Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia CIRP 7 (2013) 61 – 66

www.elsevier.com/locate/procedia

Forty Sixth CIRP Conference on Manufacturing Systems 2013

Conceptual framework for non-hierarchical business networks for complex products design and manufacturing

Luis Maia Carneiro[a*], Pedro Cunha[b,c], Pedro Sena Ferreira[c], Ahm Shamsuzzoha[d]

[a] *INESC Porto, Rua Dr. Roberto Frias 378, 4200-465 Porto, Portugal*
[b] *IPS, Estefanilha, 2910-761 Setúbal, Portugal*
[c] *CENI, Campus do IPS, Estefanilha, 2910-761 Setúbal, Portugal*
[d] *University of Vaasa, Po Box 700, FI-65101, Vaasa, Finland*

* Corresponding author. Tel.: + 351 22 209 4000; fax: + 351 22 209 4350 .*E-mail address*: luis.carneiro@inescporto.pt.

Abstract

The effective creation and management of business networks is more and more an important contribution for the competitiveness and sustainability of European SMEs. In Non-hierarchical networks SMEs join their competencies and resources to grab profitable business opportunities. In these networks SMEs take the leading role and control the business instead of being subcontracted by large companies and traditional supply chains. This paper presents a conceptual framework, including methodological approach, best practices and reference processes aiming at supporting SMEs in creating and managing non-hierarchical networks for complex products design and manufacturing. The framework high level structure and the most specific processes are presented, including: capacity management, collaborative operations planning, risk and event management and performance management. The framework was validated in three pilot networks, from the textile, footwear and machine tools industries.

Selection and peer-review under responsibility of Professor Pedro Filipe do Carmo Cunha

Keywords: Non-hierarchical business networks; Conceptual Framework; Reference processes

1. Introduction

In order to survive in today's competitive business environment manufacturing firms, especially small and medium enterprises (SMEs), need to establish collaborative networks to join and share the needed knowledge, capabilities, resources and critical mass to develop new business and delivery higher quality and complex products. Collaboration is seen, especially for European SMEs, as a critical factor to shift from cost competition to a high value added competition for delivering product and services in the global market.

The concept of non-hierarchical networks is in opposition with the traditional supply chains because it allows higher involvement of SMEs in controlling their business and managing their value creation throughout the value chain. In this type of networks SMEs are invited to share resources, capabilities and to cooperate in the decision making processes and achieve quick response, faster time-to-market and differentiated offerings at competitive prices.

This paper presents a conceptual framework for the creation and management of non-hierarchical business networks developed in the scope of the European RTD Net-Challenge project. This Framework defines the high level concepts and activities that support non-hierarchical collaboration and it was especially developed for the design and manufacturing of high-variety and low-volume complex products, e.g. products with a high number of components or customized according to specific customer needs.

2. Collaborative Networks Background

Collaborative networks can assume different legal forms such as explicit consortium, internal consortium, sub-contracting and partnership. They can also assume other forms such as industrial district, industry cluster, virtual organisation (VO), virtual organisation breeding

Selection and peer-review under responsibility of Professor Pedro Filipe do Carmo Cunha
doi:10.1016/j.procir.2013.05.011

environment (VBE), business community (BC) [1] and business ecosystems.

The formation and management of a collaborative network is facilitated by today's fast evolution of Information and Communication Technologies (ICTs) that have provided a powerful enabler for collaboration, particularly among geographically dispersed organisations. A Virtual Organisation is a powerful concept to analyse organisations working on a common business goal [2]. It highlights the importance of sharing relevant resources, knowledge and decision making processes to create value for the organisations within its boundaries. Collaboration requires the establishment of common business goals, building trust, which can lead to higher levels of knowledge sharing and building sustainable business transactions and cooperative work.

The success of collaborative business environments depends on the design and execution level of its cross-enterprise business processes. Implementing a consistent business process modelling method increases the transparency and structuring of cooperation and creates a basis for communication between participants.

Inter-organisational business processes became more complex as a result of the numerous possibilities of interaction as well as the strategic, structural and cultural differences between the partners [3]. Stohr and Zhao [4] define the focus of business process management (BPM) as the range to more technical perspective that provides an overview on the relationship between information systems and the innovation within collaborative network.

