Collaboration behavior enhancement in co-development networks

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Chapter 7

Conclusion, Validation, and Future work

This chapter addresses how the set of research questions posed in the Introduction Chapter of the thesis are responded in our research. It further addresses where and how the thesis and our results are evaluated and validated, and presents some directions for future research and development in this area.

7.1 Addressing Research Questions

To answer the first main question RQ1 on how to model and assess work-related collaborative behavior of organizations in the VO, we pinpoint below each of its two subsidiary questions.

In Chapter 2, we address the sub-question S1-RQ1:

How to characterize and model past collaborative-behavior of members in the VBE?

Next to characterizing collaborative behavior of organizations, this chapter presents a quantitative causal approach to measure and assign a *degree of collaboration* to each member organization based on its Individual Collaborative Behavior (ICB) in comparison to other organizations' behavior that are involved in a VBE. Our proposed approach has two stages. First, a new hierarchical model for ICB evaluation is proposed. Second, the causal inter-dependencies among different elements of the model are investigated, to ultimately generate a measurable function applicable to organizations. In this model, an organization's behavior is evaluated through four behavioral dimensions, i.e. integrity, openness to experience, agreeableness, and courage, while each behavioral dimension is in turn associated with a set of traits. Moreover, several known factors with their associated metrics are defined and their causal influence on the traits and behavioral dimensions are concisely specified. Based on these causal relationships, some formulas are derived and used to calculate the comparative degree for ICB of organizations involved in a VBE. This measure constitutes one criterion in our proposed approach for evaluating collaborative trustworthiness of the partner organization. This measure is needed during the VO operation phase.

Chapters 3, 4 and 5 respond to the second sub-question S2-RQ1:

How to monitor and measure the current collaborative-behavior of partners in VOs?

To address this question, we introduce the S3C model, which characterizes four specific kinds of behavioral norms, including: (i) Socio-regulatory norms, (ii) Co-working norms, (iii) Committing norms, and (iv) Controlling norms.

The **socio-regulatory norms** in the model are defined as the set of common social rules for all partners, and setting each partners' expectations of others, through applying the coercive power of a joint VO consortium agreement. They consist of some authorization prohibition and obligation agreements that are defined for partners, e.g. partners are obliged not to share with external parties any information about other partners. Although these norms are very important in VOs, they are typically not directly related to the operational goals of the VO, rather to supporting the collaboration atmosphere and the infrastructure, which is required for fulfilling its operational goals. As such, socio-regulatory norms are therefore only minimally addressed in our current research in the thesis.

The **co-working norms** are requirements defined at the VO level to be obeyed by all partners involved in joint-tasks with others, in order for partners involved in each joint-task to jointly keep the responsibility of performing that task together. The co-working norms are well defined and formalized in Chapters 3 and 4 as joint-promises.

The **committing norms** are requirements defined for performing one sub-task by individual partners. Our approach to co-working and committing norms introduces new formalization and mechanisms for organizations to make promises (for performing individual sub-tasks) and/or joint-promises (for performing joint-tasks), thus the VO partners committing themselves in a bottom-up manner to perform tasks, as opposed to the VO coordinator assigning tasks to them in a top-down manner. The bottom-up manner is more in line with the collaboration nature in the VOs that resembles a federated partnership among organizations. Furthermore, in this approach tasks are gradually defined in the VO that in turn enables the approach to effectively cope with the dynamic nature of the VO, and its potential continuous evolution during the operation phase. The committing norms are defined and formalized in Chapters 3 and 4.

The **controlling norms** are defined as requirements for coordinating the tasks of each partner, imposed/enforced by the VO coordinator during the VO operation phase. In this work, requirements related to trust level of partners, maximum work overload, and maximum level of failing communications imposed by the VO coordinator are defined as controlling norms. Due to the fuzzy nature of trust, the trust requirement for each partner is specified as a fuzzy norm, the so called trust-related norm. The VO coordinator defines the minimum required/-tolerated trust level for partners in the VO. The controlling norms are defined and formalized in Chapters 3 and 4.

