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Interpretive structural modeling of risk sources in Virtual Organisation

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Speedier network decision making together with shorter time to bring items to market together with lower network operating costs all result from enhanced knowledge sharing. In addition re-use of enterprise and network knowledge resulting from improved capture means that any risk of repeating earlier project work is limited, repetition of past mistakes is reduced. Decisions are made with greater awareness of any risks involved and therefore there is likely to be a reduction in costs arising from faulty decisions and failed collaborations.

While there are many advantages attaching to the use of virtual organizations (VOs) there are also challenges, including risks that have become apparent through undertaking a review of the literature. In total 13 sources of risk were found stemming from the network related risks in a VO, where the emphasis of the study was placed. This paper contains a thorough study that will identify these threats as well as gaining a sound understanding of them by examining them one by one as they have been identified by the literature and previous studies. Subsequently, their relative importance will be analysed through the use of Structural Modeling (ISM) using information gathered in a questionnaire.

Keywords: virtual organisation; VO; risk; SME; interpretive structural modelling; ISM

1 Introduction

Collaboration between enterprises is vital if businesses are to meet their objectives. Doing business world-wide has become crucial to the survival of some enterprises while for others the vital element is focusing locally. It is necessary for all enterprises, whatever their size, to come to corporate agreements with other enterprises and this is particularly important for small and medium sized enterprises (SMEs) who in order to increase their own added value need to operate together with others within the market. In today's market, whether or not an enterprise is successful will often be largely dependant upon whether it is able to interoperate smoothly with others.

The environment within which SME's have to function in the 21st century is one that is increasingly competitive and dynamic and therefore, simply to cope in such a situation, SMEs have to seek methods to employ: one of these is to group together within a VO. It is, however, not easy to become part of a VO and there are risks to be dealt with throughout the whole process from the initial formation of such a group through to the point where it dissolves. In order that the challenges can be met successfully, it is important that enterprises should be helped to both recognise the risks and then surmount them.

Collaboration is necessary in order for enterprises to compete and it is also necessary for them to operate with as much speed and flexibility as possible so that ideas and proposals can become initiatives with the capacity to generate new revenue.

As is the case in the supply chain, the risks associated with VOs have multiple sources and Juttner et al. (2002) have suggested that the sources of risk as they affect supply chains should be categorised into three areas, those being risks external to the supply chain, risks internal to the supply chain and those that are network related. Such risks as natural risks, political and social risks and risks connected to the industry market would be categorised as external risks while internal risk sources are likely to be associated with labour problems such as strikes, or production problems such as machine failure, as well as problems with IT systems and network related risks stemming from the relationships between the supply chain,

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2
3 also been by Blackhurst et al. (2004) as a risk that is different in kind but that has a direct
4 relationship with collaboration.
5

6 While the risk sources that are internal or external are essentially similar for supply
7 chain and virtual organisation, the network related risks have a different source as a result of
8 the different relations between the SC and the VO partners. Those network risks that relate to
9 any collaboration do not depend solely on the enterprise goals and objectives. A dyadic type
10 of assessment is necessary as a result of the sharing of responsibilities and the changing
11 nature of the relationships involved if these situations are to be actively managed in relation
12 to network related risks, since the identification of risk becomes more complex as a result of
13 the interdependency of enterprises (Hallikas et al., 2004).
14
15

16 The aim of this study is to explore various risk sources in the VO, to establish
17 relationships among the sources through ISM methodology and to classify these sources
18 depending upon their driving and dependence power using indirect relationship MICMAC
19 analysis ISM is a well-established methodology for identifying and summarising the
20 relationships among specific elements which define a problem or an issue (Sage, 1977;
21 Warnfield, 2005). The proposed model provides a useful tool for SMEs to focus on those risk
22 sources that are most important for effective risk management in VOs. Understanding the risk
23 sources and their relationships will help organisations address them or at least understand so
24 they can plan for them if and when they occur.
25
26

27 Based on literature, risk sources that affect VO directly and indirectly, are identified.
28 A survey was prepared and administered to test the validity of each of these sources as well
29 as to identify additional sources affecting VO. In this paper the literature related to the risk
30 sources in the network level of the VOs will first be examined, and then the ISM
31 methodology will be explained before mapping the relation between risk sources using ISM.
32 Finally results of MICMAC (Duperrin and Godet, 1973) analysis of the sources will be
33 presented in section 4.
34
35

36 **2. Identification of risk sources in the Virtual Organisation**

37

38 A number of authors who have researched and written about this area have identified where
39 risk arises in VO. Comprehensive examination of the literature identified 13 sources of risk
40 and impediments which can be possible causes of failure to hit targets in the areas of delivery
41 time and cost and quality and in some instances where the collaboration has collapsed
42 completely. A brief discussion of each of these sources as identified in supply chain
43 management literature and related literature follows and will be the basis of the subsequent
44 survey and analysis.
45
46
47
48

49 **2.1. Lack of trust**

50 This was the most frequently discussed VO risk. The degree of trust that exists between
51 partners relates to how much partners believe in the honesty, generosity and overall
52 competence of the others. Where there is no trust between partners problems arise; for
53 instance they become unwilling to pass on sensitive information, find it difficult to agree
54 about how finances should be managed. In short they do not work to promote VO
55 collaboration.
56
57

58 Trust and commitment are crucial to collaboration and for cooperation over a period
59 of time together with a preparedness to share risks (Sahay and Maini, 2002). The more the
60 trust between SC partners, the more the commitment (Mistry, 2005). However a lack of trust
is one of main contributors to SC risks (Sinha et al., 2004). According to Lengnick-Hall

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3 (1998) where trust has grown out of good communication, it leads to resources that
4 themselves can give a competitive edge. Trust assumes that those party to an agreement will
5 not act opportunistically even when they are tempted by possible short-term advantage to
6 themselves (Chiles and McMackin, 1996) and it can make a marked contribution to the
7 stability of an organisation in the long term and to its network (Speckman and Davis, 2004).
8

9
10 For collaboration to work all partners must work together to solve problems and this
11 demands that there is powerful mutual trust and the commitment to expend time and effort
12 (Camarinha-Matos and Afsarnesh, 2007). Where risk arises from the VO being exposed to
13 partners' opportunistic behaviour, or else to any uncertainty and ambiguity or only partial
14 information, trust becomes vital in order to reduce it. However trust itself invites risk since it
15 exposes those who trust to the opportunistic behaviour of others (Panteli and Sockalingham,
16 2005). There is an important constructive relationship between trust and conflict resolution in
17 any inter-organisational arrangement (Twomey, 1995) and trust enables benefit to be gained
18 from conflict since conflict can often lead to innovation (Pascale, 1994).
19