There are various frameworks developed for the purpose of defining business process management in collaborative business. Adam et al [5] proposed a collaboration framework for cross-enterprise BPM, where they defined how cross-enterprise processes can be planned, implemented and controlled. Adamides and Karacapilidis [6] presented a knowledge framework for collaborative BPM with the aim to highlight the design rationale, the structure and the use of web-based information systems for business collaboration. A holistic analysis framework for collaborative e-Business process modelling approach that takes into account the specific challenges for SMEs is defined by Hoyer and Christ [7]. A framework for process-driven business integration management for collaborative networks is proposed by Vanderhaeghen et al. [8] and addresses the organisational and technical dimension of cross-organisational business processes. Romero and Molina [9] proposes a generic business process management framework for VO breeding environments and virtual organizations. Sriharee [10] proposes a collaboration framework to support the implementation, comprising three layers: business process, ontology and technical layer.

3. Net-Challenge Conceptual Framework

The Net-Challenge Conceptual Framework to form and manage collaborative organisations is composed of conceptual definitions, general guidelines and reference collaboration processes. The Framework is structured in four main modules [11] (Figure 1). The first three modules support the formation and management of:

- Dynamic Business Communities (BC);
- VO for Engineering-to-Order business opportunities;
- VO for Customize-to-Order business opportunities.

Each of these modules is structured in the main phases for the respective life-cycles, namely: Create, Operate, Metamorphose and Dissolve for BC and Form, Operate and Dissolve for VO (Collaboration projects).

The framework fourth module supports performance management of BC and VO.

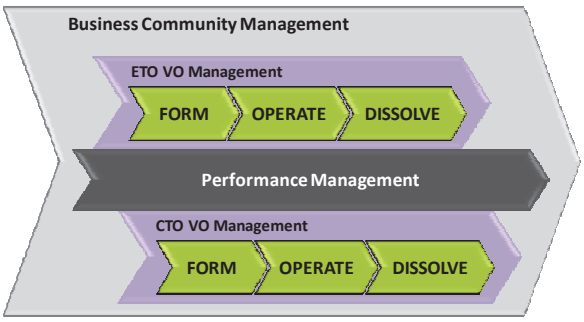

Fig. 1. The Net-Challenge Conceptual Framework modules

In the BC Management module potential business partners are attracted, developed and qualified, and trust and information sharing is promoted [12]. This module goal is to promote a suitable environment for collaboration. To respond to specific business opportunities to manufacture and deliver complex products, VOs are formed for either Engineer to Order (ETO) or Customize to Order (CTO) scenarios.

The performance management module aims at the alignment and achievement of strategic and operational business objectives of BC and VO. It is based on an external perspective in order to assure that the organisation's performance is tightly linked with competitiveness.

3.1. Build Business Communities

The establishment of dynamic BCs is an important enabler for the fast and efficient formation of temporary partnerships (e.g. VOs), able to successfully respond to specific market opportunities [1]. The objective of the Build Module of the Net-Challenge Framework is to provide the conceptual background, methodological guidance and Reference Collaboration processes to

organisations that want to create and manage BCs supported by advanced ICT tools. These BCs are business environments that comprise a significant number of organisations, mostly SMEs, where trust is developed between its members and communication mechanisms are established. There should be easy mechanisms to find business partners and to Form VOs to respond to specific market opportunities.

The Build Module is structured following the main phases of the life-cycle of a BC, namely: Create, Operate, Metamorphose and Dissolve. In the first phase the BC is created and includes activities like: identification and evaluation of the opportunity to create a BC, identification and selection of the initiators and the definition of the Business model, governance model, operating rules. The first steps to create a BC are related with the identification and evaluation of the opportunity to create the BC and the definition of its mission, main objectives and strategy. Particularly important is the definition of BC Business Model, particularly the value proposition and the cost and revenue structures. BCs should also support risk management of collaboration. There should be rules for defining confidentiality agreements as well as predefined sets of procedures on how to handle conflicts in a productive way.

The second phase in the Build module is the BC Operation. In this phase the management of the community is implemented (admission and withdrawal of members), trust is promoted, networking and knowledge sharing is supported and promoted, community members are qualified and the community capacity is managed. For this phase reference processes are proposed to manage the community's capacity and the member's qualification. When the need for more capacity for a specific manufacturing operation is identified, the relevant capabilities of the Community members can be developed or new members with those capabilities can be identified. When those capabilities need to be audited, collective qualification programmes can be implemented.

