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MODELLING OF NETWORKED CONSTRUCTION OPERATIONS

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Abstract. *Operations in construction and real estate sector are increasingly networked. Practically this appears as a very high share of subcontracting, and recently the outsourcing as a lasting trend has even strengthened this phenomenon. In a major construction project the project manager and the company (s)he is representing can be connected to tens or even several hundred different partners who each are providing services to the project in question. Likewise, the daily business as a whole and its potential for future success is crucially dependent upon the network of partners and potential partners. Monitoring and understanding the status of such networks can be considered as one of the key challenges in modern construction and real estate business. However, the state of the art business process modelling solutions including also project modelling and relating knowledge look rather undeveloped fields from the described viewpoint. This paper reviews first the previous work in relation to modelling of networked companies and business operations. Second, the results shall be presented from case studies in which a tool is being developed for analyzing and visualizing the status of partnering companies around a parent company. In the studied cases the business context is the construction business in Russia and the research object is the networked operations of Finnish companies in this business context.*

1 INTRODUCTION & CONCEPTS

1.1 Background

The construction industry is a very heterogeneous combination of localised needs, various crafts, services, products and their professional providers. Even each service or product supplier can be seen as a business line of its own inside construction sector due to its specific characteristics, culture and terms of business. Different suppliers and other stakeholder are brought together around temporary projects in different stages of the production process. These conditions are often referred as fragmentation of the sector.

Restructuring of companies around their core businesses and outsourcing have formed the origin for long term trend along which construction operations are split increasing number of assignments as total. For example, data gathered from thousands of contractors indicates that subcontracting in French construction is now twice that fifty years ago[26]. Practically this means that the former general contractors with their diversified capabilities have disappeared, and, instead of them the number of parties involved in each project is bigger and they can be connected to each other in a manner that can easily increase the complexity of project in question. It is also very common that subcontractors are further subcontracting partially their assignments to their associates.

The described modern and increasingly complex construction environment need to be analysed, modelled and managed using approach(es) that embrace(s) the diverseness of operations and players in charge of them. Apparently, the traditional centralized project management paradigm has little to provide for this purpose. Some recent studies are clearly focusing on the challenges that are arising from the diverseness of construction operations. Examples of these viewpoints are i) models of networks of suppliers[27], ii) communication aspects[28], iii) value creation in networks of suppliers[29], iv) delays[24], and v) health and safety[25]. These studies are providing new knowledge about the characteristics of modern construction that may result in a new management paradigm that can be a decentralised one being rather different than traditional project management paradigm.

The objective of this paper is to present starting points of an on-going research effort focusing on modelling of networked construction operations. In this research six Finnish companies operating in Russia are used as cases where their local network (in Russia) is modelled for understanding the present situation and its potential business implications. The paper presents first earlier work by the authors forming the background for the research. Second the paper includes the early results of the development of a modelling solution addressing rapid portraying and communicating the current status of a company network around the focal company.

1.2 Some main concepts

Networking and collaboration in networks have created a high interest in both research and in practical applications during the last decade, especially in the eBusiness area. In parallel with the development and spreading of Internet technologies, traditional collaboration networks have found new leveraging tools and the new collaborative business forms have emerged. Although many solutions have been based on ad-hoc applications of available technology, there have also attempts to create some systematic approaches for understanding collaboration in networks. The European project VOSTER (Virtual Organizations Cluster) analysed the research in this field[1]. Used main concepts and approaches are reported in Virtual Organisations – Systems and Practices[2].

In most analyzes of collaborative networks, a distinction between the collaborative activities and the network itself is made. For the collaborative activities a temporary consortium is formed with the aim to fulfil a specific need or business goal. The need is in many cases a business opportunity appearing on the markets. After the performance of the task or mission, it is disclosed. This temporary consortium is usually called Virtual Organization (VO) or Virtual Enterprise (VE), stressing the aim that the collaborative organizations (enterprises) are assumed to behave like a single entity, although it consists of independent voluntarily collaborating parties.