As the main contribution of this thesis, a VO supervisory assisting tool (VOSAT) is designed and developed, handling the above norms. VOSAT includes five components, as indicated in Figure 4.1. One main component of the VOSAT, detailed in Chapter 4, is Norm Monitoring Component (NMC). This component is responsible for checking the states of the four kinds of norms, addressed above to issue relevant warnings when necessary, and to impose sanctions in any violation state of any norm, which results in the effective control of partners' behavior. The configuration of this component is specified based on: (1) a set of propositions denoting environment-related facts, (2) a set of Norm Manipulating Rules (NMRs), (3) a set of norms, and (4) a set of Reaction Rules (RRs). The state of the system can make a transition either when the actions are performed by the agents, or when some external events have occurred. When the set of propositions are updated, some of the NMRs may be triggered, and consequently the states of promises are changed or the violation/obedience of other norms are specified. It may in turn trigger some RRs, which themselves may in turn result in sending related warning messages, or imposing sanctions in case of violation states.

It should be noticed that if either a committing norm or socio-regulatory norm is violated, then the trust-related norm gets activated, in order for organization trust level to be measured and monitored. To implement this component, we have used and extended the environment provided by the 2OPL (Organization Oriented Programming Language) with addressing the new formalization of promises, joint-promises, and fuzzy norms.

The second main component addressed in Chapter 4, is the Norm Abidance Component (NAC), which is responsible to measure the socio-regulatory norms obedience degree (SNOD) and the committing norms obedience degree (CNOD) of partner organizations. As mentioned in Chapter 3, every joint-promise is decomposed into several individual promises, so the violation and obedience of co-working norms are considered in evaluation of the organization's committing norms. There is however no obedience degree considered for controlling norms, because the violation of these norms are directly considered in the VO's failure risk prediction, while the violation and obedience of socio-regulatory norms and committing norms are considered in evaluation of trust level of organizations.

The Trust Evaluating Component (TEC) is the next main component, addressed in Chapter 5. Based on the results of monitoring the socio-regulatory norms, co-working norms, and committing norms, as well as the value of partner's ICB, the trust level of each partner is evaluated, applying the AHP fuzzy comprehensive evaluation method that is used as a base for applying trust-related norm and is itself considered as a kind of controlling norms.

In order to answer the second main question RQ2 on how does the partner' work-related behavior influence the achievement of the VO goals, we discuss below each of its two subsidiary questions introduced in the Introduction Chapter.

In Chapter 6, we address the sub-question S1-RQ2:

What are the main behavior-related risk factors in VOs?

In VOs, all partners are jointly responsible for achieving the goals and sub-goals of the VO, and therefore, the success or failure of every one of its involved organizations is directly related to the success or failure of the VO as a whole. The unavoidable existence of joint responsibilities in VOs is the main reason why in the case when one partner cannot perform its sub-task in the VO, other partners volunteer to perform it in its place, so that the VO as a whole does not fail and has a chance to succeed. Consequently, the joint responsibility notion within VOs in turn creates complex inter-relationships among its involved partners.

All risks raised from the collaborative relationships among organizations in a VO, are clustered under the network-related risk category. A list of important sources/causes for network-related risks in VOs as for instance addressed in [8], includes: lack of trust, lack of clarity in the agreements/commitments, partners heterogeneity, loss of communication, lack of information sharing, heavy workload, ontology differences, heterogeneity in structure and design, cultural differences, geographic distance, etc. In other words, any of these sources represents the possibility of a risk in the VO, and depending on its severity can contribute to its failure. In our research, we focus only on three specific factors among those, consisting of, trust, communication, and workload of the organizations (considered as agents), which we have identified as the main measurable aspects related to the partners' behavior. These factors are considered in order to predict probability of failure for each agent in fulfilling its individually assigned sub-tasks, during the VO's operation phase.

The sub-question S2-RQ2 below is addressed in Chapter 6:

How to predict risk of failure in achieving VO goals, considering the behavior-related risk factors?