20 Ryutor et al. (2007) consider that the establishment of trust between VO collaborators
21 is essential to successful joint performance and presents a conceptual framework dealing with
22 key concepts that will initiate trust between VO collaborators in on-demand VO. Lewicki et
23 al. (1998); Zaher et al. (1998) argue that without trust it is not possible for there to be social,
24 economic or political dealings since one party must initiate the contact making the unspoken
25 assumption that there is likely to be a positive response from the other party. Adobre (2005)
26 showed that the trust building in partnership maybe sort of self fulfilling prophecy in which
27 initial expectation positively impact behaviour and trust building, where there may be some
28 optimal level of expectation. In his study he found that both too low and too high an
29 expectation was counterproductive to trust building.
30
31

32 33 **2.2. Inadequate collaboration agreement**

34 A lack of clarity in the agreement into which partners enter is one of the circumstances that
35 can lead to insufficient collaboration. According to Camarinha-Matos and Afsarmanesh,
36 2007; Westphal et al., 2007; Bullinger, 2003 where any definition dealing with objectives is
37 weak, together with the strategies and basic conditions and where expectations are poorly
38 managed, and contracts perceived as inadequate or unfair, there may well be risk of failure.
39

40 The moral risk before the VO is set up was discussed by You and Yu (2006), when
41 members may be able to reduce the extent of knowledge sharing though setting up a contract,
42 with Quirchmayr et al. (2002) describing contracts for negotiation where a legally binding
43 contract may have to be signed by each partner requiring them to accept the process,
44 protocols, and constitution of the VO. Both risks and rewards must be shared among SC
45 members according to Mentzer (2001) if Supply Chain Management (SCM) is to work
46 efficiently since all members must respond to the same incentives which results in a fair
47 distribution across the network of the risks as well as the costs and rewards of the business
48 (Narayanan and Raman, 2004). Tsay (1999) describes the sharing of revenue as a type of SC
49 contract that facilitates the sharing of risks also.
50
51

52 The degree of risk and benefit sharing differs with the type of the collaboration. Joint
53 ownership is often the mechanism with risks arising from joint venture or strategic alliance
54 (Zheng et al., 1998). Methods of incentive for the collaborating parties may be through the
55 use of obligation contracting, schemes for profit sharing and shared property rights as well as
56 ownership control. Where collaborations are not so formal the nature of sharing risks and
57 benefits may not be so clear, therefore lasting commitment may depend on agreements being
58 made so that sensitive information, knowledge and competencies can be shared. Where there
59 is trust there will be less reluctance to share sensitive information since the perception of risk
60 is reduced. This in turns means that complex contracts are less likely to be seen as necessary

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2
3 to protect interests and there is trust in the decision making across the group since it is
4 believed that all perspectives will be considered (Chiles and McMakin, 1996).

5 6 7 **2.3. Ontology differences**

8 Ontology is a philosophical system that is concerned with the nature of being. Gruber (1995)
9 defines ontology as “a formal, explicit specification of a shared conceptualisation”. Problems
10 in this area of ontology crop up when there are two different words with the same meaning or
11 even where one word means different things as it used by different partners.

12
13 According to Plisson et al. (2007) ontologies can be said to offer an economical and
14 unambiguous way of representing knowledge so that it can be jointly understood and
15 therefore provide a basis for sharing. However, before terminology can be shared, there needs
16 to be consensus between partners as to which terms they will use when collaborating where
17 problems have previously arisen because ontologies have not been held in common between
18 organisations working together (Camarinha-Matos, 2002).

19
20 What ontology can do is provide a means of sharing knowledge where there is an
21 understanding of concepts and relationships within a certain area and communication
22 between those involved in this area where the fundamental ontology is one acting as a
23 glossary for a limited vocabulary which are the agreed terms used within a specific area.
24 Where problems occur as a result of differing ontologies there may be disagreements in
25 relation to both the formation and the processes of collaboration which will add to the risks in
26 the VO.
27
28

29 30 **2.4. Heterogeneity of partners**

31 Heterogeneity means the differences that exist between partners in terms of incompatible
32 hardware and operating systems, differences in language and the recording of data and in the
33 meaning of the terms that are used. (Camarinha-Matos and Afsarmanesh, 2007; Sari et al.,
34 2007) have all referred to this heterogeneity between possible partners as it exists in
35 information technology infrastructures, working methods and business practice, as a possible
36 obstacle to the VO operation.
37

38 Where there is poor technological infrastructure this makes it difficult to put in place
39 knowledge management (Singh and Kant, 2008). Jung (2008) saw variations between these
40 categories as an impediment to the progress of efficient cooperation since the semantics of
41 the information from various entities may differ. These variations occur because of the
42 variations in terminology with a number of synonyms and antonyms in use but also and more
43 importantly because of differences within the databases derived from the knowledge
44 structures (Hull, 1997) and the ontology (Jung, 2005).
45
46

47 48 **2.5. Structure and design**

49 VO's dynamic structure creates problems since it is not possible to co-ordinate comparable
50 activities because responsibilities are not adequately shared out and it may not be clear what
51 the tasks and the rules are nor who is in overall charge, nor how far any control extends, and
52 where a phase leader is unable to manage the other partners and does not have the right to
53 make decisions the whole network is affected. Elements of structure and design include
54 central planning or decentralisation, the extent of any specific control and specialisation and
55 how labour is divided (Zhang and Dilts, 2004).
56

57 According to Camarinha-Matos and Afsarmanesh (2007) where the infrastructure
58 does not offer the opportunity for joint collaboration, this proves an obstacle to a VO. Control
59 that is weak or ineffective can occur outside the project and can spring from inter-
60 organisational networking in a way that resembles that in which (Finch, 2004;

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3 Bandyopadhyay, et al., 1999) found that where control over suppliers and customers was
4 weak within the grouping, risks could occur.
5
6

7 **2.6. Loss of communication**

8 The variation inherent in VO and the changes in structure can lead to less communication and
9 here an inverse relationship comes into play since the less the communication the more the
10 uncertainty.
11

12 According to Grabowski and Roberts (1998) while communication is fundamental to
13 any organisation it is of even more vital importance within VOs. Any communication in a
14 virtual form must respond to specific customer demand with speed (David and Malone,
15 1992). Others (Camarinha-Matos and Afsarmanesh, 2007; Westphal et al., 2007; Bamford et
16 al., 2004; Bullinger, 2003; Gunasekaran et al., 2008) have all seen failing communication as
17 an obstacle within VOs and where this happens, failure could follow.
18