The lifetime of a VO is typically restricted. It is created from the network in order to perform the defined task and it is dissolved after the task has been completed. However, effective operations in VOs require preparedness, which can only be developed in a long-term proactive co-operation[3]. Previously, this underlying environment was called “Network” or

"Source Network". In the European research project ECOLEAD (European Collaborative Networked Organizations Leadership Initiative)[4], the term "Breeding Environment" has been introduced to underline the need to support and maintain the preparedness for collaboration. The VO Breeding environment (VBE) - represents an association or pool of organizations and their related supporting institutions committed to collaborate, if the opportunity appears. Contrary to a more traditional understanding of networks of companies, ECOLEAD stresses that the breeding environment needs to be taken care of. It has to continuously be developed and managed. The VBE environment forms a sustainable framework supporting the whole life-cycle of VOs. In the ECOLEAD project, management and other support tools are developed and maintained. These tools help the organizations to be prepared for reaction to business opportunities. They can help in finding the most suitable partners for a specific task, based on e.g. competence catalogues and references. The tools also help in contracting and in the collection and maintenance of experiences. Consequently, information and related value systems are essential elements of the VBE, which its management has to take care of.

An efficient collaboration has to be supported by the Information and Communication Technology (ICT). Although it can rely much on the available ICT-infrastructure, the lack of common reference architectures and generic interoperable infrastructures, together with the rapid evolution of the underlying technologies, represents a major obstacle to the practical evolution of the area[2,5]. In order to leverage the potential benefits of the collaborative networked organization paradigm, more flexible and generic infrastructures need to be designed and implemented. E.g. in the ECOLEAD project, a generic, transparent, easy to use and affordable horizontal infrastructure for collaboration is being developed[4].

The previous ad-hoc approach to collaborative networks and the related poor understanding of the behaviour of the structures and processes has been addressed in attempts to model networking and to create reference models, which could be used as a basis for managing and supporting networking and VO activities. Many of them have their roots in the long tradition of enterprise modelling[6,7] . The distinction between the VBE (or network) and the VO (or VE) is usually also made in the models.

As stressed above both the VBE and the VO need management. In the models mentioned above, there are specific tasks and roles for these activities. The VBE manager is responsible for the continuous development of the network in order to maintain its preparedness for appearing opportunities. A main task is to create and maintain trust and collaboration spirit among the partners. Naturally the manager's tasks also include daily management and the maintenance of competency data-bases and support tools. The VO manager is mainly responsible for managing the activities. The task can be defined as the organisation, allocation and co-ordination of resources and their activities as well as their inter-organisational dependencies to achieve the objectives of the VO within the required time-, costs- and quality frame. The fact that the members of a VO are independent organizations creates major challenges for the management[4].

2 OBJECTIVES & FOCUSING

2.1 Modelling network operations

Business process modelling (BPM) is often used as an approach when one needs to analyse and portray existing processes and their phenomena. BPM enjoys also wide usage in relation to general business process re-engineering and development of company wide ICT systems which as examples demonstrates the overall importance of business process modelling. As a consequence of this position there are several hundreds of BPM tools available. In those, three main modelling approaches have been identified:

1. Process-centred modelling (verb plus context description)
2. Data-centred modelling (attention on inputs and outputs)
3. Behaviour-centred modelling (behavioural aspects of a system)

When applying the BPM tools the attention is usually on a single 'focal' company whose internal operations or operations with associated remote business units (e.g. subsidiaries or geographically dispersed production) are modelled. This type of business process modelling task can be considered as standard BPM state-of-the-art due to their wide usage. However, when approaching networked operations the world of business process modelling becomes different one compared with the modelling of operations of single companies. In networked operations our attention is on characteristics of partners, on dependencies between partners and on dynamics how the mentioned factors are causing impacts within the network. Figure 1 presents the modelling context with the concept 'string model' that illustrates how dependencies can have impacts over network of projects and operations in them.