3.2. ETO Collaboration Projects

The ETO module of the Net-Challenge Framework is used to support the management of projects (VOs) for the collaborative design and manufacturing of custom made and complex products and is structured in three main high level phases: Form, Operate and Dissolve. The most challenging aspect in the ETO Management Module is to manage the long lead times, due to a time consuming design phase and complex bill of materials.

Form an ETO Collaboration Project

The objective of the Form phase is to form a partnership (or VO) to respond to a specific business opportunity. This includes the selection of partners, the product concept development and the definition of a quotation for the customer. The product concept development is done just with the detail necessary to allow the quotation preparation. The output of this high level phase is a formalized contract among the partners that contributed to the best proposal in the negotiation process and agreed to collaborate in the VO.

In non-hierarchical networks the VO is formed by a partnership of companies that have similar bargain power and invest in the opportunity and share risk, which increases their engagement and business control. The following picture presents the activities performed in each step of the ETO VO FORM phase.

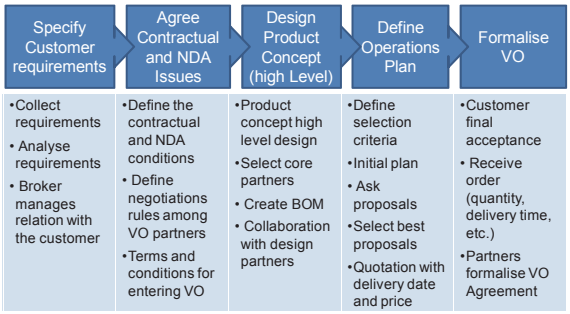

Fig. 2. ETO VO Form phase of Net-Challenge framework.

Especially important in this context is the collaborative product design, for which partners bring unique competencies and capabilities. Specific and innovative approaches are proposed for collaborative operations planning and event management.

Collaborative Operations Planning

The proposed planning approach considers the aggregate operations that are assigned to the partners in the VO being formed, leaving the internal operation details to be managed by the respective partner. This approach is based on a decentralized negotiation model, allowing partners to propose delivery dates and respective costs [13]. This collaborative planning approach defines two types of partners: i) *Core partner*: organisations collaborating actively in the formation of a VO and playing an active role in the definition of the product concept (high level design), sharing the investment and the risks inherent to the exploitation of the given business opportunity; and ii) *Potential partners/additional partners*: are the partners that Core partners jointly decide to involve in the formation and operation of the VO, to provide some of the necessary components, parts or services. These partners can only access the information on their own activities.

The proposed approach for aggregate collaborative planning includes the following main sequential steps:

- The customer presents the business opportunity requirements to the Broker, e.g. company that

identified the business opportunity and is responsible for the interaction with the customer;

- The criteria for partner evaluation and selection in the scope of specific operation plans are defined and agreed in the beginning by the core partners;
- Then, a product concept/design is defined by the Broker and by the Core partners that are invited to join the VO based on their specific competencies and availability. In this context, the necessary main operations of the VO are defined, with its sequence and timing restrictions (start, finish and leading times), taking into account the theoretical capacities defined in each partner profile;
- A first "rough" operations plan is proposed by the Broker to the VO core partners;
- Partners receive this first "rough" plan and a set requests for quotations, one for each operation allocated to them. Each partner considers their local capacity and evaluate if it is possible to accept the proposed dates and lead time for the specified order quantity. A quotation is presented by each partner, in which the price is specified and the proposed plan is accepted or an alternative is proposed;
- The proposed "rough" plan changes its state to "feasible" or "not feasible";
- After this analysis, any core partner may initiate a new "negotiation" round between the partners in order to reach a plan with a better evaluation;
- Additional partners may be invited to participate and present quotations for operations not allocated to core partners. Their selection is performed according to the multiple criteria defined initially.

The Form Phase concludes when the customer confirms the order and partners formalize a VO contract.

Operate an ETO Collaboration Project

The objective of the operate phase in the ETO scenario is the development and manufacturing of one-of-a-kind products, whose concept and quotation was develop in the Form phase.