The controlling norms are defined as requirements for coordinating the tasks of each partner, imposed/enforced by the VO coordinator during the VO operation phase. These norms apply three specific measurements related to the VO partners, including their lack of trustworthiness, work overload, and failing in communication. For each of these three measurements, the VO coordinator defines a threshold, and VOSAT specifies whether a partner violates one of these norms. For example, if the trust level of a partner, measured through applying AHP fuzzy comprehensive evaluation method, is lower than the minimum level tolerated in the VO, that partner's trust-related norm is violated, indicating the lack of trustworthiness of the partner. If any controlling norm, including trust-related norm, communication-related norm, or workload-related norm is violated for a VO partner, then the risk prediction mechanism, which is realized by the Risk Predicting Component (RPC) as represented in Figure 4.1, issues a warning to the VO coordinator. Failure in fulfilling a sub-task by a VO partner may depend partially on the failure by the partner responsible for it (which is specified through monitoring its controlling norms), and partially by the failure of its preceding sub-tasks on which it depends. Therefore, using the controlling norms, as well as the responsibility inter-dependencies, a Bayesian network is defined and applied to measure the probability of failure in each of the planned sub-task, task, sub-goal, as well as the general VO goal. At each time stamp, if the probability of failure for any of these, as calculated by a node in Bayesian network is higher than certain threshold, the VO coordinator is warned to check the situation and make suitable plans to prevent potential failures.

To answer the third main question RQ3 on how to enhance the collaboration success in VOs, in relation to partners' work-related collaborative behavior, we address below each of its two subsidiary questions. In fact, the novel models and mechanisms proposed in this thesis that are applied for the development of the VOSAT, provide the VO coordinator with assistance to act proactively, enhancing the success of the VO. This assistance include providing decision making suggestions for intervention toward failure prevention, and collaboration promotion in VOs, which results in enhancing the success rate of VOs. The Partner Selecting Component (PSC), as represented in Figure 4.1, assists with ranking partners for potential task reassignment and rewards distribution.

The sub-question S1-RQ3 below is addressed in Chapter 6.

How to prevent potential work-related VO failure, through task reassignment?

The VOSAT system can support the VO coordinator during its operation phase, with altering the situation of a risky sub-task, through finding/suggesting alternative suitable partners among those that will volunteer to accept taking over the execution of that failing sub-task. To support the VO coordinator, we propose a competency-based model to find the most suitable partner for task reassignment, applying Analytic Hierarchy Process (AHP) method. In this model, both soft and hard competencies of organizations are considered. Soft competencies are related to the behavioral characteristics of partners, including committing norm obedience degree (CNOD), socio-regulatory norm obedience degree (SNOD), cooperative traits (CT), and communication rate (CR), while hard competencies of organizations include cost and partners' work overload.

The sub-question S2-RQ3 below is also addressed in Chapter 6.

How to promote work-related collaboration behavior among VO partners?

The VOSAT can also assist the VO coordinator during the VO operation phase through recording and ranking VO partners' performance and collaborative behavior. This can then be applied for creating incentives for good behavior in the VOs, or used indirectly for some forms of reward distribution at the VO level. To promote collaborative behavior among organizations, we apply AHP to rank the partners, aiming at some form of reward distribution, which may even include increasing the organizations' reputation and prestige. The main criteria considered for such reward distribution are performance on their responsibilities and the voluntary performance. Three considered sub-criteria for responsibility performance are: CNOD, SNOD, and CT. Furthermore, the VO coordinator can assign different weights to different criteria, based on the type of the VO, and which one of these are more important in it.

7.2 Evaluating and Validating Research Results

In scientific research, it is important to evaluate and validate both the obtained results as well as the applied research steps. Among different techniques that can be applied to this evaluation and validation, we choose those that are fitting more appropriately to our purpose, applying the approach suggested by Pfleeger [76]. This approach suggests a number of techniques among which the following two techniques are applicable and chosen for our validation purposes:

(i) **Case study -** *which is suitable for showing a holistic picture of applying the approach and results related to the developed system. This technique suggests that according to what we as the evaluator aim to examine, an application case shall be defined to test the functionalities and usage of the results.*

(ii) **Feature analysis -** *which is suitable to rate and rank the features of a developed system, e.g. for its novelty, complying to certain standards, or against competitive research results. This technique is also used to validate our findings in scientific communities.*

We validate our results, applying these two mentioned techniques, as detailed out in the following paragraphs and represented in Figure 7.1, as a summary.