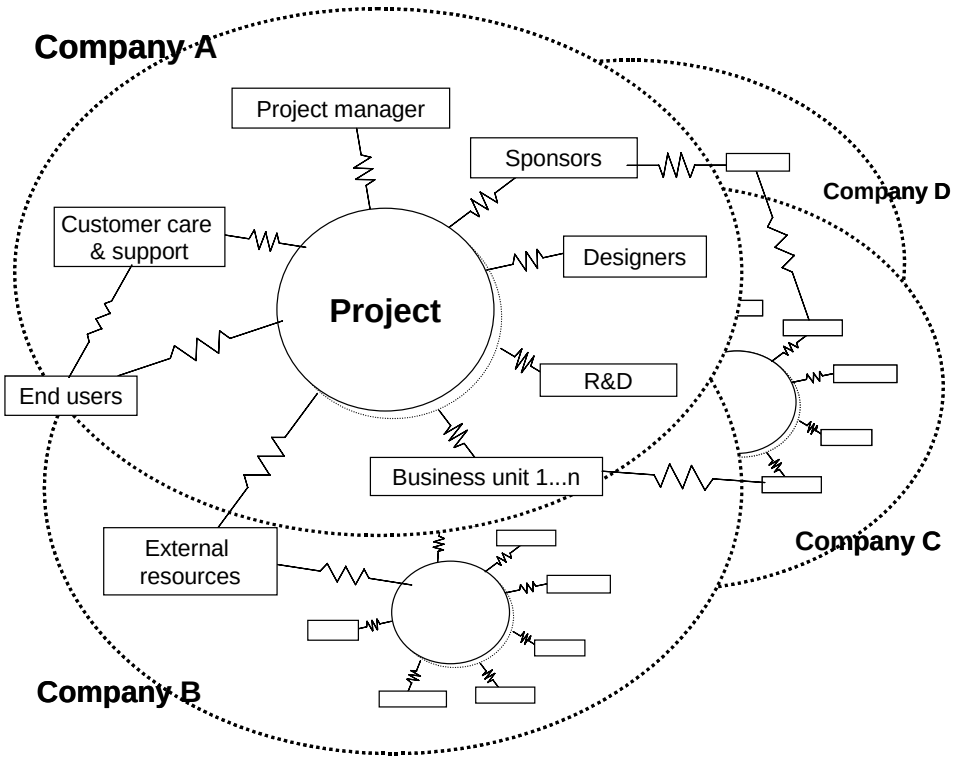

Figure 1: 'String model' of networked projects and their partners.

Modelling approaches

The aim of the modelling is the main feature affecting the needed detail in the modelling of collaboration and networking. The area of enterprise modelling has generated a huge amount of approaches for different needs[8,9,10,11]. In figure 2, a summary of different uses of modelling is illustrated. The presentation is a modification of a summary presented by Löh, Zhang and Katzy[12].

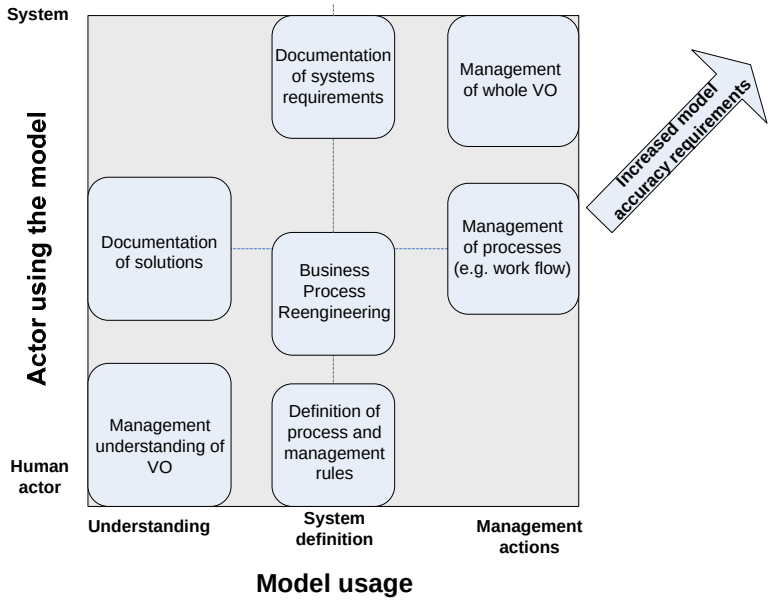

Figure 2: Different uses of models of enterprises and Virtual Organizations (based on Löh, Zang and Katzy[12])

