CE Challenges
Work to Do

Stjepandic, J; Verhagen, Wim; Wognum, Nel

DOI
10.3233/978-1-61499-544-9-627

Publication date
2015

Document Version
Final published version

Published in
Transdisciplinary Lifecycle Analysis of Systems - Proceedings of the 22nd ISPE Inc. International Conference on Concurrent Engineering, CE 2015

Transdisciplinary Lifecycle Analysis of Systems
R. Curran et al. (Eds.)

doi:10.3233/978-1-61499-544-9-627

CE Challenges – Work to Do

Josip Stjepandić [a] , Wim Verhagen [b] and Nel Wognum[1]
[a] *PROSTEP AG, Germany*
[b] *Technical University of Delft, Faculty of Aerospace Engineering, Air Transport & Operations.*

Abstract. CE has been used for more than two decades now. Despite many successes and advantages, there are still many challenges to be addressed. These challenges are both technical and organisational. In the paper we will address the current challenges of CE. Many challenges are related to the exchange of data and knowledge and to the systems that make data and knowledge exchange possible. Although much progress has been made in enabling extensive data and knowledge exchange and use, much remains to be wished. For example, there are still barriers to data exchange. Technically, these barriers may consist of different formats, differences in infrastructures and systems, and different semantics. There are also organisational and political barriers. For example, investment in information system may heavily impact upstream suppliers, while revenues of better information exchange may predominantly be gained by downstream actors. Without sharing costs and revenues, chain-wide information exchange will not be easily realised. Another barrier is the possible lack of willingness to share information, because of potential misuse of knowledge and loss of power. The paper is organised as follows. First we will describe the current manifestation of CE as described in a recent book. Second, we will list current trends in CE. Third, we will present some Critical Success Factors (CSFs) that are considered relevant for implementing and adapting CE practices. Last, we indicate some research and practical questions to be addressed, especially for areas that have a high potential and actual impact.

Keywords. Cross-disciplinary, cross-functional, cross-boundary collaboration, information and knowledge exchange.

1. Introduction

CE has been known for more than three decades now. It is a encompassing concept, emphasizing collaboration between relevant stakeholders throughout any innovation process, whether product, process or organization innovation. The aim of CE is to reduce time-to-market, improve quality and reduce costs by an ever more efficient product creation process. CE is justified by higher competitiveness. Already from the inception of an idea for an innovation, the whole process of development, production or implementation, usage, service and maintenance, and finally disposal or recycling should be highly transparent. People from various lifecycle stages, different companies, and also from other stakeholders like government, financial institutes, knowledge institutes, and possibly others need to be involved [1]. CE requires people from different functions, disciplines, and cultures to collaborate deeply in an inherently uncertain process for a dedicated period of time. They need to communicate continuously and exchange huge amounts of data.

[1] Corresponding author, E-Mail: wognumnel@gmail.com

Although CE in principle is not difficult to understand, it is tremendously difficult to implement and use. An investment for the implementation of CE is hard to justify with exact calculation. There are many barriers to reach an optimal CE situation. First of all there are the technical barriers. Despite the fact that many systems have been developed that allow the exchange of data within and across organizational borders, there is still much that needs to be aimed for [2].

Second, there are economic barriers. Many different information systems are in use by powerful parties in collaboration. For SMEs in a supply chain or network it is often not possible to buy new systems for collaboration with strong parties like OEMs. They may adapt their existing systems or take the additional burden for exchanging data. In a supply chain, a supply chain-wide information system has many advantages, especially when they are web-based. It may be able to connect to different proprietary systems and offer a communication platform for supply chain actors as well as additional processing power. However, the need for such a system may be larger in one stage of the supply chain, while benefits may be larger in another stage. The willingness to invest in a supply chain-wide information system may thus not be equally divided [3]. When investments and benefits are not well balanced in a supply chain, adoption and implementation of a supply chain-wide information system may not be possible. Moreover, the processes in individual companies may not yet be ready to be harmonized [4] thus leaving many gaps in the information flow.

Third, there are the cultural and power barriers. The willingness to collaborate may be limited, in particular when involved parties have different positions and goals e.g., in a joint venture. The free exchange of knowledge is not without danger. Companies may be afraid of loosing their competitive position and power [5], while people may be afraid of loosing their expert position when they share their knowledge. We have also to keep in mind that a collaboration lasts for limited time.

