# Dimensioning Virtual Organizations based on Risk Levels

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**Abstract.** In an increasingly competitive market, small and medium enterprises have the option to take advantage of collaboration opportunities to consort their core competencies to achieve an objective. In fact, this is the purpose of the so-called Virtual Organizations (OVs), which aim to attend a goal joining partner forces. However, when these Virtual Organizations are created, it is necessary to deal with the maximum number of participants involved in the process and the risk involved in these relationships, which should be measured through a well-defined process. This paper aims to present an approach to dimensioning the number of participants involved in the formation of a Virtual Organization composed of several service providers (SPs). This approach is based on the overall risk level of the participants and uses different Risk Analysis Methods to assess the suited number of participants to be part of a Virtual Organization.

**Keywords:** Virtual Organization, Dimensioning, Risk Analysis

## 1 Introduction

Recent years have witnessed the explosion of the use of computers in daily life and business. Information Technology and Communication (ICT) began to stand out in everyday use of organizations, from the development of the interconnection between machines (Internet) to the popularization of mobile devices (tablets and smartphones). The increasing use of technology in business operations allowed the organizations to be assisted in decision-making and how to manage their new products, thus sharpening the competitiveness and expanding trade barriers.

The quest for efficiency and fast responsiveness to market stimuli presents a series of new challenges for enterprises leading to a question: how to attend several demanding customers in such a short time and with a great quality of service? One answer that can be found in the literature is: Virtual Organizations (VOs). A VO consists of a set of independent organizations (companies) that share resources, skills, costs, risks and information, where each member collaborates in a certain function in order to achieve a mutual goal [4, 6].



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The VOs have many advantages ranging from adaptability and flexibility to the ability to quickly respond to market changes. However, it is not always easy to determine the number of participants to begin the process of collaboration. This task is often performed based on the VO manager's perception and on successive attempts based on trial and error. Therefore, the use of a scientific and well defined approach to dimensioning the number of VO participants supports the VO manager decision regarding the number of competencies and sub-competencies to be managed and it also increases the confidence of partners involved in the VO formation and operation [5, 9].

Thus, this paper addresses the problem of dimensioning the number of VO participants based on their overall risk level. Therefore, this work consists on analysing the VO behavior regarding the involved risks when raising the number of partners involved in its formation.

The remainder of this paper is organized as follows: Section 2 covers the essential concepts for understanding how VO works, as well as understanding their risks and their dimensioning. Section 3 describes how the proposed dimensioning approach is structured. Subsequently, Section 4 describes the scenarios and simulations in order to validate the designed proposal. Finally, Section 5 presents conclusions and future work.

## 2 Related Work

### 2.1 Virtual Organizations

As aforementioned, different enterprises, i.e., service providers, can collaborate in order to achieve a particular goal. This paper uses the definition of VO formation according [6], which recommends a series of steps ranging from the identification of the collaboration opportunity to the launching passing through partners search and selection ones.

In the context of this work, the VO dimensioning works as an auxiliary approach to decision making in the partners search and selection step. This is the moment when the VO manager analysis the necessary partners to compose a VO. Thus, the dimensioning process execution instigates the VO manager to check if there really is a need to allocate certain partners, splitting or not the core competency in sub-competencies to attend the same collaboration opportunity (OC).

### 2.2 Risk Analysis

The word risk is associate to notions of uncertainty. Risk is the chance of something happens causing a negative impact on the objectives on a given task. In the literature it is found some definitions for risk. Bernstein [3] and Alawamleh [1] state that risk is the probability of an adverse event, causing a kind of uncertainty, generated by decision alternatives of an administrator.

Several risk factors threat the alliance operations between partners. These factors can be used to derive risk levels. Particularly, risk levels can be measured

by means of occurrence probability, consequence degree and control degree [12]. According Alawamleh [1] risk comes from three sources: organization internal sources; organization external sources and; organization environment.

Taking this into account, the risk definition in the context of VOs becomes the likelihood of one or more participants do not attend the minimum demanded requisites of the CO and because of that compromising the success of the VO operation. Moreover, it is worth noting that participants depend on each other, raising the probability of fault occurrences. In this sense, using the Alawamleh's definition [1], it is possible to say that the risk in VO can be involved in: 1) Internal risks: reliability and quality of the participants; 2) External risks: cultural, social and operational environment of the participants; 3) Organization environment: network infrastructure or means of interaction of the participants.