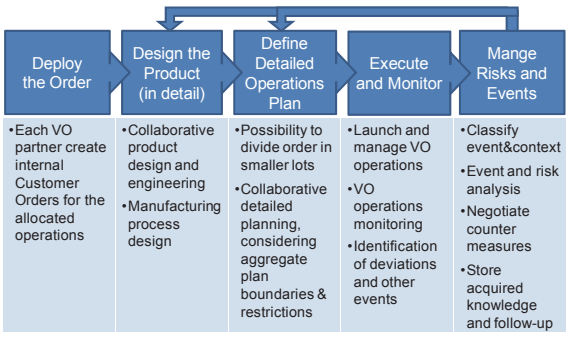

Fig. 3. ETO VO Operate phase of Net-Challenge framework.

The operate phase starts with the order deployment, which is followed by product engineering, detailed planning and execution processes. The picture below presents the ETO VO OPERATE phase.

The detailed operations planning follow the same approach of the aggregate planning. It considers the real customer order delivery date, the partner's availability and may detail each operation is smaller transportation lots if necessary to achieve the required lead time.

Monitoring and Event Management

The monitoring and event management is the global process to minimize the probability and to deal with adverse events. The event management reference process is initialized before the VO is formed, in the business community context, where sub-processes are foreseen to ensure the organisation preparedness. It continues throughout the VO formation and operation phases. The risk management process occurs in the formation and operation phases, aiming to establish a dynamic and quick response process. In the operation phase, event handling will make use of existing competencies within the network and other resources for communication and knowledge sharing [14].

Events are detected in the course of business activities or through the monitoring activities: i) risk monitoring (part of the risk management process) and ii) production monitoring. The production monitoring activity is the key to event management. When detecting some production related events, passes them to event handling. Event handling is a sub-process of the event management for collaborative problem solving that needs a dialog between the actors or resources performing diagnosis and planning recovery actions.

For expected events, the network should be able to mobilize the available knowledge compiled in the context of the risk management process, for a planned reaction to the event. Unexpected events are dealt with in a discretionary approach using a problem solving methodology. Depending on event's complexity, its classification may not be determined on the first approach and, consequently, the decision making process is not a once-through process searching for the best option, but rather a cyclic process aiming to choose an acceptable option and then improve it, based on the observed system performance.

Organisation preparedness to respond to events is of paramount importance to handle events in the most effective and efficient way. Preparing the organisation involves the understanding of how risks and events develop and the experience of handling previous events. It should enhance response to both expected and unexpected events, through structured, unstructured or mixed mechanisms, particularly in non-hierarchical networks.

Dissolve an ETO Collaboration Project

When the one-of-a-kind product is delivered to the client, the VO completes its mission and is dissolved.

The activities of the reference process to dissolve the VO are related with performance evaluation and the archive of knowledge for future use. These are essential activities for future performance in BCs, as performance evaluation will be used for continuous improvement and the acquired knowledge will increase member's competence and capability. Communities, as well as companies, that are able to learn with their own action and are able to retain and share that memory will be significantly enriched and will have decisive competitive advantages [15].

3.3. CTO Collaboration Projects

The Customize-to-Order (CTO) module of the Net-Challenge Framework supports the management of projects where a group of partners decide to offer on the market a platform based product family at a competitive price and lead time. A basic requirement for implementing a mass customization strategy (MC) is the ability to configure a product according to the specific needs of each customer, balancing the needs of personalization with the level of flexibility and adaptability of industrial production. All the tasks that differentiate the product for a specific customer must be postponed until the latest possible moment in the production flow.

The CTO scenario can be positioned between the ETO and MTO traditional production strategies. CTO can guarantee different levels of customization: best-fit, personalization, product platform creation, aesthetic vs. functional customization. In the CTO scenario, a product platform is designed and engineered by the partners, which represents the basis for the collaboration in the VO. Product variants are manufactured and delivered to different customers according their specific requirements. Reference processes support this scenario.

The Form phase in the CTO scenario aims at bringing together partners to design the product family and to define a business plan. The Form phase is concluded when the VO members agree with the defined business plan and formalize the VO contract.