In section 3 we will address current trends in CE as have been identified in a recent publication [6] following a description of the current manifestation of CE in section 2. In section 4, Critical Success Factors (CSFs) are listed that are deemed relevant in a CE context. The last part of the paper will address research and practical question that still exist. We will limit the discussion to areas that have a high potential and actual impact.

2. Current manifestation of CE

Concurrent Engineering (CE) as a concept is still very much alive, although the term as such is not often heard anymore. As was the case with CE already from the beginning, also now the emphasis is on collaboration between multiple disciplines, functions and, most of the cases, companies, which may be separated in large time and space. Current CE is about (open) innovation of products, processes, and organisations (see also [1]). From the early inception of ideas the whole trajectory of product development, production, service, and even destruction or assett recovery has to be understood and taken into account. The customers of (intermediate) products and services and consumers also play a large role in the processes. In Figure 1, the essence of current CE is depicted.

In Figure 1, CE is depicted as an encompassing innovation system aimed at generating either a totally new product or service or at changing existing ones, where the changes may be large or small. The CE process influences the production system, which may already exist or needs to be created, possibly including a totally new organisation. The production system is an essential part of the design that is the output of various stages of the innovation process. For example, in the case of adaptation to existing products the changes that are needed in the production system need to be taken into account. In the case of a new product or service the way in which the new company or even a whole supply chain needs to be structured is also part of the total design and also gradually evolves with during the design process. It is important that relevant important parties are involved in this process. Collaboration between all different parties and actors needs to be arranged and governed well with specific arrangements and possibly also contracts.

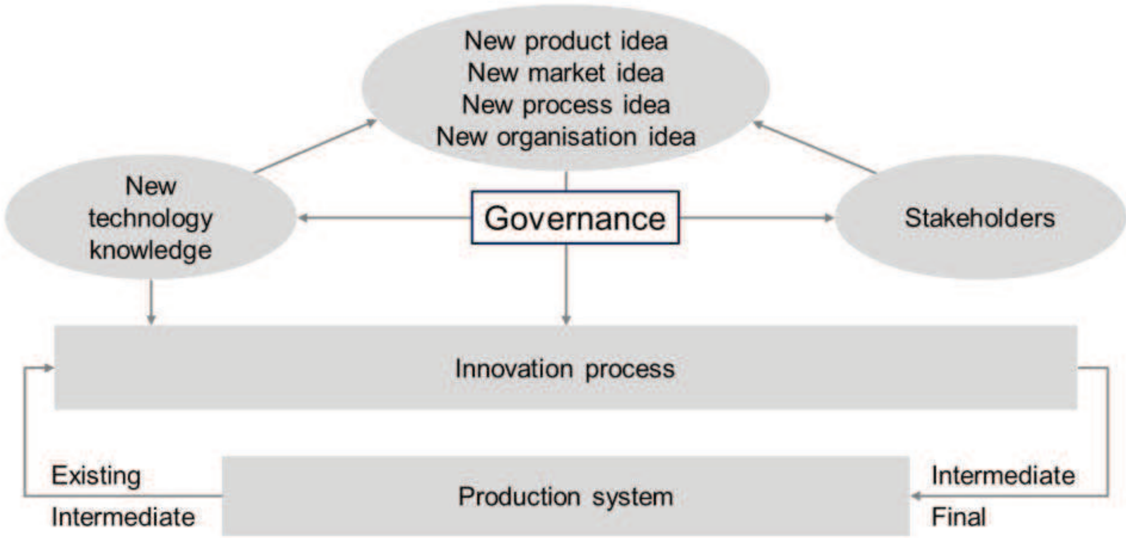

Figure 1. The system of CE

As can be inferred from Figure 1, the exchange of information and knowledge plays a crucial role in the whole process from inception of an idea to actual production and use. Information and knowledge can be exchanged by means of documents and drawings and by intensive discussions in design meetings. Face-to-face meetings occur especially in the earlier stages of design with also much paper documents exchanged. Time and money can, however, be saved with information systems, that exist in many different forms and formats and for different stages of the development process.