Case Studies	Case 1	Supporting SOA-based VOs (Chapter 5)	
	Case 2	Supervision of R&D projects (Chapter 6)	
Feature Analysis	Developed Concepts Analysis (peer-review)	Models	• Hierarchical model of ICB of organizations in VBEs (Chapter 2) • Causal model of organization behavior in VBEs (Chapter 2) • Organization's behavioral norms (S3C model) (Chapter 3) • C3Q competency model (Chapter 5)
		Mechanisms and Approaches	• Monitoring behavior of VO partners (Chapter 4) • Competency-based selection of shared assets in VBEs (Chapter 5) • Prediction of failure risks in VOs (Chapter 6) • Competency-based selection of partners for task reassignment (Chapter 6) • Performance-based reward distribution (Chapter 6)
	Developed Components Analysis (key indicators)	Component 1	Norm Monitoring (Chapter 4)
		Component 2	Trust Evaluation (Chapter 5)

Figure 7.1: Summary of research results validation.

Case studies - Our research works out two case studies, one focused on supporting SOA-based virtual organizations, and the other focused on the supervision of R&D projects.

- *Supporting SOA-based virtual organizations.*

  Chapter 5 of the thesis addresses our designed case study in which a part of our results, related to norm monitoring of VOSAT, is used to find the best-fit service in a SOA-based VO. VOSAT detects the norms violations, based on which the service providers' trust levels are measured and then used in service selection among the services shared by service providers. For implementing this case study, we apply VOSAT results to the case of effective service selection, as discussed in [86]. Organizations involved in many service industries are increasingly active in pursuit of both online provision of their business services and collaborating with others in joint initiatives as well as developing and provision of integrated services in VOs. At present, due to the lack of any uniform unambiguous formal definitions for potentially sharable business services at the VBE, as well as the lack of awareness about the providers' behavior and trustworthiness, SMEs involved in VOs can neither be properly supported with discovering most appropriate sharable services in the VOs nor facilitated for potential service integration/ composition in the VO. In our approach, for this case, the behavior of service providers is monitored based on their related norm abidance in the VO. Furthermore, organization's trust level is then used as a non-functional criterion for service discovery. We also further apply our C3Q competency-model for the purpose of selecting the most-fit services.

- *Supervision of R&D projects.*

  A second case study is designed within the framework of an EU-R&D project, as discussed in Chapter 6. This case study aims to validate the other important part of our research results, specifically addressing challenges related to risks in VOs and the prediction of failure risk in fulfilling any of the VO goals or any task, and making recommendations for intervention by the VO coordinator. This case and its development is addressed in great details in Chapter 6 of the dissertation.

Feature analysis - We classify our research findings into two main categories of developed conceptual results, including models and approaches that need to be validated for their novelty, as developed components that represent the prototypical results and mechanisms implemented as proof of concepts in our research.

Validation of the developed conceptual models and approaches are primarily achieved through submission of these to the scientific community and receiving their evaluation results, which in turn has enhanced our approach, resulted in publications and thus validated these set of our results.

For validating the components developed in VOSAT, we compare their features and appropriateness against a number of other competitive components and systems, for which the results are provided in this section.

- **Scientific Community peer reviewed - Conceptual developments validation:**

  The conceptual developments in this research are published through different scientific channels, e.g. peer reviewed conferences proceedings and journals, as presented in Section 1.4 of Chapter 1. These address the two main categories of the developed models and the developed mechanisms and approaches.

  The novel developed models include: the hierarchical model of ICB of organizations in VBEs, the causal model of organization behavior in VBEs, the model of organization's behavioral norms (S3C model), and the C3Q competency model for effective service selection in SOA-based VOs. Besides publications, for the causal model we have used a questionnaire directly addressed to expert users from the scientific community of SOCOLNET. Gathering their input, we have enhanced and validated this causal model.

  The novel developed mechanisms and approaches include: the mechanism and approaches for monitoring the behavior of VO partners, the mechanism developed for competency-based selection of shared assets (e.g. services) in the VBE, the approach and mechanism for prediction of failure risks in

VOs, the mechanism for competency-based selection of partners for task reassignment and the mechanism for performance-based reward distribution.

- **Key indicator assessment- Components development validation:** At first, feature analysis is applied *to compare the appropriateness of VOSAT against other competitive environments and systems* for its two main functionalities, i.e. norm monitoring, and trust evaluation. See Figure 7.2 for a summary of our evaluation/validation results.