19 It is likely that a more trusting relationship between collaborators will be the result of
20 better communication; the crucial aspect is to go beyond technology to establish trust over
21 key issues with a free flow of information and where the most critical issues can be raised
22 with the partners being at ease even when exchanging sensitive information. Partners must
23 understand that communication has to be about commitment levels rather than about
24 technology (Speckman and Davis, 2004).
25
26

27 **2.7. Culture differences**

28 There may be several cultures within a VO and this may lead to lack of alignment between
29 processes and inaccurate communication impacting on the sharing of information (Grabowski
30 and Roberts, 1998; Chen and Fang; Prefontain, 2003; Camarinha-Matos and Afsarmanesh;
31 2007).
32

33 The fundamental values and beliefs of any culture, together with value norms and the
34 customs underpinning the behaviour of people within an organization, define it (Singh and
35 Kant, 2008; Lemken et al., 2000). However, where there is no over-arching culture in any
36 organisation this has a negative impact on the successful management of knowledge (Chase,
37 1997).
38

39 You et al. (2006) focus on members of a VO, saying the centre of any enterprise
40 resides in its values and they therefore use such terms as staff value, faith and behaviour in
41 relation to this so and those joining a VO undertaking come from different enterprises and
42 therefore shared knowledge will be in short supply. It may be that those who come together
43 to form a VO are culturally dissimilar and they may never before have worked as a
44 partnership and so they will have little experience in common. This is an important issue
45 since enterprises have become increasingly transactional and virtual partnerships have been
46 made easier by technological advances and this brings with it different cultural backgrounds
47 and different uses of language as well as values, all of which impact on the dispersed team
48 function (Crossman and Kelley, 2004).
49
50

51 **2.8. Bidding for several Virtual Organisations at the same time**

52 Some partners may choose to be active in several VOs simultaneously when they do not have
53 the capacity to cope with this. Risk then occurs when one partner wins two or more VO bids
54 and his capacity as a partner, either in terms of resources or staff, is not sufficient to
55 undertake the tasks involved in more than one VO. Although this risk occurs, there is as yet
56 little discussion of it in the literature and it has not been much researched. Even in
57 Camarinha-Matos (2002) the vagueness is there when he discusses only the other causes of
58 risk in a VO. Nguyen et al. (2005) discuss only resource management and bidding strategies
59 as possibly problematic in a VO.
60

2.9. *Lack of information sharing*

It is crucial for information to be shared where there is decreasing information visibility in the VO so that there is less risk including that of catalogue non-availability that includes up to date and standardised profiles of organizations. However, the availability of more information sharing can cause loss of IPR. In order for knowledge sharing to be accepted, a VO must have established values relating to sharing and collaboration as part of their fundamental ethos. Some may feel that they have an advantage because they possess knowledge that others do not and this causes a refusal to share knowledge with others out of a desire to protect their own interests (You et al., 2006).

Networks must share information because where it is lacking the result may be panic, confused behaviour and increased costs (Childerhouse et al., 2003). It is agreed currently by models for SCM that sharing business information is vital, connecting SC completely together (Zhenxin et al., 2001; Yu et al., 2001). According to Rahman (2004) it is felt that there is a risk involved in sharing with other members such sensitive information as inventory levels and production schedules. Information sharing should be subject to choosing those with whom the information will be shared, what type of information it will be and of what quality.

Efficient network coordination depends upon information sharing, with a number of studies finding that it impacts significantly on network performance and, in particular, is able to reduce the bullwhip effect. Information sharing leads to better operational decision making within enterprises which leads to more efficient use of resources and lower costs (Lee et al., 1997; Yu et al., 2001).

2.10. *Lack of top management commitment*

Risk is increased where a weak part is played by top level management at particular points in VO formation or operations where crucial decisions are made (Camarinha-Matos and Afsarmanesh, 2007; Westphall et al., 2007; Bamford et al., 2004; Bullinger, 2003).

According to Kanter (1997) there is a risk that low commitment to a partnership will lead to a failure to meet objectives. The role of top management is critical with it being responsible for all activities at every level of an organisation, for the technological infrastructure and for decision making in order that there will be efficient creation of knowledge together with sharing and use (Brand, 1998).

2.11. *Lack of knowledge about risks*

Where there is no knowledge of the risks that may occur there is an increased likelihood that these risks will occur and also have a greater impact.

According to Hallikas et al. (2004) where there is a greater understanding of the risks that may occur in an SC there is likely to be improved decision making and lower risk to each enterprise involved as well as to the whole undertaking. It is possible to categorise the many different forms of SC risks in terms of how their occurrence would affect a business and its environment (Harland et al., 2003). With an understanding of the range of SC risks and how they interact can come a response from the enterprise creating balanced and efficient risk reduction strategies (Chopra and Sodhi, 2004). It is important for organisations to come collectively to an understanding of the risks they may face (Jüttner, 2005).

Risk analysis has the means to detect risk in a process (Sinha et al., 2004) and this enables a secure environment in which decisions can be taken so that there is a continuous assessment of the possibility of risk; it is possible to decide which are serious and then take appropriate action to deal with them (Shtub et al., 1994).

2.12. *Wrong partner/s selection*

According to Camarinha-Matos and Afsarmanesh, 2007; Westphall et al., 2007; Bamford et al., 2004; Bullinger, 2003 such things as objectives, strategies, core competencies and capabilities that are irreconcilable cannot be complementary. While Sari et al. (2007) considered insufficient information about partners to be an obstacle to the VO selection, others including (Grabowski and Roberts (1998); Chen and Fang (2002)) thought that a range of interests increased the risks to a VO.

According to Wilmont and Hocker (2001) conflict can be viewed as the manifestation of a struggle between a minimum of two parties who are mutually dependant but who have divergent goals, with limited rewards, and who have other parties placing obstacles in the way of the achievement of their goals. Organisational conflict manifests itself through conflicting relationships or affective conflict, cognitive or task conflict, and conflict over process. Furthermore, Wong (2009) acknowledged that conflicts between partners is one of the obstacles of virtual networks, where Susman et al. (2003) suggested that conflicts could appear due to the polarisation of functions as between marketing and designers where they want customised product, whereas production department wants to manufacture standardised products.

2.13. *Geographic location*

Risk may be increased by geographic locations with there being a direct correlation between distance and risk. Some locations throw up more problems because of, for instance, political and legal difficulties (Ritche and Brindly, 2002; Dewitt et al., 2006). Prater et al. (2001) looked at the size of any geographic area that a network covered, what political areas it encompassed and which borders were crossed, considering these all to be elements contributing to the partners' exposure to risk.