The development process can, in general, be divided into the following steps, in line with the systems engineering V model [7,8,9]:

1. Concept generation and requirements analysis
2. System specification (incorporating conceptual, preliminary and detailed design)
3. Implementation
4. Integration and testing
5. Verification & validation

Numerous disciplines and associated types of information systems and applications target individual or multiple stages of the development process. Because product development has become an increasingly global activity, involving many different organizations, complexity and dynamics have dramatically grown [10]. This situation poses significant challenges on interoperability of methods, tools as well as on organizations and users. Below, some trends are discussed that aim to deal with the growing complexity and dynamics.

3. Reducing complexity and dynamics

Globalization as well as increasing complexity are drivers of increasing integration of method and tools. Integration and interoperability are assumed to speed up development and lower costs, yet developing and implementing interoperable, integrated solutions can be assumed as a driver of complexity as well. To simplify these aspects, existing standards may be employed to reduce complexity and improve interoperability [11].

Besides standardization, there is a trend towards loosely coupled models in federated environments. On a local level, users can specify their domain models without worrying about integration aspects. On a global level, the federated framework takes care of model integration and interoperability. Furthermore, globalization requires a high level of time synchronization of distributed teams [12].

Another major strategic shift is servitization of manufacturing industries, i.e., the innovation of organization's capabilities and processes to shift from selling products to selling integrated products and services that deliver added value [13].

With increasing complexity and integration, the size and complexity of the stakeholder environment are also expanding. First of all, this sitution has implications for short-term dynamics in stakeholder environment composition, which emerges typically as a network-centric structure with various level of interdependence based on operational needs [14]. The realization of complex systems usually requires the temporary collaboration of a multitude of stakeholders from different domains, such as hardware, software and services [15]. Besides the customer/user and the system integrator, there are stakeholder groups for the system components, life cycle services and system environment, each with their own objectives and context. During the various stages of the design process, these stakeholders will generate dynamic and sometimes conflicting sets of requirements. Involving all stakeholders continually in the process may very well drive up overall design time. To counter this, techniques may be employed such as agile design and development, where fast prototyping, test-driven, model-driven and behavior-driven development methodologies allow focusing on specific business cases [16].

The stakeholder environment is also subject to long-term dynamics. In this light, the previously mentioned trend towards servitization will impact stakeholder composition. A trend towards the provision of product-service packaging and the proliferation of service businesses introduces both tangible and intangible elements into system design. It requires the utility of hierarchical system models as a way of flexibly combining such elements by focusing on requisite functionality [17]. In the digital context, organizations are increasingly focusing on value creation outside their boundaries, because value is created through interplay of customers, competitors, collaborators and the wider community. In terms of product lifecycle management, this trend gives after-sales importance equal to other phases of the product lifecycle, including added value generated from Big Data and Internet of Things [18, 19].

The aforementioned trends towards integration and interoperability have an impact on the exchange of knowledge and information. By using technology means sharing has become easier than ever. However, sharing is not yet good enough, because the amount of data being created, stored and used every day is growing exponentially. Moreover, the way in which the knowledge is used in the design process is changing continuously. Some of the driving factors of sharing are listed below [20]:

1. **The rise of the wikis**. A wiki is a database of interactive web pages that allows members of a user group to collectively edit the same material from any computer with an Internet connection. Wikis provide a flexible and self-organizing platform that is especially useful from the point of view of early design, when the information and knowledge is unstructured, and from the point of view of collaborative design, where all communication is persistently recorded and loosely organized through user-defined tags. With such capabilities wikis aims to fill gaps left through large software systems in almost each enterprise [21].
2. **Bio-inspired knowledge for design**. Bio-inspired designs can be classified under the heading 'conceptual', when the result of the inspiration is an artifact, or 'computational', when the result is a process. Both areas face the challenge of identification of relevant biological phenomena, the abstraction of concepts to a level that can be understood by engineers without a background in biology, enabling non-obvious applications of the phenomena, and avoiding misinterpretations of the underlying biological phenomena [22,23]. Such approaches are already widely known and applied like bionics and evolutionary computation. They may become even more important for the product design process, but are not dominant yet.
3. **Ontologies and semantic interoperability**. Ontologies are required for both encoding design knowledge and for facilitating semantic interoperability. Development of engineering ontologies on a large scale can evolve in a similar manner to the compilation of the Oxford Dictionary. Researchers (across the globe) could undertake ontology development in selected areas and then contribute to a global repository [24]. This would require the establishment of appropriate standards for encoding ontologies. Here occurs another collision of the reuse of knowledge and intellectual property protection, which is still to be resolved.
4. **Natural user interfaces**. Reality-based systems facilitate intuitive human–computer interaction with little user training or instruction. This is evident in the recent upsurge in touch-based personal computing devices like smartphones and tablet computers, and in gesture-based controls in gaming. The portable and ubiquitous nature of tablet computers make them ideal for collaborative design processes like the recording and progressive documentation of design discussions. It is thus likely that NUIs may prove an important factor towards mass collaboration and the democratizing of the design process. Utilization of a user-friendly common client architecture based on backend services helps reduce training and support effort, in particular in case of a change. Definition of different roles in a sole architecture will foster agility.