Several risk analysis methods have been proposed in literature. Particularly, regarding risk analysis in the context of VO, Vieira et al. and de Lemos et al. [11, 15] present different risk analysis methods based on historical key performance indicators such as confidence, collaboration, information sharing and communication processed by a combination of multi-criteria decision making approaches. Basically, these approaches are applied in the partners search and selection step of the VO creation stream leading to the selection of the least risky partners therefore minimizing the chance of VO failure during its operation.

This risk analysis approach is well suited for the purposes of VO dimensioning. It makes possible to choose the right quantity of partners to compose a VO without raising the global risk to unacceptable levels.

### 2.3 Dimensioning Overview

According [14], dimensioning should be done whenever the responsible for a particular operation feels the need of checking if his resource sets are correct and well balanced regarding current and future demand. Moreover, it should be prioritized not only at the beginning of a project but also in the optimization of existent structures.

The attention to the client needs fosters enterprises union. The availability of the number of resources and people that have appropriate skills, experiences and competencies at the opportune place and moment becomes an stimuli to the involved organization managers. It is worth noting that the VO composition do not has a limitation on the participants number. However, this flexibility needs to be identified and measured through a well defined process.

The determination of the number of participants for the formation of a VO is not easy and widely explored in the literature. Most publications highlight the advantages of the formation of the VO itself rather than how it is actually done [6, 10]. It is important to note that only a proper structural configuration (e.g., techniques, methods or approaches) can take advantage of all the benefits expected by a VO (e.g., sharing skills, resources, costs, risks, trust and information). Considering that, the number of participants is an essential variable on this context. Therefore, this paper focuses on the process of how to find the best total number of participants in a VO.

Several important contributions are found in literature depicting characteristics that can be used to achieve suitable VO dimensioning. Some of these characteristics [2] are: a) time, which involves delivery time, short or long-term contracts, etc.; b) cost, which involves market performance, profitability, necessary resources, etc.; c) risk in the association with other participants. This work copes with the risk characteristic. Thus, the dimensioning is achieved analysing the VO behavior based on the existent risks between the involved participants.

## 3 Proposed Dimensioning Approach

As aforementioned, the proposed dimensioning approach is based on the risk assessment of the VO participants. Sections 3.1 and 3.2 present the two risk analysis methods used to accomplish that. These methods work at the set of service providers committed to the VO creation and they assume these service providers keep available a key performance indicators (KPI) historic. According Nelly et al. [13], a KPI is considered a metric or a combination of metrics that aims to quantify the efficiency and/or effectiveness of part or the full process, project, system or product.

Therefore, the partner's risk level is generated by these methods using KPI historical data. Regarding this work, the four risk sources that presented more occurrences in the Alawamleh's work [1] were used as KPIs. These KPIs are: confidence, communication, collaboration and information sharing.

### 3.1 MARTP

The MARTP method [16] aims to measure how risky is to use a particular SP in the VO composition. MARTP is split in two stages. First stage analyses the individual SP risk and the second stage performs a collective risk analysis involving all selected SPs. MARTP is presented in Fig. 1a.

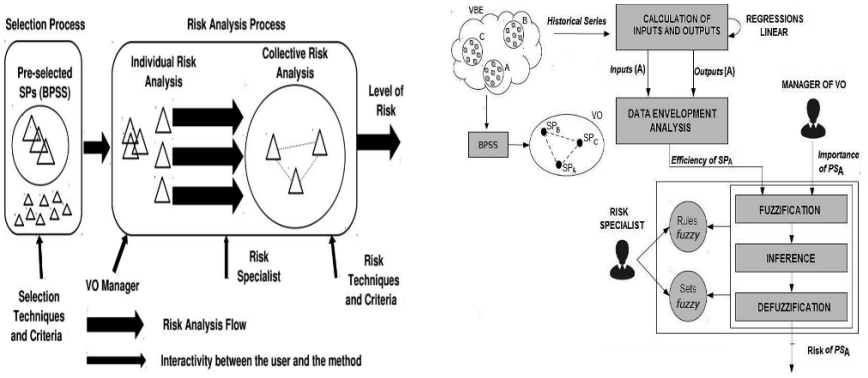
The first stage (left side of Fig. 1a) performs the individual risk analysis using the Event Tree Analysis (ETA) technique [8]. It uses as input the service provider KPI historical data and presents as output a service provider risk level percentage and a logical value 1 or 0 according the SP is under or above a risk limit, respectively. This stage applies an event aggregation approach by multiplying the success and failure events associated with each KPI historical value. The second stage (right side of Fig. 1a) performs the collective risk analysis using the Fault Tree Analysis (FTA) technique [8]. It takes as input the logical values generated on the fist stage and generates as output the information regarding the set of partners that is able to proceed with the VO formation.

