].

Once defined all possible outputs of P for each v'_i, the method calculates the $S(v'_i)$, which represents its quantitative risk level. The procedure for this calculation considers the application of a Harmonic Weighted Average (HWA) over all $P(v_i')$ values [17]. Therefore, the method will be able to analyze the G' risk from the set of obtained results $S(v_i')$, i.e., the risk of each partner.

The collective analysis of G' (i.e., for all $v_i' \in G'$) will be performed by measuring the level of intensity among the partners who compose it. The intensity (also referred as level of correlation) is a concept widely adopted in network theory for measuring how connected two or more elements are in a network [13]. In this work the intensity is modeled between two partners (i.e. LPs to LPs, or IPs to IPs) and considers two different indicators [13]: the *VO co-participation* and the *feedback*. *VO co-participation* between two partners v_i' and v_j' is referred as $C(v_i', v_j')$ and means the number of VOs that they have previously collaborated with. *Feedback* of a partner v_i' over v_j' is referred as $F(v_i', v_j')$ and means the average score that a provider v_i' gives to a partner v_j'. C is calculated equally in a bi-directional relation, while F is calculated separately for each of the two directions.

Given the two previous mentioned indicators, the intensity $I(v_i', v_j')$ can be calculated by averaging $C(v_i', v_j')$ and $F(v_i', v_j')$ values. Given that the two indicators have different evaluation scales (i.e. two partners can attend any amount of VOs, but the feedback is restrict in a scale from 0 to 10) then a normalization vector $n(f(x))$ had to be defined, where $f(x)$ represents the function to be normalized in a scale that varies from 0 to 1, as seen in Eq. 1. Thus, applying Eq. 1 the normalized VO co-participation $C_N(v_i', v_j') = C(v_i', v_j')\, n(C(E))$ and feedback $F_N(v_i', v_j') = F(v_i', v_j')\, n(F(E))$ can be obtained. The *level of intensity* is defined according Eq. 2:

$$\boldsymbol{n}(f(x)) = \left(\frac{1}{max(f(x))}\right) \quad (1)$$

$$I(v_i', v_j') = \frac{C_N(v_i', v_j') + F_N(v_i', v_j')}{2} \quad (2)$$

Once again, from the intensity among all v_i' of G', it is necessary to perform a general calculation to obtain the risk level of G'. The risk level is represented by $R(G')$ (Eq. 3). The first part calculates the average of the individual risk levels of each $v_i' \in G'$, and the second part calculates the average of the sum of intensities $I(v_i', v_j')$ and $I(v_j', v_i')$. The values obtained are then averaged again in order to obtain the final level of risk.

$$R(G') = \frac{1}{2}\left(\sum_{i=1}^{|V'|} \frac{S(v_i')}{|V'|} + \sum_{j=1}^{|V'|-1} \sum_{k=j+1}^{|V'|} \frac{I(v_j', v_k') + I(v_k', v_j')}{2\,|V'|}\right) \quad (3)$$

3.3 Third Layer

The third layer of the proposed method performs a high-level analysis of the VO by aggregating the results provided by the second layer (i.e. the set of LPs and IPs) to calculate a Global Risk Level (GRL) of the entire VO. The Analytic Network Process (ANP) [5] was used by its ability to deal with interdependent attributes. Moreover, the

ANP method is very suitable for decision-making problems that involve multiple criteria variables.

The ANP initial set up consists of identifying and structuring the elements belonging to three basic groups: goal (A_G), criteria (A_C) and alternatives (A_A). In this work, the goal (or objective) refers to calculate the Global Risk Level (GRL) of the VO. The criteria are represented by the outputs of the second layer, i.e., the set $A_C = \{S(x), R(x)\}$, where $S(x)$ and $R(x)$ represent the individual level of risk of each v_i' or v_i'' and the level of risk of G' or G'', respectively (the values of the criteria change according to the partner being analyzed). The alternatives are represented by the set $A_A = (v_1', \cdots, v_n', v_1'', \cdots, v_m'')$, comprising all the v_i' and v_i'' partners. Fig. 3 shows the network structure, which comprises the goal, criteria, alternatives, and the relationships (represented by the arrows).