In this positioning of the model approaches, the left lower corner represent the simplest case. The aim of the model is to help a human actor to understand the behaviour of the networked organization. I models for this type of purposes, a rough models of relationships and causes-and-consequences are usually enough. In the opposite, right upper corner, the models are the basis for management actions, which to a large extent are created via the system itself. In such cases, ambiguity has to be avoided and the accuracy requirements on the models are high. Similarly, the flexibility for changing models decreases[12]. Because of increased complexity and details, such models less support human understanding of the behaviour.

The purpose of framework models, mentioned in section 1.2, is to provide a structure for thinking about and defining organizations. The mainly fit into the lower left corner in figure 2 and they are usually an "empty shell" with different place holders and their relationships. These serve as a checklist of what elements should be defined by management or discussed in order to make assumptions about them explicit. Modelling frameworks like VERAM[11] and ARCON[7] belong to this category.

Concept models describe the main principles and features of networked organizations. This type of models may describe e.g. relationships between partners, characteristics and roles of partners or business processes. The modelling of the competencies and profiles of the partners in a network is an example of such models. Other examples could be models of trust creation and trust enhancement in a network. As examples of process models, one can mention the work-break-down structure of a task to be fulfilled in the network[4].

Management models support the operative management of virtual organizations as indicated in figure 3. The VO manager can make operational decisions based monitored status of the

VO process and supported by a decision support system. Both the monitoring and the decision support rely on the VO model and the related performance measurement[13,14].

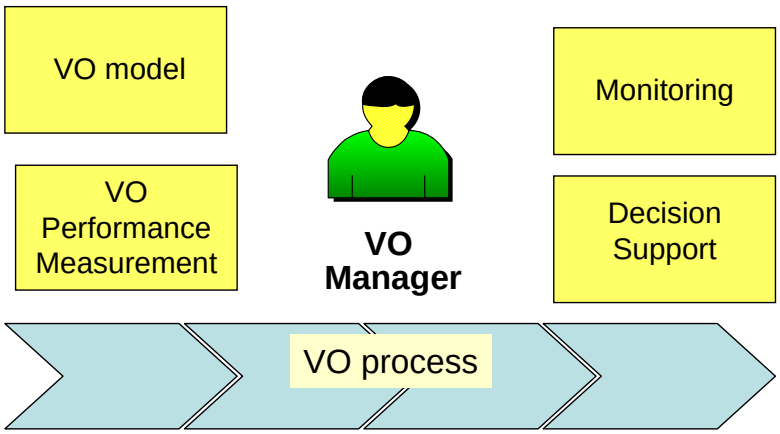

Figure 3: Model supported management of Virtual Organizations.

Based on the monitoring and the VO model, a dashboard for efficient visualization of the status of the VO can be realizad.

2.2 Recent approaches of analyzing enterprise networks

The objective of enterprise network analysis depends on the role of the analyzer. An enterprise network may be analyzed from the following viewpoints:

- network management or network broker role
- VO /VE management role (temporary consortiums created for a specific task)
- network partner or member role
- customer of the network
- financier or significant owner of the network / involved companies
- independent external evaluator.

The different views affect on the analyzed issues. Some approaches have been developed for the network manager or the VO manager roles. The network management or broker is typically interested in the assessment of the network competitiveness, capability or robustness; to design and implement a network, to evaluate potential partners or to identify the weak points and the improvement needs for an existing network. The analysis may be performed at different levels; either on the network/ collaboration level or analyzing the involved organizations.

Many methods are aimed for the self-assessment of the networkability of an organization. There are also some solutions for collaboratory assessment to evaluate the participation in the network from the partner viewpoint. However, there are no established practices for the

analysis; in most networks no systematic analysis are used.