The Operate phase starts by the *detailed* engineering of the product platform by the VO partners. When the design is complete, partners start offering the product on the market. The delivery of specific product variants is managed following the "Operate an ETO collaboration project" presented above. The approach allows the platform to include components that may be specified by the customer, which are referenced as "white boxes". The ICT support designed by the Net-Challenge project uses a product platform to manage this process [16].

3.4. Performance Management

Performance management is critical to the success of collaborative networks. For its effective implementation, suitable approaches and processes are required. The performance management module aims at guaranteeing the alignment and achievement of strategic and operational business objectives in the BC and VO environments. It also intends to support the evaluation of alternative system configurations, to contribute to the robustness of processes and, by this, to enable network reliability and service level. It covers objectives, strategies, performance measurement and evaluation, monitoring, learning and improvement. However, special emphasis was put in the specific aspects of performance management in collaborative networks still lacking research support. It does not address directly the performance management internal to network members, but the performance management at network level.

The main components of Net-Challenge performance management framework are the stakeholder perspective, the factors in the organisation which can be acted upon in order to change performance, the reference processes to define a strategy and make it succeed, the information system, the process resources and the communication processes [17]. Performance can be changed by taking actions in the two environments, which means in two time horizons. In the VO, depending on its lifetime and in the BC, where members develop their capabilities, share knowledge and get to know each other.

This performance management approach encompasses the processes to define the objectives and to formulate a strategy, to establish what to measure and the targets, to the setup the measurement system, to measure and analyse performance and, finally, to decide and execute actions in order to achieve the targets.

An web based ICT platform was designed and developed to support the management of BC and VO, following the Net-challenge conceptual framework.

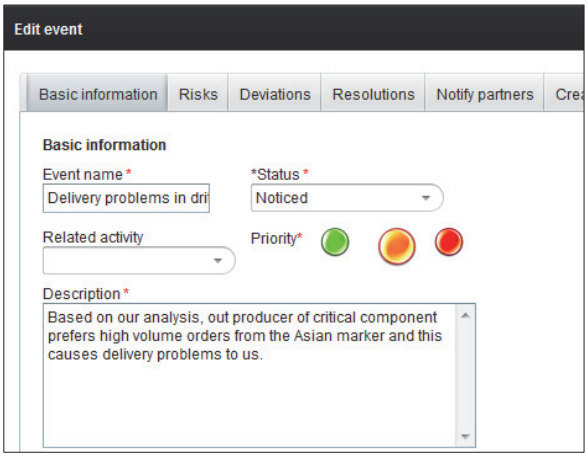

Fig. 4. Sample screens from the support ICT platform

4. Validation

Three demonstrators were implemented in networks representing different industrial sectors: textiles and apparel in Portugal; footwear in Italy and machine tools in Spain, allowing the Framework and the support ICT tools improvement and validation.

The cases were selected to be representative of a large variety of industries, dimension and industrial sectors or activities, to ensure the Framework wide applicability and to facilitate its future exploitation. The machine tools case validated the ETO scenario. The textile and the footwear case validated both the ETO and the CTO scenarios.

5. Summary

Available methodologies for managing collaborative networks do not cover the requirements of non-hierarchical networks for complex product manufacturing. The Net-Challenge Framework fills this gap through specific concepts, processes and support tools to drive SMEs in establishing dynamic and non-hierarchical networks. The main developments were summarised in this paper and include Capacity management in Business Communities, collaborative design, collaborative operations planning, risk and event management and performance management. Specific approaches were designed to manage ETO and CTO collaboration projects. CTO projects can be managed using standard product configurators and the delivery of each variant is managed using an approach similar to ETO operation.

The Net-Challenge Framework was implemented in an ICT web based platform with a set of decision support tools that support SMEs in managing BCs and VOs for product design and manufacturing, including performance management.

Acknowledgements

This work has been partly funded by the EC through the EU FP7 Project Net-Challenge (No. FP7-CP-FP229278-2). Our gratitude and appreciation also goes to all project partners for their contribution during the development of various ideas and concepts presented.

References

[1] Camarinha-Matos, L.M., Silveri, I., Afsarmanesh, H. and Olivera, A.I. (2005), ”Towards a framework for creation of dynamic virtual organizations”, In Collaborative Networks and their Breeding Environments, (PRO-VE’05), Springer, Valencia, Spain, 26-28 September, 2005.