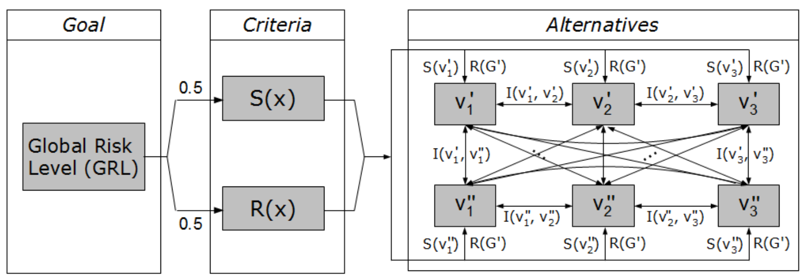

Fig. 3. The third layer of proposed method.

Having structured the problem of VO risk analysis in terms of the three ANP clusters, the method's algorithm can be summarized in four steps:

1. Define relationship weights: At this step all the relationships between criteria (A_C), alternatives (A_A) and the goal (A_G) are weighted. These relationships, when normalized, represent the influence of an element over the other. However, they can be initially defined with non-normalized values. In this work, these relationships are split into three types: *relationships from goal to criteria* (i.e. the importance of the individual risk level of each partner and the overall risk of the composition of all partners); *relationships from criteria to alternatives* (i.e. the influence of the two criteria over a partner); and *relationships from alternatives to alternatives* (i.e. the level of intensity that a partner has one to another).

2. Build an unweighted supermatrix: In this step the normalized values [17] obtained in the previous step are added to an unweighted supermatrix S_U. This supermatrix models the relationships among all the elements of the system and it represents the importance of each element within its own clusters. The supermatrix S_U has dimension d, where $d = |A_A| + |A_C| + |A_G|$, i.e., the number of partners, criteria and the goal (Eq. 4). The relationships between

criteria and between alternatives and goal are not considered in this work, so their values are assigned to zero in the supermatrix (Eq. 4).

$$S_U = \begin{array}{c} \\ v_1^{'} \\ \vdots \\ v_m^{''} \\ S(v) \\ R(v) \\ G \end{array} \begin{array}{c} \begin{array}{cccccc} v_1^{'} & \dots & v_m^{''} & S(v) & R(v) & G \end{array} \\ \left[\begin{array}{cccccc} 1.00 & \dots & I(v_1^{'}, v_m^{''}) & 0.00 & 0.00 & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ I(v_m^{''}, v_1^{'}) & \dots & 1.00 & 0.00 & 0.00 & 0.00 \\ S(v_1^{'}) & \dots & S(v_m^{''}) & 0.00 & 0.00 & 0.50 \\ R(G') & \dots & R(G'') & 0.00 & 0.00 & 0.50 \\ 0.00 & \dots & 0.00 & 0.00 & 0.00 & 0.00 \end{array}\right] \end{array} \quad (4)$$

3. Build a weighted supermatrix: Given the unweighted supermatrix S_U obtained in the step 2, this third step performs the specification of a weighted supermatrix S_W, i.e, a stochastic matrix that represents the general importance of each element considering all groups (A_C, A_A and A_G) simultaneously. To make this possible, another normalization procedure is performed, where each element is divided by the sum of all its elements for each column (Eq. 5).
4. Calculate limit supermatrix: The last step on the ANP consists in calculating a limit supermatrix S_L, which is obtained by raising the weighted supermatrix S_W to power (i.e, $S_L = (S_W)^k$ for $k = 1, 2, \ldots$) until the convergence of its values (i.e., for every column $(S_L)_j$, $(S_L)_j = (S_L)_{j+1}$) is reached. This convergence will always occurs given the stochastic nature of the supermatrix S_W. The final results are represented by a column matrix X that is generated from any column $(S_L)_i$. The matrix X presents the level of risk of each partner in relation to the goal (Eq. 6).

$$(S_W)_{ij} = \frac{(S_U)_{ij}}{\sum_{k=1}^{d} (S_U)_{kj}} \quad (5)$$

$$X = \begin{array}{c} \\ v_1^{'} \\ \vdots \\ v_m^{''} \end{array} \begin{array}{c} A_G \\ \left[\begin{array}{c} w_1 \\ \vdots \\ w_{n+m} \end{array}\right] \end{array} \quad (6)$$

The Global Risk Level (GRL) of the VO can be obtained summing up all elements of the matrix column X.

4 An Illustrative Example

This section presents an illustrative example of the proposed method to provide a better understanding of its operation. Initially, suppose that a CO was created to attend to a given demand and a set of three LPs and three IPs were selected (via the first layer of the proposed method) to compose a new VO. LPs and IPs are represented, respectively, by two sub-graphs of G_{VO} (where $G_{VO} = G_{IP} \cup G_{LP}$), $G_{IP} = (V_{IP}, E_{IP})$, where $V_{IP} = (IP_1, IP_2, IP_3)$ and $G_{LP} = (V_{LP}, E_{LP})$, where $V_{LP} = (LP_1, LP_2, LP_3)$.