Another issue with respect to knowledge and information concerns human involvement. Humans need to be 'in the loop', especially in the earlier phases of design. Deterministic thinking is not suitable anymore for complex problems, as has been emphasize by Moser [25]. Emergent behavior cannot be explained sufficiently, because interaction between components and their behaviors is not well understood. As highlighted before, socio-technical modelling approaches are necessary to model and evaluate this emergent behavior. A significant positive influence on product innovation results is exerted by external resources such as consultants, commercial labs or private R&D institutions. Different amounts of input information provided by customers/clients/end-users have high impact on innovation results [26].

A final trend in research and practice related to information and knowledge in CE concerns intellectual property (IP) and its protection. Increasing cooperation between stakeholders necessitates intellectual property protection and enterprise rights management. As virtual product design increases (see previous section), the risks and consequences associated with intellectual property theft rise dramatically. Methods for patent infringement tracking as well as for IP protection in information and data flow must be developed to a further extent [5].

Complexity and dynamics, however, also impact upon the adoption and implementation of CE in practice, in particular because the many different solutions and trends require organizations to adapt their strategies, technology, and way of working. The fact that CE processes are also performed in collaboration between different departments within companies and between different companies complicates this continuous adaptation [27].

Adoption, implementation and continuous adaptation of CE has many pittfalls. Knowledge of these pittfalls is necessary for reducing failures and achieve success. Below, we list some Critical Success Factors (CSFs) that are considered relevant for implementing and adapting CE practices.

4. Critical Success factors for implementing CE

The implementation of CE in organizations is in essence not much different from the implementation of complex information systems or the adoption of different work practices. Much has been published already on complex change processes within and across organizations, including the many barriers, like in [27]. Many pitfalls exist. Ignoring them may dramatically impact complex change processes like CE implementation. In the literature Critical Success Factors (CSFs) can be found that need to be taken into account in such processes.

In a recent publication critical success factors for the implementation of supply chain-wide information systems have been discussed [28]. A chain-wide information system, as is necessary in CE, requires the alignment of existing information systems and work practices, as well as collaboration between people with their different culture and power. As such, we can learn from the area of information system implementation to start defining CSFs for implementing CE in its current manifestation: complex innovation of products, processes and organizations, requiring the adoption and use of information systems within and across organizations.

Starting point of the research, as published in [29], was the extensive literature on the implementation of ERP systems. CSFs from this literature were used as a starting point for identifying CSFs in the context of implemention of information systems in supply chains. A list of 21 articles on supply chain information systems was analazed. In total 13 CSFs have been formulated. CSFs are, however, not stand-alone issues, but interact with each other. To model this interaction the encompassing MIT90s framework of Scott Morton [30] was used. In Table 1, the CSFs are listed according to this framework. CSFs are generic in the sense that more detailed guidelines and actions are needed to be able to apply and use the CSFs. Besides actions, responsibilities need to be clear in any change project. This aspect is often neglected. Project experience helps in understanding the depth of CSFs and applying them in specific situations.