  – *Norm Monitoring Functionality.* Here we evaluate some key indicators and appropriateness of norm monitoring functionality of VOSAT against three competitors: OperA+, NMAS, and IRN, as described below.

    * **VOSAT.** It is implemented as an extension of the environment provided by the 2OPL with the added novel formalization of the notions of promises, joint-promise, and fuzzy norms. Promises and joint-promises with different states are formalized in VOSAT to support the VO's evolution and VO's dynamism, because it is for VOSAT to adapt with the new situations only by introducing new promises and joint promises, or by changing the states of the existing promises and joint-promises. VOSAT supports the implementation of fuzzy norms, as explained for trust-related norms in Chapters 4 and 5. In VOSAT, norms are specified for agents, while in other systems norms are defined for roles.
    * **OperA+** [55]. It is a model for context-aware organizational interactions in Virtual Organizations rooted in an organizational modeling framework OperA. The assumption behind this model as a competitive environment is that multi-agent systems imitate human societies, so an organizational structure is applied for its norm modeling. This framework also initiates the idea that agent societies cannot rely on individual agents, and the society's goals are not achieved without a framework that specifically enforces those goals. However, because it is not guaranteed that the agents tend to achieve the goals of the society, the goals and norms of the society should be identified independently of the participating agents.

      In OperA+, there is a relationship between the agents and the roles or groups of roles within the organization. In other words, norms are defined for roles, and not for the agents, which shows a main difference with our approach that emphasizes individual behavior. It causes to be difficult to change the pre-defined roles and their defined norms, when the VO is changed. For example, if the VO sub-goal is completely changed then it is needed for example to define new roles, with new norms and then assign them to the agents. It means that OperA+ does not support the VO's evolution. As mentioned before, day-to-day activities of VO partners are gradually defined during the VO operation phase, while in OperA+, norms are assigned to some pre-defined roles at VO creation phase. However, VOSAT supports both VO's evolution and dynamism though formalization and monitoring the partners' promises and joint-promises. The implementation of fuzzy norms, and norm abidance measurement are not supported in OperA+.

* **VO as a Normative Multi-agent System (NMAS)** [15]. It is a conceptual model of virtual organizations offering an elaborate normative structure. Within this model, different interactions among agents and normative systems are considered, based on which agents make decisions to perform specific actions. The normative system defines some roles, which are assigned to the agents. The normative system is modelled as an agent for other agents. In NMAS, human or artificial and normative systems are BDI (beliefs, desires and intentions) agents. A number of recursive games in a standard game theory are defined and used to model the behavior of agents and normative systems. In the system implemented based on the NMAS, norms and social structures can evolve, while the system is still stable. This system supports the dynamic aspects of VOs, using speech act theory. Implementation of the fuzzy norms, and norm abidance measurement are also not implemented in this framework. However, another difference between VOSAT and this model is that we do not know how the agents work internally as we only monitor the external actions of the agents.

* **Institutional Reality and Norms in VOs (IRN)** [25]. This work introduces three kinds of norms (institutional norms, constitutional norms and operational norms), based on which a normative system is defined to monitor the agents' behavior. Institutional norms are defined for setting up the normative platform for VOs with assuming general roles, such as policies for handling norm violations. Constitutional norms specify the norms for regulating a VO as a certain cooperation agreement, which usually exists for a period of time. Operational norms specify the actions to be performed by each agent in each VO. Institutional norms are pre-defined in this system. Some default template rules are defined for representation of the constitutional and operational norms. It means that it provides a platform which supports the gradually

definition of VO's activities during the VO operation phase. However, it cannot support the changes in VO's goals/sub-goals, or planned task assignment, which can be happened during the VO operation phase, because the norms defined in this model have only two states of violation and obedience. It does not support promises, fuzzy norms, norm abidance measurement, which are the contributions of VOSAT.

– *Trust Evaluation Functionality.* Here we evaluate some key indicators and appropriateness of the trust evaluation functionality of VOSAT against three competitors: GTM, TrustMan, and HMDT.