### 3.2 DEA x Fuzzy

The DEA x Fuzzy method [11] presents the same purpose of the MARTP method. However, though both methods aim to measure how risky is to use

a particular SP in the VO composition, DEA x Fuzzy uses different techniques and stages. In any case, the number of stages are the same. DEA x Fuzzy is split in two stages. The first one performs the efficiency analysis for each one of the SPs that aims to be part of the VO. The second one performs the service provider impact analysis on the entire potential VO assuming this SP fails. DEA x Fuzzy method is presented in Fig. 1b.

Thus, on the first stage (top of Fig. 1b) is performed the SP efficiency analysis using the Data Envelopment Analysis (DEA) technique [7]. This stage reveals the compared SP efficiency value by means of successive linear regressions on the KPI historical values. On the other hand, on the second stage (bottom of Fig. 1b) is performed the SP impact analysis on the entire VO using a Fuzzy technique [17].




(a) MARTP Method [16] (b) DEA x Fuzzy Method [11]

**Fig. 1.** Risk Analysis Methods

### 3.3 Proposal

This Section addresses necessary parameters and how the proposed dimensioning approach works. Thus, some limitations and assumptions regarding the collaboration opportunity and the partners involved are needed to the overall dimensioning approach understanding.

1. This work assumes the collaboration opportunity can be attended by several different VO sizes. This means that it is possible to test several VO with different number of partners from the minimal necessary of two to the maximum proposed by the VO manager.
2. This work also assumes that service providers being tested in a particular VO were already been selected by a partners selection method.

Fig. 2 shows the architecture of the proposed dimensioning approach.

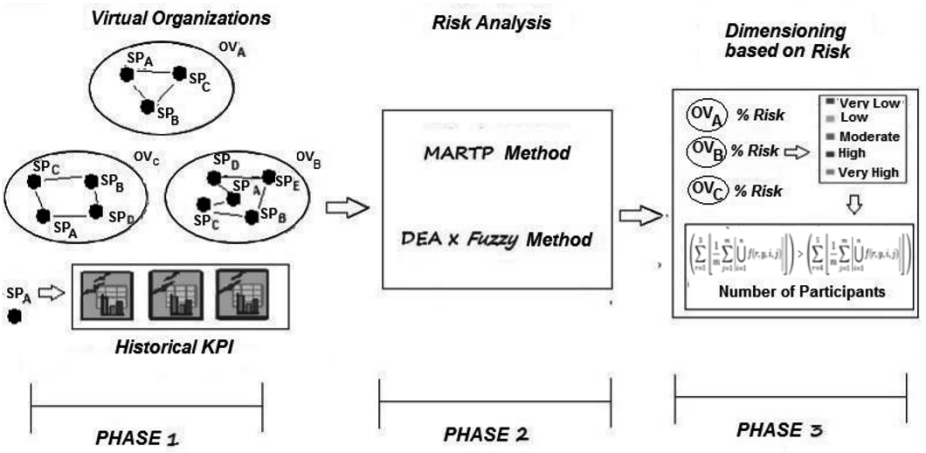



**Fig. 2.** Dimensioning Approach Overview

Phase 1 (Input) is composed by the input data used: a) Service providers previously selected; b) Key performance indicators (KPIs): confidence, communication, collaboration and information sharing; c) Historical values of KPIs: the set of values, for each KPI, assigned on participations in VOs already executed and finish for each service provider involved.

Phase 2 (Risk Analysis) takes as input data the service providers and their historical KPI values from Phase 1. This phase executes the risk analysis methods MARTP and DEA x Fuzzy, described on Section 3.1 and 3.2, respectively. At this phase the service providers are submitted to each risk analysis method in order to comnpute the risk level of the entire VO.