Porter (1998) observed that geographic distance gives rise to complications and to an increase in logistic cost. Also Grabowski and Roberts (1998), Chen and Fang (2002) considered that there was increased risk as a result of geographic distance.

3. **Interpretive Structural Modeling (ISM)**

ISM is one of the Interactive Management methods which assist research groups in dealing with complex issues (Warnfield, 1974; 1990; 2005). ISM transforms unclear, poorly articulated mental models of a system into visible well defined, hierarchal models. It is a well known methodology for identifying and summarising relationships among specific elements, which define an issue or a problem, and provide a means by which order can be imposed on the complexity of such elements (Mandal and Deshmukh 1994). Thus, a set of different and directly related elements are structured into a comprehensive systematic model. ISM is primarily intended as a group learning process, but individuals may also apply it (Ravi and Shankar, 2005, Faisal et al., 2007). Any methodology for dealing with complex issues, must, therefore, be able to break complexity down into manageable chunks of information so that the human mind can deal with it. ISM tries to do this, by enabling an individual or a group to focus on the interrelations between two elements in an issue at a time, without losing sight of the properties of the whole (Waller, 1975).

From the risk sources which have been identified earlier and the potential impact of failure to meet delivery time, cost and quality targets or total failure for the collaboration, a questionnaire was developed using ISM methodology to determine underlying relations among these sources. ISM is a process that helps people to structure their collective knowledge and to model interrelationships in a way that enhances our ability to understand

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3 complexity. In other words, it helps to identify structure within a system of related elements
4 and provide the opportunity to analyse it from several viewpoints.
5 Steps involved in ISM methodology which are summarised in (Figure 1) are as follows:
6
7

8 Insert Figure 1
9

- 10 1) Identification of the elements that are relevant to the problem or issue.
- 11 2) From the elements identified in the first step, establishing the contextual relationship
12 among them. This represents the relationship indicating whether or not one element
13 leads to another.
- 14 3) Developing a structural self-interaction matrix (SSIM) of sources which indicates a
15 pair-wise relationship between sources of the system under consideration.
- 16 4) Developing a reachability matrix from the SSIM, and checking the matrix for
17 transitivity. Transitivity of the contextual relation is basic assumption in ISM which
18 states that if element A is related to element B, and B is related to C, then A is
19 necessarily related to C. The SSIM format is transformed in the format of the
20 reachability matrix by transforming the information in each entry of the SSIM into 1s
21 and 0s in the reachability matrix.
- 22 5) The reachability matrix obtained in the fourth step is partitioned into different levels.
- 23 6) Based on the relationships in the reachability matrix, removal of the transitive links
24 and drawing a directed graph.
- 25 7) Constructing the ISM model by replacing element nodes with statements.
- 26 8) The ISM model developed in the seventh step is reviewed to check for conceptual
27 inconsistency, and to make the necessary modifications.

28 These steps in more details below:
29
30
31
32

33 **3.1. Survey**

34
35
36 A questionnaire was presented to the respondents of the survey and respondents were asked
37 to complete it. We sent the questionnaire via the INTEROP-VLab mailing list which contains
38 224 members mainly experts in the interoperability and collaborations issues from both
39 industry and academia. INTEROP-VLab is the "International Virtual Laboratory or
40 Enterprise Interoperability", officially created as a non profit organisation under Belgian law
41 (interop-vlab.eu, 2009). 45 experts from the INTEROP-VLab members participated in the
42 study. Using the research data collected from these respondents and following the steps
43 described above, the ISM directional graph is developed.
44
45
46

47 Insert Table 1
48
49

50 Table 1 is a summary of the questionnaire of the survey. The questionnaire was
51 presented to the respondents to the survey, and respondents were asked to answer a total of
52 78 questions, with each cell in the upper right cells representing a question. Respondents
53 were asked to compare the column statement with the row statement for each cell and to
54 choose a value from the set (V, A, X, or O) to represent their perception of direct relationship
55 between two sources at each time. V represent relation when the first source i influence the
56 second source j , but not in the reverse direction, A for the relation when the second source j
57 influence the first source i , but not in the reverse direction, X represent interrelation between
58 both sources (both directions), finally O represent that both sources (i and j) are unrelated.
59

60 The symbolic values (V, A, X, or O) are translated into binary values (section 3.3) to
develop a directional graph (figure 2). The detailed ISM methodology used to develop the

directional graph is explained below. The contextual relation is established based on a pairwise assessment of all the thirteen risk sources as shown in (Table 2), and the majority (70%) of the respondents agreeing to a specific relation between any two sources. With the use of this methodology, we can identify the direct and indirect relationships between risk sources in the VO.

3.2. *The Structural self-interaction matrix (SSIM)*

ISM methodology suggests the use of the expert opinions in developing the contextual relationship among the risk sources. The approach relies on academic experts or managerial background from the INTEROP-VLab who answered our questionnaire with their opinions to arrive at the structure and relationship of the risk sources.

Keeping in mind the contextual relationship for each source, the existence of a relationship between any two sources (i and j) and the associated direction of the relation are questioned. Based on the contextual relationships the SSIM (Table2) is developed for the 13 sources identified for the risk in the VO.

Insert Table 2

3.3. *Reachability matrix*

The SSIM (Table 2) is transformed into a binary matrix, called the initial reachability matrix by substituting V, A, X and O by 1 and 0 as per the case. The rules for the substitution of 1s and 0s are as follows:

- If the (i, j) entry in the SSIM is V, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry becomes 0.
- If the (i, j) entry in the SSIM is A, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry becomes 1.
- If the (i, j) entry in the SSIM is X, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry also becomes 1.
- If the (i, j) entry in the SSIM is O, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry also becomes 0.

After incorporating the transitivities as described in step 4 of the ISM methodology, the final reachability matrix is shown in table 3.

Insert Table 3

In this table, the driving power of a particular source is the total number of sources (including itself) that it influences. The dependences is the total number of sources (including itself) that it may help influencing its growth. These driving power and dependency values will be used in classification of risk sources (MICMAC analysis).