  ∗ **VOSAT.** Trust requirements of VO partners are specified as fuzzy norms, called trust-related norms, which are kinds of controlling norm specified by the VO coordinator (see Chapter 3). In VOSAT, if one of the agents' norms, e.g. committing norms or socio-regulatory norms is violated then that agent's trust-related norm gets activated. To monitor the violation of trust-related norm, it is necessary to evaluate the current agent's trust level. To evaluate the overall trust of each agent in a VO, as the main factors, both its Individual Collaborative Behavior (ICB) recorded at the VBE and its work behavior in the current VO are taken into account. The work behavior of the agent is evaluated through considering the agent's Committing Norm Obedience Degree (CNOD), the agent's Socio-regulatory Norm Obedience Degree (SNOD), and the agent's Cooperative Traits (CT) to evaluate this factor. Furthermore, Interaction Rate (IR), Co-work Quality (CoQ), and Not Being Opportunistic (NBO) are the three qualitative sub-factors considered for the CT. It means that our approach applies the combination of objective evaluation and subjective evaluation. In other words, VOSAT evaluates the agent's work behavior as the second factor in trust evaluation based on both the norm obedience degrees and the recommendations of other agents about the behavior of that agent in its joint responsibilities. It should be noticed that due to the fuzzy nature of trust (see [29]), in VOSAT, the trust requirements related to the VO partners, are implemented as fuzzy norms, which are monitored during the VO operation phase.

  ∗ **A Goal-oriented Trust Model for virtual organization creation (GTM)** [70]. This model uses a fuzzy inference system to evaluate trust of each enterprise, based on the goal of the projects, in which the enterprise is involved. The proxy server stores some trust factors for each goal. After factor selection, it is needed to get help from some experts to design a fuzzy inference system. The uncertainty of human reasoning and computational logic is covered by fuzzy logic. The selected factors for each goal are the inputs of the fuzzy inference system and the trust level of a single enterprise for a specific goal is the output of fuzzy system. Besides the specific factors, some characteristics, such as cost and assets are also used as inputs of the fuzzy inference system. This system focuses on partner selection among trustee members of the VBE to respond a new opportunity. In other words, in contrast to VOSAT, this approach is used at the VO creation phase. This approach is not appropriate for virtual organizations that have several goals and sub-goals. Moreover, another limitation of this system is the necessity of the intervention of experts in designing the fuzzy systems and their related rules.

∗ **TrustMan** [69]. In this system several trust elements from different perspectives (structural, social, technical, and economical perspectives) are considered, and then some approaches and mechanisms are formulated to support the inter-organizational trust within VBEs. However, trust evaluation in VOSAT is based on the behavior of VO partners in the VBE, as well as in the current VO. It means that VOSAT monitors the trust level of partners during the VO operation phase. Moreover, the distinguished target of VOSAT is that the trust evaluation and monitoring aim to predict potential risks of failures in VOs, while TrustMan aims to select the best-fit members of VBEs for formation of a new VO. VOSAT evaluates partner's trust level only based on its behavior, while TrustMan applies a multi-perspective trust evaluation method at the VBE level.

∗ **Hierarchical Multi-attribute Decision-support-based Trust estimation (HMDT)** [61]. In this work, two main high-level factors, reputation and collaboration of members are considered for mutual trust evaluation. The sub-factors that can affect these two main factors are considered in their proposed hierarchical tree of the decision criteria. Information of the sub-factors for a partner is collected through questionnaires given to other partners to estimate the partner's reputation and past collaboration. Then applying a multi-attribute decision support method, for each pair of agents, a numerical estimation is computed. After that, a graph is created in which nodes represent partners' reputation and arcs represent the collaboration between two partners. Wider nodes with a large number of thicker arcs show the organization with higher trust value. This work is a recommendation-based evaluation of trust and used at the VO creation phase, while VOSAT, besides using others' recommendations about the partner's collaboration traits, monitors their behavior during the VO operation phase against some defined norms. The fuzzy nature of trust is also ignored in HMDT.