In order to measure the risk level of the G_{IP} and G_{LP}, they are submitted to the second layer of proposed method, firstly applying ETA calculation. In ETA, the risk (considering G_{IP} and G_{LP}) takes into account the quantification of three risk sources: trust, commitment and information sharing. Although it is not possible to show here how the KPIs associated to these sources were calculated, its values are necessary to obtain the set of probabilities $P(v)$, where $v = \{IP_1, IP_2, IP_3, LP_1, LP_2, LP_3\}$ as showed in Table 1. In this case, applying the Harmonic Weighted Average (HWA) calculation over all $P_i(v)$ values (i.e. the outputs of the ETA method - see description at Section 3), it can be obtained the individual risk level of each partner ($S(v)$), which is used to calculate the risk of the sub-graphs G_{IP} and G_{LP}. This procedure is performed equally for all the six partners (IPs and LPs) that are being analyzed.

Table 1. Results from event combinations for all partners of G_{IP} and G_{LP}.

	$P(v)$								
	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	S
IP_1	0.392	0.168	0.168	0.072	0.098	0.042	0.042	0.018	0.584
IP_2	0.612	0.153	0.108	0.108	0.068	0.017	0.012	0.003	0.767
IP_3	0.360	0.240	0.090	0.060	0.120	0.080	0.030	0.020	0.569
LP_1	0.494	0.026	0.123	0.006	0.266	0.014	0.066	0.003	0.614
LP_2	0.608	0.152	0.032	0.008	0.152	0.038	0.008	0.002	0.734
LP_3	0.810	0.090	0.090	0.001	0.000	0.000	0.000	0.000	0.885

Next step (yet at the second layer) refers to performing the collective analysis of G_{IP} and G_{LP}, which is carried out by means of the intensity analysis. Table 2 (left) presents hypothetical numbers of previous VO participations and the feedback of each relationship among all pairs v_i, v_j, where both $v_i, v_j = \{IP_1, IP_2, IP_3, LP_1, LP_2, LP_3\}$. The intensity of each two partners is calculated applying Eq. 3 and it is presented in Table 2 (right). Then the risk level R of G_{IP} and G_{LP} can be also calculated.

Table 2. (left) Quantitative values of VO Co-Participation and Feedback for all partners of G_{IP} and G_{LP}; (right) Level of intensity among all partners of G_{IP} and G_{LP}.

	G_{IP}			G_{LP}		
$C; F$	IP_1	IP_2	IP_3	LP_1	LP_2	LP_3
IP_1	–	15; 5.5	27; 7.1	33; 6.8	65; 9.1	41; 8.3
IP_2	15; 6.3	–	22; 6.9	10; 8.3	68; 9.7	67; 8.3
IP_3	27; 7.4	22; 7.6	–	49; 7.0	26; 8.3	14; 9.8
LP_1	33; 5.5	10; 5.7	49; 6.8	–	39; 8.1	66; 7.6
LP_2	65; 8.7	68; 9.4	26; 9.5	39; 7.4	–	62; 9.3
LP_3	41; 7.0	67; 8.9	14; 7.1	66; 8.5	62; 7.7	–

	G_{IP}			G_{LP}		
I	IP_1	IP_2	IP_3	LP_1	LP_2	LP_3
IP_1	–	0.39	0.56	0.59	0.94	0.72
IP_2	0.43	–	0.51	0.52	0.99	0.91
IP_3	0.57	0.55	–	0.71	0.61	0.60
LP_1	0.52	0.36	0.70	–	0.70	0.87
LP_2	0.92	0.98	0.67	0.66	–	0.93
LP_3	0.66	0.96	0.46	0.92	0.85	–

$$R(G_{IP}) = \frac{1}{2}\left(\frac{0.584+0.767+0.569}{3} + \left[\frac{0.43+0.9+0.57+0.56+0.55+0.51}{2*3}\right]\right) = 0.730$$

$$R(G_{LP}) = \frac{1}{2}\left(\frac{0.614+0.734+0.885}{3} + \left[\frac{0.70+0.66+0.87+0.92+0.93+0.85}{2*3}\right]\right) = 0.783$$