It is expected that in many industrial fields customer-involvement will increase in the product / service lifecycle. This will increase the interest of the customers to understand in more detail the capabilities of the network.

The analysis is most often based on a "model" of the influencing factors of a network from a specific viewpoint. Sometimes the results of the analysis are presented as a documented network specific model; sometimes more sophisticated results are created. Quite often the objects or elements of the model are turned into quantitative measurements or qualitative questionnaires. Generally the "analysis" methods are not developed into analysis tools, but represent more general frameworks to structure the interesting elements.

Depending on the scope the analysis may require:
- description of the network structure, objectives, visions & strategies
- collection of information about the involved organizations, for example their capabilities and knowledge
- collection of information about the past experience of the network operation
- collection of customer feedback
- refinement of the collected information
- conclusions and setting up actions based on the analysis.

The analysis may use both quantitative and qualitative information.

ECOLEAD (EUFP6 IP 506958[4]) reviews enterprise networks as "Virtual Breeding Environments" to emphasize that networks require care and management. In ECOLEAD methods and tools to support the network creation and management, and management of the temporary consortiums (Virtual Organizations) have been developed. These methods include also some approaches which could be used as a basis for network analysis. At the network level methods like partner trustworthiness assessment[8] (between members, towards VBE administration, customer to VBE) have been developed.

Figure 4 presents an example of visualization of results of a network trust analysis applied for an SME network called Virtuelle Fabrik[15] . In the visualization:
- Nodes denote reputation: higher trust/ better reputation –> wider node.
- Arcs denote links: thick link –> high mutual trust.
- Most incoming links –> most trusted partners.
- Most outgoing links -> best connected nodes.

The results have been created by mutual evaluation in the network: Each partner has evaluated the other partners with which it has had collaboration. The properties used in the analysis include competencies, activity, punctuality, reliability, partnership, love of risks and economical situation. This type of analysis is quite heavy and it seems to suit best for non-hierarchic networks with not only vertical but also horizontal collaboration. it may not be as good for networks with a strong leading company.

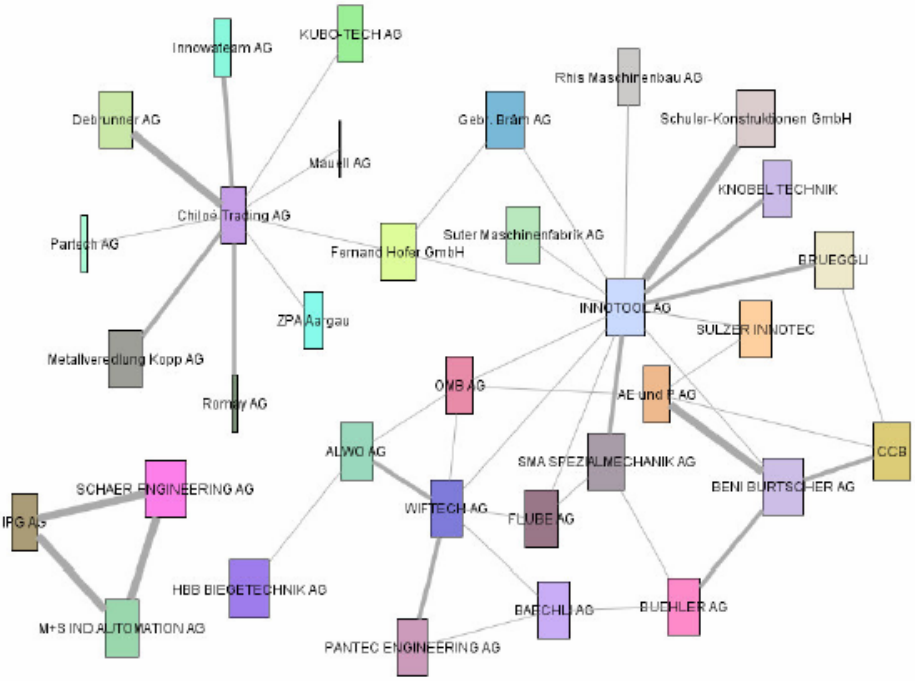

Figure 4: Example of enterprise network visualization[15].