3.4. *Level partitions*

The reachability and antecedent set (Warfield, 1974) for each source are obtained from final reachability matrix. The reachability set for a particular source consists of the source itself and the other sources, which it influences. The antecedent set consists of the source itself and the other sources, which may influence it. Subsequently, the common sources of the reachability and antecedent sets from the intersection sets are the same as assigned as the top-level element in the ISM hierarchy as it would not help achieve any other source above their own level. After the identification of the top-level source, it is discarded from further hierarchical analysis (i.e. removing that source from all the different sets). For example, as

1
2
3 seen in Table 4, 'Wrong partner/s selection' (Source 12) is found at level 1 due to similar
4 reachability and intersection sets. Thus, it would be positioned at the top of the ISM
5 hierarchy. Source 12 is then removed from all different sets for further analysis, as its level
6 has been obtained This iteration is repeated till the levels of each source are found out (Tables
7 4 to 10). The identified levels aids in building the digraph and the final model of ISM.
8
9

10 Insert Tables (4-10)
11

12 **3.5. Formation of ISM-based model**

13
14 The structural model (Figure 2) is generated from the final reachability matrix and the
15 digraph is drawn. Removing the transitivities as described in the ISM methodology, the
16 digraph is finally converted into the ISM. The contextual relationship in this structure was
17 "leads to". This implies that each arrow is read as "leads to".
18
19

20 Insert Figure 2
21

22 **4. Classification of the risk sources (MICMAC analysis)**

23
24 MICMAC was developed by Duperrin and Godet (1973) to study the diffusion of impacts
25 through reaction paths and loops for developing hierarchies for members of an element set.
26 MICMAC analysis can be used to identify and analyse the elements in a complicated system
27 (Warfield, 1990). Generally, the elements will be classified into four clusters of autonomous,
28 dependent, linkage and independent (driver) sources according to the driving power and
29 dependencies of all the elements (Ravi and Shankar, 2005).
30
31

32 The objective of the MICMAC analysis is to analyse the driving power and the
33 dependence of the elements (Mandal and Deshmukh, 1994, Faisal et. al., 2006). In this
34 analysis, the risk sources described earlier are classified into four clusters. The first cluster
35 consists of the "autonomous sources" that have weak driving power and weak dependence.
36 These sources are relatively disconnected from the system, with which they have only few
37 links, which may not be strong. In our case there are no sources in the autonomous cluster
38 which indicates no sources can be considered as disconnected from the whole system and the
39 management has to pay attention to all the identified risk sources in VO.
40

41 The "dependent sources" constitute the second cluster which has weak driving power
42 but strong dependence. We have six sources in this cluster; Lack of top management
43 commitment, lack of information sharing, lack of trust, bidding for several VO at the same
44 time, lack of knowledge about risks and wrong partner/s selection. It forms the top level in
45 the ISM hierarchy. It represents the source that is the resultant action for risks in VO. Its
46 strong dependence indicates that it requires all the other risks to come together so as to
47 increase them in VO risks. The third cluster has the "linkage sources" that have strong
48 driving power and strong dependence. These sources are unstable due to the fact that any
49 change occurring to them will have an effect on others and also a feedback on themselves.
50 Just one of the risk sources in this cluster which is loss of communication is influenced by
51 lower level sources and in turn impacts other sources in the model. The fourth cluster
52 includes the "independent sources" having strong driving power but weak dependence. Six
53 risk sources are in this cluster: geographic location, culture differences, ontology differences,
54 heterogeneity of partners, inadequate collaboration agreement and structure and design.
55 These six sources play a key role in risks in a VO.
56
57

58 The objective behind this classification of the risk sources is to analyse the driver
59 power and dependency of sources (Jharkharia and Shankar, 2005). In general, higher sources
60 driver power means that a large number of sources could be easily removed by its removal.

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3 Higher dependence values for sources require a large set of sources to be addressed before its
4 removal and a more likely success in the implementation of VO risks. The classification of
5 risk sources within the four clusters helps identify the difficulty removal potential of the risk
6 sources.
7

8 The driving power and the dependence of each of these sources are shown in (Table 4). In
9 this table, an entry of '1' along the columns and rows indicates the dependence and driving
10 power, respectively. Subsequently, the driver power–dependence diagram is constructed
11 which is shown in (Figure 3).
12

13
14 Insert Figure 3
15
16

17 **5. Discussion**

18
19 The objective of the ISM model in this research is to develop a hierarchy of risk sources that
20 would help mitigate risks in VO. The model developed in this paper provides the opportunity
21 to understand the network risk sources in VOs. It is clear that awareness about risk sources is
22 very important as it would lead to efforts being undertaken to minimise these risks. The task
23 of management is to place high priority on those sources that form the base of ISM model
24 because it is they who would drive other sources. The significant features of ISM
25 methodology can be summarised as:
26

- 27 • it provides an understanding of the relationships among the risk sources in the
28 network level in the VO;
- 29 • classification of sources under autonomous, dependent, linkage and independent
30 categories;
- 31 • it attempts to develop a new understanding of risks sources due to the SMEs'
32 collaboration.
- 33 • Suggested methodology would help the SMEs to develop strategies to mitigate risks.
34
35
36

37 **6. Conclusion and future work**

38
39 Based on the literature review and expert opinions, a number of risk sources in the VO which
40 may cause to have negative effects on the time, cost, quality or total failure for the
41 collaboration have been identified. The 13 risk sources identified in this research have
42 significant overlaps and relationships that are sometimes difficult to see. A more complete
43 understanding of these risks sources and their relationships, through logical structure, will
44 help enterprises to take better decision as to whether to participate in a particular VO. For this
45 reason we have sought to present an application of the ISM process to the data collected on
46 relationships between the risk sources.
47

48
49 ISM can only act as a tool for imposing order and directions on the complexity of
50 relationships among the variables. It does not suggest any relative weights associated with the
51 variables (Kannan et al., 2008). Even so, this model can be applied with other approaches
52 such as the Analytical Network Process (ANP) (Saaty, 2001), which requires a decision
53 structure to help determine the weights of each risk source. Simulation and systems dynamics
54 modeling may also be used to help identify how risk sources in VO will influence it and its
55 performance results.
56

57
58 We therefore conclude that there is a sufficient body of expert opinion relating to the
59 risks arising in the creation and operation of VOs to support a meaningful analysis leading to
60 enhanced understanding of the relationships between sources of risks and the relative
significance (weights) of these risks. This can inform an SME (or indeed larger enterprise)

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3 decision to participate in a VO, as well as operational decision-making once a VO is
4 established. For this reason we consider that deeper analysis may yield further valuable
5 insights.
6