The third layer of the method consists in aggregating the partners of G_{IP} and G_{LP} and the results of second layer (S and R) to analyze them as a whole. This is done using ANP method calculation, whose network structure was presented in Section 3. Three *normalized* relations (related to criteria, criteria to alternatives, and alternatives to alternatives goals) are assigned in order to build the unweighted supermatrix S_U. The normalization procedure for each column of the unweighted supermatrix is executed after that, resulting in the weighted supermatrix S_W. The limit supermatrix S_L can also be built up by raising S_W until their values converging. This matrix shows the risk level of each partner in relation to the goal. The final results are represented by a matrix X that is generated from any column of S_L:

$$\mathrm{X} = \begin{array}{cc} & \begin{array}{cccccc} v_1' & v_2' & v_3' & v_1'' & v_2'' & v_3'' \end{array} \\ A_G & \begin{bmatrix} 0.10 & 0.07 & 0.12 & 0.09 & 0.08 & 0.13 \end{bmatrix} \end{array}$$

Finally, summing up all elements of X, the *Global Risk Level* of the VO G_{VO} can be calculated:

$$GRL = \sum_{i=1}^{|X|} X_i = 0.09 + 0.07 + 0.11 + 0.09 + 0.08 + 0.12 = 0.59$$

Considering this example, the VO as a whole has 59% chance of success. This value should then be used by the VO manager or responsible actor to decide how low or high this value is to be handled regarding the given CO. The whole method should be all over executed again (so including a new round of IPs and LPs' search and selection) for other evaluations looking for a less or for the lowest risky VO composition in the case such manager considers that the calculated risk is too high.

5 Final Considerations

This paper has presented results of an ongoing research on VO risks measurement and analysis. It provides an additional decision dimension to managers in the VO creation phase indicating not only the most capable teams of companies to form a VO, but also which are the less risky VO compositions for a given business.

Compared to the state-of-the-art in the area, the proposed method adds value when comprises the entire VO in the risks calculation, i.e. both industrial and logistics partners. Besides that, it considers partners relationships intensity and historical performance, having as the premise that a given VO composition would be less risky if partners have already worked together before in a good way.

The method is strongly based on performance management, whose information about partners is modeled as KPIs. The method is constituted by some steps, providing decision-makers with a more systematized, transparent and quantitative process of partners' search and selection. On one hand this helps VBE and VO stakeholders to identify and mitigate risk sources, both in the VO creation and further operation phases.

On the other hand, this gives more confidence to managers for their decision-making, helps in the trust building among autonomous partners, and in the creation of a basis for continuous improvement. Actually, the essential purpose of the proposed method is not to automate the risk analysis process. Instead, it aims at providing VO managers with additional information about VO members and possible compositions for better and more agile decision-making, so helping to speed up the VO creation process.

The proposed method splits the problem solver into three hierarchical layers, which one using adequate techniques for risk calculation and modeling. Although implemented within a computing controlled environment and using hypothetical values, the achieved results gave evidences about its potentialities to be applied in real cases. However, other dimensions of the problem have to be dealt with for real VOs, such as the organizations, cultural and financial impacts of the implementation of a method like the one proposed. This is out of the scope of this current research though.

Three assumptions are important to be pointed out about the proposed model. The first one refers to assuming that companies are all members of a VBE-like long-term alliance, which tends to facilitate tremendously the collaboration among members and their performance measurement and management, key aspects for the proposed model. The second one is that the third model's layer inherits a "legacy" from two previous authors' works. Industrial partners and logistics partners are grouped separately (at the second layer) instead of being put all together into a large single group. This might facilitate the calculation of the optimum VO partners' combination/composition in terms of the best risk case, but this increases a lot the combinatorial problem and the algorithm's complexity. The third assumption refers to the type of partners a VO can have. In fact, "real" VO may comprise other type of "actors" (e.g. auxiliary services providers, regulatory institutions, etc.). In the current stage of our work it is assumed that such partners are equivalent to IPs in the sense they are responsible for relevant tasks of the given VO.

The model was evaluated only experimentally, in a simulated way, using hypothetical data. Actually it is very difficult to get data from companies and VOs, in particular the ones related to performance and historical behavior. The used data was however conceived based on the authors' experience on CNO and inspired in some VBE/VO pilots involved in a past EU project as well as in on current pilot being developed in the South of Brazil close to a mould-makers cluster.

The results obtained from the collective risk analysis (based on the qualification and quantification of the level of intensity between partners provided by the ANP method) lead us to realize that the method gives more transparency and assertiveness in the risk measuring process.

Future work mainly includes testing the method in near-real scenarios as well as extending the devised framework to also consider risks in the VO operation phase.

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