Measurement of partner performance is developed to be used both at the network level and as support in managing the VOs[13] . The performance measures include not only “hard” issues like financial, quality and timekeeping, but also “soft” measures of collaboration. Additionally, to support the VO management, qualitative monitoring of VO status, based on the “feelings” and attitudes of the VO participants has been developed[14].

One approach for analysis in the networking field is to support an organization to self-assess its preparedness to networked operation. Österle et al.[16] analyse the networkability of enterprises looking for example at the company products, processes, information management etc. Ruohomäki et al.[17] present a method called “network rating” in which different perspectives, like business idea, strategic development, process management etc. are studied. In Hallikas et al[18] and Karvonen et al[19] a methodology and a tool has been developed to analyze the risks of an enterprise network from the viewpoint of a network partner. Additionally a collaborative process for risk analysis in a network is proposed.

3 PROFILING NETWORKS

3.1 Descriptive parameters of networks

Different networks have different challenges and thus also the focus of network analysis may vary to some extent. The Globeman21 approach[20] has considered the different characteristics by making a separation between two kinds of descriptive parameters:

- situational factors: these are conditions coming from the environment (lead time

requirements, distribution of partners and customers, types of needed competencies, ..); that is, factors which cannot be changed or selected.

- design parameters: these are selected parameters (rules for the management, for exposure of competencies, legal aspects).

These types of descriptive parameters can be analysed both at the network level and at a VO/VE level. In fact, the network features are situational factors for each VO built from the network.

One typical parameter which has been used most often to describe a network is the network topology. The topology is usually understood as a structure describing all the different relationships between the partners (nodes of network), including:

- information flows
- material flows
- monetary flows
- control flows, responsibilities, power relationships and decision making.

All the different flows don't always have the same routes and directions.

In CE-NET[12] and VOSTER[22] which have collected together experience and knowledge of research and development projects in the networking field, the following topologies were identified (Figure 5):

- supply-chain topology; interaction of partners follows mainly a chain, links are in a tiered structure with each partner relating to its upper and lower neighbours.
- star topology, or hub and spoke –topology, with one central partner (main contractor). Links are arranged predominantly star-like between a central partner and the other organisational entities.
- peer-to-peer topology; interaction between all nodes without hierarchy.

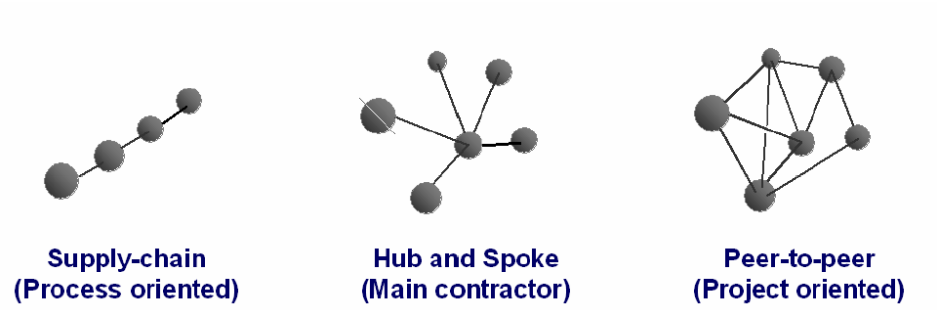

Figure 5: Topologies for Virtual Enterprises[16]

3.2 Characterizing networks

The aim of the characterization of networks in the current project has been to identify the important features which have an influence on how the network should be constructed, operated and managed. It also supports the specification of what elements should be included

in the network analysis, when reviewing the network from the view of the main enterprise (network manager). An advanced network analysis could even be configured according to these features to focus on the most essential elements of each network. The configuration could be performed in different respects:

- selecting the enterprises which should be analyzed from the network (if all enterprises cannot be analyzed),

- definition of the level of detail for the analysis,

- configuring the used questions for the analysed enterprises.