7 In the future work we can quantify the risks in VO. This depends upon the degree of
8 inheritance of various variables and the amount of interaction that is possible by using
9 Delphi, AHP, ANP, SEM or fuzzy logic. While using graph theory and matrix methods the
10 interaction among the variables can be easily analysed and transformed into mathematical
11 equation. The graph theory and matrix methods consist of the digraph representation, the
12 matrix representation and the permanent matrix representation. The digraph is the visual
13 representation of the sources and their interdependencies. The matrix converts the digraph
14 into mathematical form and the permanent function is a mathematical representation that
15 helps to determine a risk index. This would enable SMEs to understand the contribution of
16 various risk sources and put their efforts into mitigating these risks.
17

18 Furthermore, fuzzy ISM, a step ahead of binary ISM, may also be carried out. While
19 only the existence of relations is considered between elements in the ISM, the strength of
20 relations is additionally considered in FISM. The strength of relation can be quantified using
21 0-1 scale. Additional future research could include broadening the inputs and validation with
22 more practitioners and by evaluating an actual set of risk sources in a real case study with an
23 experimental approach to determine if the model's relationships are influenced as
24 hypothesised on expert opinions.
25

26 In addition to the above directions identified already, Structural Equation Modelling
27 (SEM) has the capability of testing the validity of such hypothetical models. Therefore, it
28 may be applied in future research to test the validity of this model. SEM models can be tested
29 using LISREL or AMOS software. SEM models also provide the path coefficients for the
30 different relationships among the sources. This would complement the MICMAC analysis to
31 further strengthen the understanding about the more important relationships requiring
32 maximum attention.
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Table 1. Summary of the questionnaire.

Risk sources	1	2	3	4	5	6	7	8	9	10	11	12	13
1) Lack of trust	■												
2) Inadequate collaboration agreement	■	■											
3) Heterogeneity of partners	■	■	■										
4) Ontology differences	■	■	■	■									
5) Structure and design	■	■	■	■	■								
6) Loss of communication	■	■	■	■	■	■							
7) Culture	■	■	■	■	■	■	■						
8) Bidding for several VO at the same time	■	■	■	■	■	■	■	■					
9) Information sharing	■	■	■	■	■	■	■	■	■				
10) Top management commitment	■	■	■	■	■	■	■	■	■	■			
11) Knowledge about risks	■	■	■	■	■	■	■	■	■	■	■		
12) Wrong partner selection	■	■	■	■	■	■	■	■	■	■	■	■	
13) Geographic location	■	■	■	■	■	■	■	■	■	■	■	■	■

Contextual relationship = leads to

What to enter in the white cells

Enter **V** when the row influences the column

Enter **A** when the column influences the row

Enter **O** when there is no relation between the row and the column

Enter **X** when row and column influences each other

Table 2. Structural self-interaction matrix (SSIM).

Risk sources	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Lack of trust between partners		A	A	A	A	A	A	V	X	X	O	V	A
2. Inadequate collaboration agreement	V		O	A	O	V	O	V	V	V	V	V	O
3. Heterogeneity of partners	V	O		O	V	V	O	V	V	V	V	V	O
4. Ontology differences	V	V	O		O	V	O	V	V	V	V	V	O
5. Structure and design	V	O	A	O		V	O	V	V	V	V	V	O
6. Loss of communication	V	A	A	A	A		A	V	V	V	V	V	A
7. Culture differences	V	O	O	O	O	V		V	V	V	V	V	O
8. Bidding for several VO at the same time	A	A	A	A	A	A	A		O	A	V	V	A
9. Lack of information sharing	X	A	A	A	A	A	A	O		X	V	V	A
10. Lack of top management commitment	X	A	A	A	A	A	A	V	X		O	V	A
11. Lack of knowledge about risks	O	A	A	A	A	A	A	A	A	O		V	A
12. Wrong partner/s selection	A	A	A	A	A	A	A	A	A	A	A		A
13. Geographic location	V	O	O	O	O	V	O	V	V	V	V	V	

Table 3. Reachability matrix table.

Risk source	1	2	3	4	5	6	7	8	9	10	11	12	13	Driver
1. Lack of trust between partners	1	0	0	0	0	0	0	1	1	1	0	1	0	5
2. Inadequate collaboration agreement	1	1	0	0	0	1	0	1	1	1	1	1	0	8
3. Heterogeneity of partners	1	0	1	0	1	1	0	1	1	1	1	1	0	9
4. Ontology differences	1	1	0	1	0	1	0	1	1	1	1	1	0	9
5. Structure and design	1	0	0	0	1	1	0	1	1	1	1	1	0	8
6. Loss of communication	1	0	0	0	0	1	0	1	1	1	1	1	0	7
7. Culture	1	0	0	0	0	1	1	1	1	1	1	1	0	8
8. Bidding for several VO at the same time	0	0	0	0	0	0	0	1	0	0	1	1	0	3
9. Information sharing between partners	1	0	0	0	0	0	0	0	1	1	1	1	0	5
10. Lack of top management commitment	1	0	0	0	0	0	0	1	1	1	0	1	0	5
11. Knowledge about risks	0	0	0	0	0	0	0	0	0	0	1	1	0	2
12. Wrong partner/s selection	0	0	0	0	0	0	0	0	0	0	0	1	0	1
13. Geographic location	1	0	0	0	0	1	0	1	1	1	1	1	1	8
Dependence	10	2	1	1	2	7	1	10	10	10	10	13	1	

Table 4. Iteration 1

Risk source	Reachability set	Antecedent set	Intersection set	Level
1. Lack of trust between partners	1,8,9,10,12	1,2,3,4,5,6,7,9,10,13	1,9,10	-
2. Inadequate collaboration agreement	1,2,6,8,9,10,11,12	2,4	2	-
3. Heterogeneity of partners	1,3,5,6,8,9,10,11,12	3	3	-
4. Ontology differences	1,2,4,6,8,9,10,11,12	4	4	-
5. Structure and design	1,5,6,8,9,10,11,12	3,5	5	-
6. Loss of communication	1,6,8,9,10,11,12	2,3,4,5,6,7,13	6	-
7. Culture differences	1,6,7,8,9,10,11,12	7	7	-
8. Bidding for several VO at the same time	8,11,12	1,2,3,4,5,6,7,8,10,13	8	-
9. Lack of information sharing	1,9,10,11,12	1,2,3,4,5,6,7,9,10,13	1,9,10	-
10. Lack of top management commitment	1,8,9,10,12	1,2,3,4,5,6,7,9,10,13	1,9,10	-
11. Lack of knowledge about risks	11,12	2,3,4,5,6,7,8,9,11,13	11	-
12. Wrong partner/s selection	12	1,2,3,4,5,6,7,8,9,10,11,12,13	12	1
13. Geographic location	1,6,8,9,10,11,12,13	13	13	-