[2] Venkatraman, N. and Henderson, C. (1998), ”Real strategies for virtual organizing”, Sloan Management Review, 40(1), 33–48.

[3] Rosemann, M., T. de Bruin, and B. Power (2006), ”A model to measure business process management maturity and improve performance”, in Business Process Management: Practical Guidelines to Successful Omplementations, Eds.: Jeston, J., Nelis, J., Burlington, pp. 299-315.

[4] Stohr, E.A. and Zhao, J.L. (2001), ”Workflow automation: Overview and research issues”, Information Systems Frontiers, Vol. 3 No. 3, pp. 281–296.

[5] Adam, O., Hofer, A., Zang, S., Hammer, C., Jerrentrup, M., & Leinenbach, S. (2005). A collaboration framework for cross-enterprise business process management. Preproceedings of the First International Conference on Interoperability of Enterprise Software and Applications INTEROP-ESA (p. 499–510).

[6] Adamides, E.D. and Karacapilidis, N. (2006), ”A knowledge centred framework for collaborative business process modelling”, Business Process Management Journal, Vol. 12 No. 5, pp. 557–575.

[7] Hoyer, V. and Christ, O. (2007), ”Collaborative e-Business process modelling: a holistic analysis framework focused on small and medium-sized enterprises”, Business Information Systsems, Lecture Notes in Computer Science, Vol. 4439, pp. 41–53.

[8] Vanderhaeghen, D., Hofer, A. and Kupsch, F. (2009), “Process-driven business integration management for collaboration networks”, in Lee, I (Eds.), Selected Readings on Information Technology and Business Systems Management, IGI Global, USA, pp. 356-374.

[9] Romero, D. & Molina, A. (2009), “VO breeding environments & virtual organizations integral business process management framework”, Information System Frontier, Vol. 11, pp. 569-597.

[10] Sriharee, G. (2011), ”Towards ontology-based collaboration framework based on messaging system”, Networked Digital Technologies - Communications in Computer and Information Science, Vol. 136 No. 6, pp. 345–356.

[11] Carneiro, L., Almeida, R., Azevedo, A.L., Kankaanpää, T. & Shamsuzzoha, A. (2010). An innovative framework supporting SME networks for complex product manufacturing. in Collaborative Networks for a Sustainable World (11th IFIP WG 5.5 Working Conference on Virtual Enterprises, PRO-VE 2010, Saint-Etienne, France, October 2010 Proceedings), Camarinha-Matos, L.M., Boucher, X. and Afsarmanesh, H. Edition, Springer.

[12] Almeida, R. Carneiro, L.M., Sá, A, Ferreira, P.S., Fornasiero, R. (2013), “Business Community Management”, in Intelligent Non-hierarchical Manufacturing Networks, John Wiley & Sons

[13] Almeida, R. Toscano, C. Azevedo, A.L., Carneiro, L.M. (2013), “A Collaborative Planning Approach for Non-Hierarchical Production Networks”, in Non-hierarchical Manufacturing Networks, John Wiley & Sons..

[14] Shamsuzzoha, A., Rintala, S., Cunha, P., Ferreira, P.S., Kankaanpaa, T., Carneiro, L.M., (2013), “Event Monitoring and Management Process in a Non-Hierarchical Business Network”, in Non-hierarchical Manufacturing Networks, John Wiley & Sons.

[15] Hormazabal, N., (2011), “On the management of Virtual Organizations' Dissolution (in Virtual Business Networks)", PRO-VE'11 - 12th IFIP Working Conference on VIRTUAL ENTERPRISES, São Paulo (Brazil),

[16] Shamsuzzoha, A., Kankaanpää, T., Carneiro, L. Helo, P, (2011), "Collaborative product design and engineering – prospects for engineer-to-order and customized-to-order production scenarios", PRO-VE'11 - 12th IFIP Working Conference on VIRTUAL ENTERPRISES, São Paulo (Brazil), October 2011

[17] Ferreira P.S. & Cunha P.F. (2011), A framework for performance management in collaborative manufacturing networks. In 7th International Conference of Digital Enterprise Technology (DET2011), September 2011, Athens, Greece.