The high level descriptive parameters characterizing the network profile are presented in Table 1.

Topic	**Descriptive parameters**
The products and services of the network: offering to the custom	Product type (physical…intangible); production type (mass…one-of-a-kind); frequency of customer deliveries; duration of a customer delivery
The size and location of the network	Number of enterprises; geographic distribution; heterogeneity of enterprises; "depth" of the network; dependencies between enterprises
Network preparedness and development stage	Current lifetime& experience; practices and rules; Utilization of ICT
Main criteria in customer deliveries	Importance of costs, punctuality, lead time, quality, preparedness to changes, ability to find new solutions
Environment	Market & customer status; number of customers; technology development in the field

Table 1. Identification of the descriptive parameters of a network.

3.3 Fast analysis of network status

Approaches to analyze enterprise networks were presented above in chapter 2. However, it was found that there is a need for a simple tool applicable to identify and present the status of

enterprises operating in a star-like international network, from the viewpoint of the main company. The tool should produce and visualize an overall view of the enterprises' status related to network operation. The aim is not to collect any quantitative information (for example of the economical indicators) but qualitative information which often is not handled at all. If a risk or an insufficiency is identified for a company, it can be taken for a more detailed analysis.

To keep the analysis simple, a questionnaire methodology is used. the planned procedure is the following:

1. Select the key experts from the network manager company for the analysis. They should be persons having experience about the collaboration in the network. A typical number of key persons could be between 1-5 (or even more).
2. Select the enterprises which will be analysed. If the network is small enough even all the enterprises can be assessed. The different key experts may also propose different companies as they do not necessarily have the same background.
3. Key experts of the main company (network manager) answer the query for the selected enterprises.
4. The results of the questionnaires are consolidated and summaries are created, partly by the tool, partly by an expert.
5. Conclusions should be made by an expert/ experts. It is recommended that the results should be discussed in the key expert group to define actions.

To keep the analysis method simple, the number of questions involved should be restricted, understandable and focused on the most important issues. To achieve this, opinions of the involved industry and experts were collected. A list of 16 topics was presented to 6 experts and they gave their opinion about the importance of each topic. In most cases the opinions of different experts were quite near each other.

Based on the opinions, the 16 topics were converted to 9 topics for the questionnaire. To make it easy for the analyzer, the topics were modified to statements. The idea is that the expert performing the analysis gives his/her opinion of the statements (from "do not agree" to "agree"), looking at the statements separately for each analyzed company. The topics of the draft questionnaire include:

1. the significance and replaceability of the analyzed company in the network
2. knowledge, resources and quality output
3. punctuality in time and adaptability to changes in deliveries
4. the correspondence of cost level and performance
5. ease of communication and collaboration
6. ability to deliver, compliance with agreements, openness in case of problems
7. reliability and networking of responsible persons
8. the needed special knowledge (ICT, customer relationship management, local knowledge and will & competence to develop)
9. ability to adapt to changing environment and collaborate with other enterprises.

The statements have now been formulated as the first version. The plan is to test the method in selected enterprises to gain experience about its applicability. Also information about the readability of the statements is needed. It is expected that after the test some improvements and clarifications to the topics may be needed.

There are different levels of the consolidation of the analysis results:

- consolidation of evaluation of one company from different experts,
- evaluation of measures at the network level by combining the results of different companies.

In creating the conclusions it should be noted that statement 1 evaluates the significance of the company to the network, while statements 2-9 evaluate the capability and performance of the company in the network. The answers to statement 1 should thus identify the most important companies; giving information about the importance of the following answers. If there is large variation between the answers of the experts the reason for this should be found; not to make misguiding conclusions.

The next step is also to specify how the results of the analysis should be visualized. One alternative is a spider web for each important company showing the mean value of the evaluations of different experts for each characteristic. It could also be possible to evaluate the "persistence" of the network as a weighted average of the performances of the companies; weighted by the significance of the company. However, these approaches need to be validated by practical tests; not to make any too extensive conclusions.