Table 5. Iteration 2

Risk source	Reachability set	Antecedent set	Intersection set	Level
1. Lack of trust between partners	1,8,9,10	1,2,3,4,5,6,7,9,10,13	1,9,10	-
2. Inadequate collaboration agreement	1,2,6,8,9,10,11	2,4	2	-
3. Heterogeneity of partners	1,3,5,6,8,9,10,11	3	3	-
4. Ontology differences	1,2,4,6,8,9,10,11	4	4	-
5. Structure and design	1,5,6,8,9,10,11	3,5	5	-
6. Loss of communication	1,6,8,9,10,11	2,3,4,5,6,7,13	6	-

7. Culture differences	1,6,7,8,9,10,11	7	7	-
8. Bidding for several VO at the same time	8,11	1,2,3,4,5,6,7,8,10,13	8	-
9. Lack of information sharing	1,9,10,11	1,2,3,4,5,6,7,9,10,13	1,9,10	-
10. Lack of top management commitment	1,8,9,10	1,2,3,4,5,6,7,9,10,13	1,9,10	-
11. Lack of knowledge about risks	11	2,3,4,5,6,7,8,9,11,13	11	2
13. Geographic location	1,6,8,9,10,11,13	13	13	-

Table 6, Iteration 3

Risk source	Reachability set	Antecedent set	Intersection set	Level
1. Lack of trust between partners	1,8,9,10	1,2,3,4,5,6,7,9,10,13	1,9,10	-
2. Inadequate collaboration agreement	1,2,6,8,9,10	2,4	2	-
3. Heterogeneity of partners	1,3,5,6,8,9,10	3	3	-
4. Ontology differences	1,2,4,6,8,9,10	4	4	-
5. Structure and design	1,5,6,8,9,10	3,5	5	-
6. Loss of communication	1,6,8,9,10	2,3,4,5,6,7,13	6	-
7. Culture differences	1,6,7,8,9,10	7	7	-
8. Bidding for several VO at the same time	8	1,2,3,4,5,6,7,8,10,13	8	3
9. Lack of information sharing	1,9,10	1,2,3,4,5,6,7,9,10,13	1,9,10	3
10. Lack of top management commitment	1,8,9,10	1,2,3,4,5,6,7,9,10,13	1,9,10	-
13. Geographic location	1,6,8,9,10,13	13	13	-

Table 7, Iteration 4

Risk source	Reachability set	Antecedent set	Intersection set	Level
1. Lack of trust between partners	1,10	1,2,3,4,5,6,7,10,13	1,10	4
2. Inadequate collaboration agreement	1,2,6,10	2,4	2	-
3. Heterogeneity of partners	1,3,5,6,10	3	3	-
4. Ontology differences	1,2,4,6,10	4	4	-
5. Structure and design	1,5,6,10	3,5	5	-
6. Loss of communication	1,6,10	2,3,4,5,6,7,13	6	-
7. Culture differences	1,6,7,10	7	7	-
10. Lack of top management commitment	1,10	1,2,3,4,5,6,7,10,13	1,10	4
13. Geographic location	1,6,10,13	13	13	-

Table 8, Iteration 5

Risk source	Reachability set	Antecedent set	Intersection set	Level
2. Inadequate collaboration agreement	2,6	2,4	2	-
3. Heterogeneity of partners	3,5,6	3	3	-
4. Ontology differences	2,4,6	4	4	-
5. Structure and design	5,6,	3,5	5	-
6. Loss of communication	6	2,3,4,5,6,7,13	6	5
7. Culture differences	6,7	7	7	-
13. Geographic location	6,13	13	13	-