Phase 3 (Dimensioning based on Risk) takes as input the risk levels of each VO tested, which are obtained in Phase 2. These data are processed and transformed in two results to the VO manager. The first result is an histogram showing the aggregated risk levels for each size of VO. Second result is the maximum number of necessary participants to attend the VO creation.

Thus, according Fig. 3, histogram presents at the x-axis the VO's number of participants and at the y-axis the number of simulated VO. Five columns are presented for each VO size. Each column represents the risk level scale defined and used in the computation of the maximum number of participants. These scales represent from the left to the right, respectively, the following values for risk levels: Very Low: 0 to 20%; Low: 21 to 40%; Moderate: 41 to 60%; High: 61 to 80% and; Very High: 81 to 100%.

In this work, the maximum number of necessary participants to attend the VO creation demand is related to the risk level associated with the different VO sizes. Thus, it depends on the VO manager to define which is the considered acceptable risk levels so that a relationship between this level and the VO size can be established. For the evaluation effects, this work considers as acceptable

the risk level scales from very low to moderated. Therefore, considering this, the VO size is determined by the highest number of participants in VOs, whose averaged cumulative amount of simulations with very low, low and moderate risk levels is greater than the averaged cumulative amount of simulations (for that number of participants) with high and very high risk levels.

The presented concepts can be formalized as follows:

Consider the risk analysis methods, represented by the set $M = \{1, \cdots, m\}$ where each element is associated with a particular risk analysis method used in the dimensioning approach. Also, considers $SP = \{2, \cdots, k\}$ a set where each element represents the number of service providers (enterprises) able to be part of a VO and $OV_y^x = \{v_i, \cdots, v_n\}$ the set whose elements represent the risk level values obtained in $n$ simulations using the risk analysis method $x \in M$ for a VO composed of $y \in SP$ service providers. Finally, lets $R = \{1, 2, 3, 4, 5\}$ the set of risk level scale associate to a risk level percentage: 1 - Very Low: 0 to 20%; 2 - Low: 21 to 40%; 3 - Moderate: 41 to 60%; 4 - High: 61 to 80% and; 5 - Very High: 81 to 100%.

$$\text{Now consider: } f(r, y, i, x) = \begin{cases} v_i \in OV_y^x \wedge 0 \leq v_i \leq 20 \wedge r = 1, \\ v_i \in OV_y^x \wedge 21 \leq v_i \leq 40 \wedge r = 2, \\ v_i \in OV_y^x \wedge 41 \leq v_i \leq 60 \wedge r = 3, \\ v_i \in OV_y^x \wedge 61 \leq v_i \leq 80 \wedge r = 4, \\ v_i \in OV_y^x \wedge 81 \leq v_i \leq 100 \wedge r = 5 \end{cases}$$

the function that returns a value from $OV_y^x$ according the risk interval $r$. Finally, the VO dimension is formally defined by Eq. 1:

$$Dim = \max \left\{ y \mid y \in PS \wedge \left( \sum_{r=1}^{3} \left\lfloor \frac{1}{m} \sum_{j=1}^{m} \left| \bigcup_{i=1}^{n} f(r, y, i, j) \right| \right\rfloor \right) > \left( \sum_{r=4}^{5} \left\lfloor \frac{1}{m} \sum_{j=1}^{m} \left| \bigcup_{i=1}^{n} f(r, y, i, j) \right| \right\rfloor \right) \right\} \quad (1)$$

Therefore, according the math presented in Eq. 1, the maximum number of service providers for the VO formation is the highest $y \in PS$ value that fits the risk level criterion defined on the dimensioning approach.

## 4 Evaluation

### 4.1 Setup

The proposal validation is addressed through simulation. The scenarios taken into account perform a defined minimal number of simulations for each VO size (number of SP). Such definition is based on a 95% confidence interval resulting

in a total of 100 simulations. Each simulation generates a risk level value that will later be organized according the risk intervals very low, low, moderate, high and very high, as already mentioned. It is important to note that for the same VO size 100 simulations are performed for each risk analysis method. In this work, methods MARTP and DEA x Fuzzy are used.