		Competitive Models /Systems						
Functionalities	**Indicators**	OperA+	NMAS	IRN	GTM	Trust Man	HMDT	VOSAT
Norm-based behavior Monitoring	VO's Dynamism Support (gradually definition of activities)		■	■				■
	VO's Evolution Support (changes in the goals/sub-goals of VOs)		■					■
	Fuzzy Norm Implementation							■
	Joint Responsibility Support	■	■	■				■
	Norm Abidance Measurement							■
Trust Evaluation in CNs	Performance- based Evaluation				■	■		■
	Recommendation-based Evaluation						■	■
	Main focus on VO creation phase				■	■	■	
	Main focus on VO operation phase							■
	Multi-perspective trust Evaluation				■	■		
	Supporting fuzzy nature of trust				■			■

Figure 7.2: Comparison of VOSAT with similar models/systems. Black cells show the positive results for the corresponding indicator.

7.3 Discussion and Future Work

Enhancing collaboration in Virtual Organizations encompasses a large number of challenges and open issues. Some of these include, how to create trust and motivate the sense of working together and toward the success of the VO. Research and practice have shown that if properly applied, monitoring and supervision of partner organizations in the VO can effectively enhance its chance of success as well as reduce its risks of failure, thus increasing the resilience of the VO. This research has focused on this endeavor, and suggested the VOSAT approach to assist VO coordinators with the above targets. Nevertheless, several of the addressed areas can be further extended with future works. These include: (i) extending the VOSAT system with the measurement of some other potential VO failure risk factors (ii) Addressing some emotional super traits of organizations and their influence on the organization's collaborative behavior. These two aspects are further addressed below.

Addressing other risk of failure factors. As mentioned before, to support and increase the success rate of collaboration in VOs, their operation stage and the performance of their tasks must be continuously monitored and supervised against the defined norms in the VO. Typically, a task in the VO is either planned to be performed by an individual partner, or jointly by a group of partners, and it consists of several sub-tasks defining the day-to-day activities of its involved partners. However, VOs are dynamic and therefore the detailed activities related to sub-tasks are only defined gradually and during the operation phase. In our current approach, as the base for discovery of potential task failures, the past performance and record of previous sub-tasks' fulfillment of each partner (our so-called agent) are considered for appraisal of its trustworthiness. Furthermore, the interaction characteristic of the agent and its current workload in all its involved VOs within the VBE are also considered as input for measuring its potential probability of failure on its currently assigned sub-tasks. In other words, we focus on three risk factors, i.e. lack of trust, lack of communication, and heavy workload. However, in [8], a number of other sources/causes for collaboration related risks in VOs is introduced, which deserve to also be considered, such as the lack of information sharing and the lack of top management commitment. As a further next step for our research, we consider that the risks in VOs are reduced when enough information is shared to update organizations' profile [8]. Lack of top management commitment as another risk factor will also be considered. The VO coordinator plays a vital role in its success, because of the crucial decisions made during the VO creation and operation phases. Although, VOSAT assists the VO coordinator to make effective decisions, the coordinator's behavior should also itself be taken into account. Considering more risk factors, when measurable will result more effective risk prediction.

Considering organization's emotional super traits. We currently propose a causal model based on four behavioral dimensions, i.e. courage, agreeableness, integrity, and openness to experience. Then, we focus on factors, which are measurable and can influence these behavioral dimensions and related traits. For future work in this area, we aim to consider also organization's emotional super traits as behavioral dimensions, such as the neuroticism and extroversion [67], as well as specifying the measurable (known) factors influencing these behavioral dimensions. Extraversion represents positive emotions, such as assertiveness, and sociability. Neuroticism specifies unpleasant emotions, such as anger, sensitivity, anxiety, depression, and vulnerability [67]. Affective computing is relatively new, investigating the personal emotional behavior, in order to develop approaches to establish better interactions. We argue that the performance and achievement level of organizations involved in virtual organizations can also be influenced by their emotions. Moreover, positive emotions play a vital role in encouraging and motivating an organization to interact with other organizations involved in the CNs. Furthermore, not only the positive emotions have direct relation with creativity [46], as an important trait for organizations involved in VOs, but they also directly relate to the motivation for achieving goals, as well as for problem solving. Another advantage of monitoring the feelings and emotions of organizations involved in VOs is for developing proactive mediation mechanisms, which are only achievable through establishment of suitable communication, and applying the affective approaches and social protocols by the VO coordinators [21].