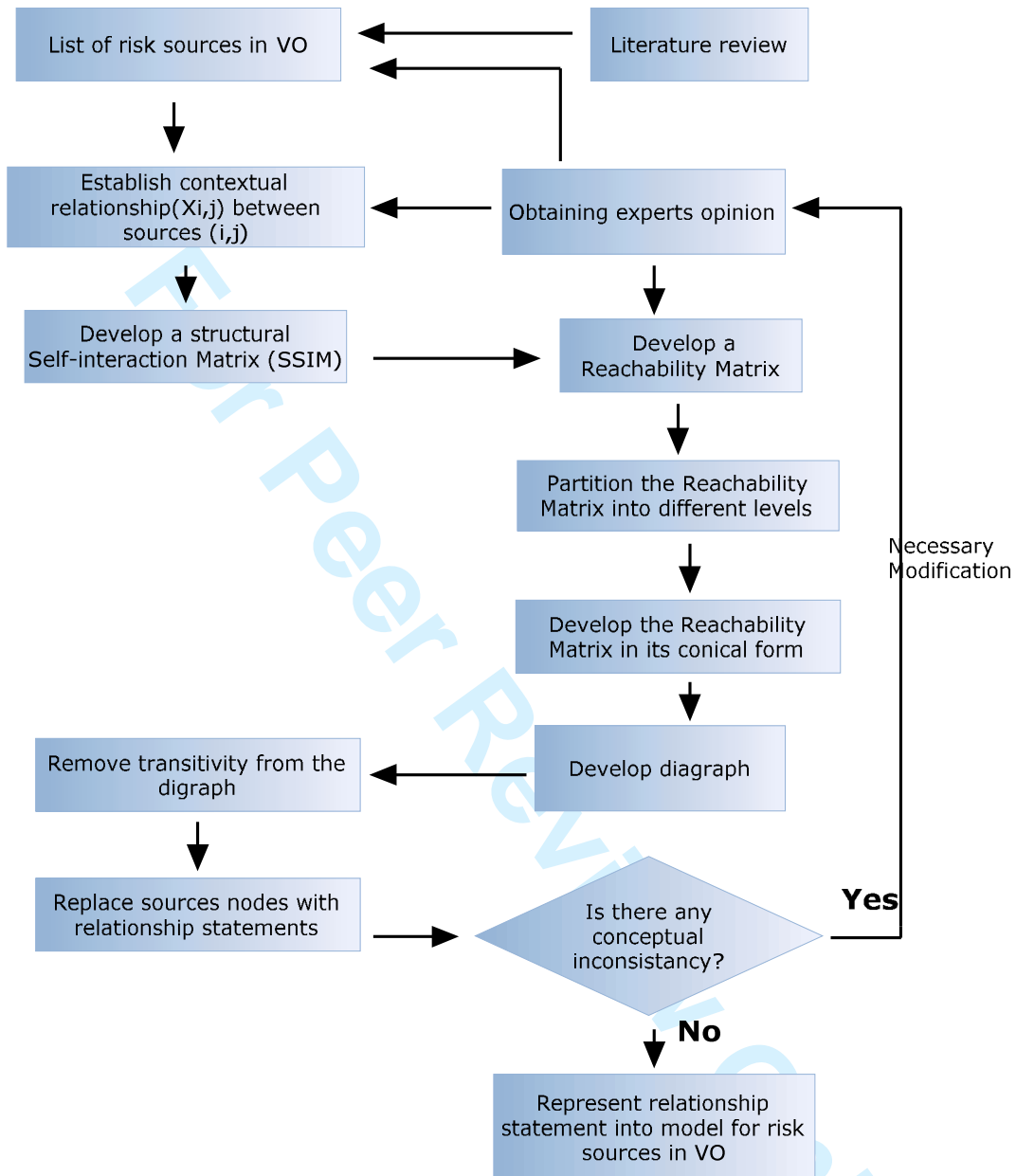
Table 9, Iteration 6

Risk source	Reachability set	Antecedent set	Intersection set	Level
2. Inadequate collaboration agreement	2	2,4	2	6
3. Heterogeneity of partners	3,5	3	3	-
4. Ontology differences	2,4	4	4	-
5. Structure and design	5	3,5	5	6
7. Culture differences	7	7	7	6
13. Geographic location	13	13	13	6

Table 10, Iteration 7

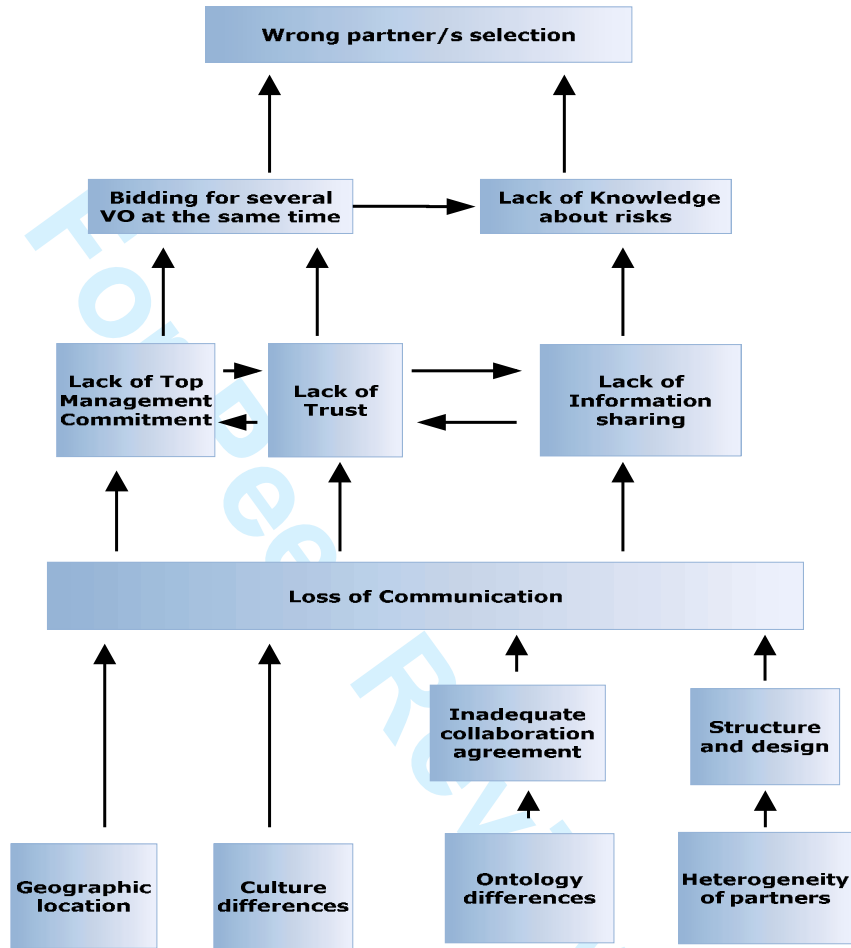
Risk source	Reachability set	Antecedent set	Intersection set	Level
3. Heterogeneity of partners	3	3	3	7
4. Ontology differences	4	4	4	7

Figure 1. Flow diagram for preparing ISM.



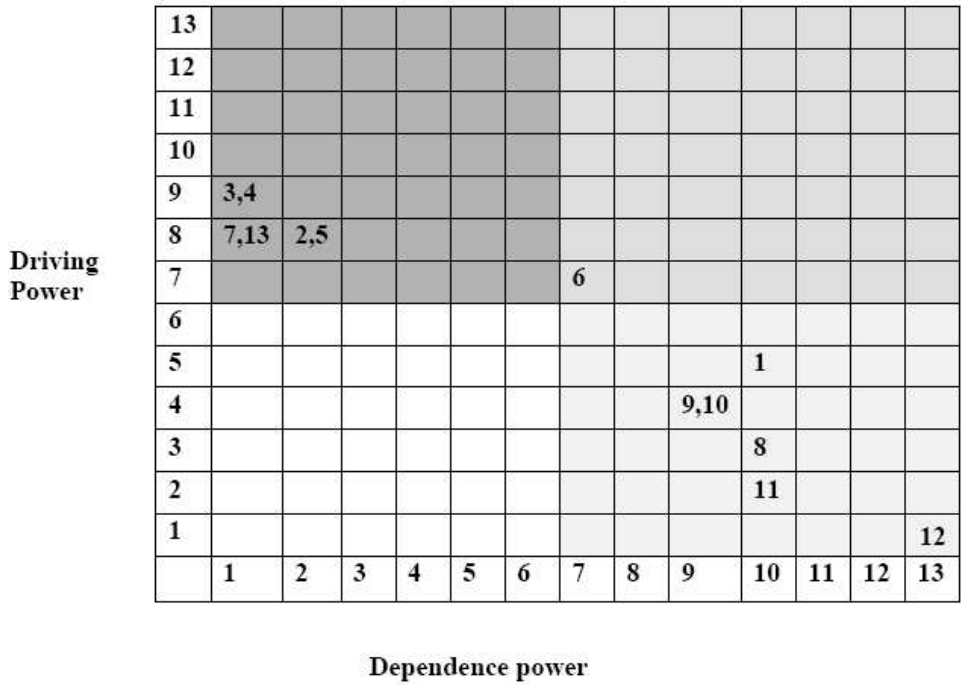
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Figure 2. ISM model.



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Figure 3. Driver power–dependence diagram.



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