Each service provider receives a dataset with historical KPI data. The historical KPI data corresponds to 10 values for each KPI. They are arbitrarily generated using the uniform statistical distribution in the same way from Viera et al. [15]. These historical KPI values range in a normalized interval of $[0.01, 1.00]$, which means SP had received grades ranging from 1% to 100% in previous VO participations for each KPI.

### 4.2 Results

This section aims to conduct the analysis of the results obtained through simulations. The simulations involve seven (7) distinct scenarios, wherein each one represents a VO size ranging from the minimal of two to the maximum partners proposed by the VO manager, which in this work is eight, according [15]. In this work, each scenario generates two sets of performed simulations, i.e., one set for each risk analysis method. Fig. 3 and Table 1 present the consolidated simulation results in order to assist the VO manager decision making regarding the VO dimensioning.

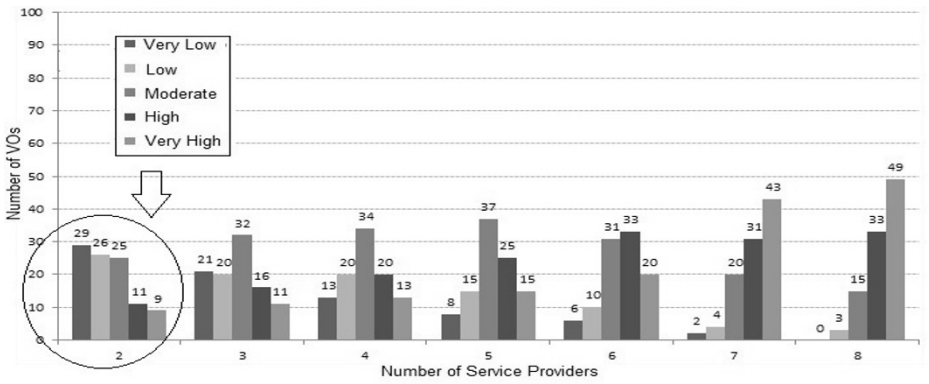



**Fig. 3.** VO's Risk Levels

According results in Table 1, it is possible to identify four (4) possible VO sizes attending the acceptable risk level criterion defined by the proposed dimensioning approach. These are VOs whose sizes are composed from 2 to 5 service providers. Therefore, according that criterion, the maximum number of participants to compose a VO is five partners.

Also, from the results shown in Fig. 3 may be noted that the greater the number of SPs composing a VO, the more likely increase the VO risk level as a

**Table 1.** Maximum number of VO participants

| VO size | Total | Risk Level | |
|---|---|---|---|
| | | Very Low to Moderate | High and Very High |
| 2 | | 80 | 20 |
| 3 | | 73 | 27 |
| 4 | | 67 | 33 |
| 5 | | 60 | 40 |
| 6 | | 47 | 53 |
| 7 | | 26 | 74 |
| 8 | | 18 | 82 |

whole. It is also worth noting that most of the evaluated VOs present very low, low and moderate risk levels. However, these values grow up when there is an increase in the number of SPs for each OV, eventually reaching levels of high and very high risk levels.

Having this in mind, it seems that the more SP being analysed the greater the likelihood of these SPs have very different levels of skills leading to a riskier scenario to the VO formation, which justifies the raising in the high and very high risk scale.

## 5 Conclusion

This paper addressed the VO dimensioning problem taking into account the need to find the maximum number of participants to start the process of VO creation. Reasoning on that, a VO dimensioning approach was proposed aiming to assist the VO manager decision making process of VO creation.

The proposed dimensioning approach assists the VO manager in the competence and sub-competencies management process, i.e., it assists the decision to aggregate more or less participants to a VO, based on the risk involved in this aggregation. In this sense, it may be noted that the proposed dimensioning approach allows careful evaluation of the VO composition regarding the number of participants by assessing the impact of the risk in the VO formation.

Accomplished results show, according the scenarios simulated, the maximum number of participants to a Virtual Organization formation is five (5).

Future work includes testing the dimensioning approach in near-real scenarios. In addition, further work can enhance the proposed approach adding more KPIs (e.g., cost) and new risk analysis methods. Also, the improvement of the proposed risk dimensioning criterion is a good target for further work. Last but not least, a comparison between other dimensioning strategies is planned.

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