4 DISCUSSION & FURTHER DEVELOPMENT

Collaboration in networks has traditionally been a natural element in the construction sector. However, the increased competition together with available new technology has created new challenges on efficient creation and management of networks with a variety of different actors. The main challenges come from the temporary nature of a VO and the distribution of operations to several independent organizations, which are expected to collaborate towards a common goal. In addition, the VO is aimed to respond to fast changes in its environment, i.e. a dynamic management is needed, which also may include restructuring of the management approach, or even the VO configuration, during the operation of the VO[23]. The networks need to be balanced to operate efficiently and reliably in the short run and to adapt also for longer term activities. They operate in different environments, are in different stages of development and require different management and development actions. Understanding the network characteristics supports the identification of the factors which are critical for each network.

There are different approaches to model and analyze enterprise networks, extending from multifaceted frameworks to narrow models for a specific purpose. For an SME operating in a network it may be difficult to find a proper model. Additionally, there are quite few tools which are easy enough to apply for the network analysis.

This paper proposes a qualitative approach to analyse enterprise networks from the network manager viewpoint. The aim is to develop a tool which adds to the quantitative

approaches, is sufficiently easy and fast to apply. The aim is not to automate decision making but to give meaningful information to support decision making. The proposed approach relies on recent work in the domain and in the presentation of the results and the applicability in the construction sector has been in focus.

The current work by the authors is addressing the development of a tool for modelling the status of company networks in the context of companies mentioned in the introduction chapter. The named companies have business operations in Russia where due to dynamics of markets it is their interest to monitor continuously the current status of their company network. An obvious solution for this purpose is a tool for collecting the network status data and for preparing network visualizations and reports to company management's decision making (Figure 6).

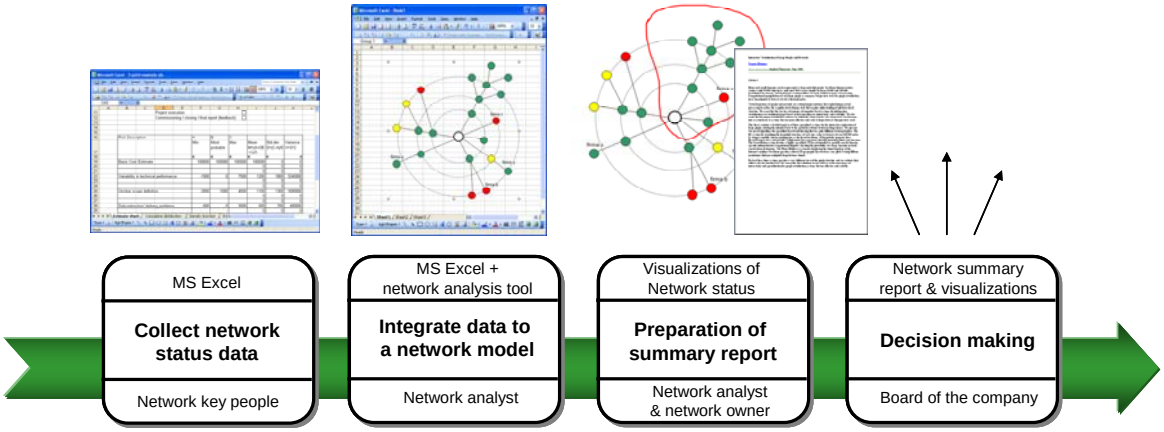

Figure 6: Tool for modelling the status of company networks.

5 CONCLUSIONS

Modelling of networked operations is a rather new topic that has an obvious connection to business process modelling. Still at present the modelling principles and methods are not well-established for this purpose. The work presented in this paper addresses subjective status modelling of company networks. Evidently, in nowadays' turbulently changing market conditions it is of importance for an increasing number of companies to monitor continuously the status of their company network. This seems to be a common need in many business disciplines but the context of the work presented in this paper are companies from construction sector. It is expected that the development of company network modelling tool shall contribute new knowledge regarding network modelling aspects. Additionally this tool, being a practical software solution, can provide a useful research platform for case studies.

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