In a CE context the CSFs listed in table 1 are relevant. The sociotechnical nature of CE becomes apparent in the list of CSFs. In particular in the multi-company environment of CE, translating and applying the CSFs is not without many challenges. Let's take the second CSF as an example. In adopting web-based technology that enable companies to exchange information, decision are needed on investments, costs, and revenues. Investments may be high in one part of the supply chain or network, including the risks, while revenues might be high in other parts of the supply chain or network. In addition, maintenance costs might also not be equally divided over the parties involved. Sharing costs, benefits, and risks is necessary to increase success of an information system that is to be used by more than one party.

Table 1. Critical Success Factors for Implementing Supply Chain Information Systems.

Scott Morton element	Critical Success Factor
Project Strategy	Align vision and build plans
	Share costs, benefits, and risks
Management processes	Manage project
	Monitor and evaluate performance
	Communicate effectively
People	Manage relationships
	Take top-management responsibility
	Manage change and deliver training
	Compose project team
Information system(s)	Assess legacy IT systems
	Select standards, vendor, and software package
	Manage data exchanged

The list of CSFs is just a starting point. They can be used as a basis for additional research in the context of CE. They need to be refined and specified for use in different CE contexts.

5. Challenges for research and practice

Current trends in economy and society can and likely will exert a sizeable influence on CE. These trends are mostly either accompanied by or related to information and communication technology (ICT). To keep pace, CE must be well synchronized with the development of ICT. Below, some recent developments in ICT are briefly discussed which are expected to influence future CE solutions.

- **Mass collaboration:** Mass collaboration involves large numbers of people working independently on a single project, often modular in nature, using social software and computer-supported collaboration tools. This idea has been implemented as crowdsourcing, which typically involves an online system of accounts for coordinating buyers and sellers of labor.
  Mass collaboration is based on the realization that customers are regarded as an important information source for product innovation. As an effective way to aggregate a crowd's wisdom for product design and development, crowdsourcing shows huge potential for creativity and has been regarded as

one important approach to acquire innovative concepts [31]. However, it is still a challenge to make use of crowdsourcing in product design: how can the large number of crowdsourcing concepts be reviewed efficiently? Challenges exist in approaches and methods to improve the efficiency of result evaluation and to assist designers in identifying promising design candidates for further design, analysis and evaluation. The workload to review crowdsourcing responses manually is very heavy. Moreover, the reliability of evaluation results heavily relies on designers' personal knowledge and experience. Concept screening methods are needed to assist designers in identifying useful responses from crowdsourcing results.

- **Cyber Physical Systems (CPS):** A Cyber Physical System (CPS) integrates computational and physical processes. CPS comprises embedded computing devices and networks that monitor and control physical processes, with feedback loops when physical processes affect computations and vice versa. Interaction with the physical environment will provide added value with new capabilities and characteristics to systems, while inclusion of physical processes not only increases the complexity of the system but also increases the uncertainties in the behavior of the system [32]. Holistic decentrality is the main challenge for cyber-physical production systems (CPPS) in which organization, services, objects and software are organized in a fully decentralized way. The industry requires such systems for the production of highly customized products in small quantities with high resource productivity and corresponding speed.
  The top level of interoperability is considered with the systems of systems in which multiple CPS can combine their autonomous singular capabilities with their own intelligence. Thus, they can evolve entirely new capabilities and develop new services. This level of interoperability remains a vision for facilitating decentralized, autonomous systems development and design with the capability for self-configuration and plug-and-produce.
- **Big Data:** The amount of data around us is growing exponentially. 'Big Data' applications promise to provide better insights into various business processes or everyday life in a novel way, by analyzing large data sets and discovering relationships across structured and unstructured datasets. Big Data is a booming topic in the scientific community as well as in the enterprise world [33]. Many of the Big Data challenges are generated by future applications with which users and machines will need to collaborate in intelligent ways.
  Within the context of CE, a huge challenge concerns the issue of Knowledge Discovery in Databases (KDD), a nontrivial process of identifying valid, novel, potentially useful, and ultimately understandable patterns in data [34,35]. Intelligent utilization of existing data (e.g., digital manufacturing) provides a new support function for modern product creation processes. Based on planning data, compiled during preceding product emergence processes, products can be evaluated more easily, which leads to a faster and easier attainment of planning and design levels. The feasibility to segment product data in valid subject-specific groups and to map adequate product-specific assembly operations will remain a subject of research.
  Big Data will likely bring disruptive changes to organizations and vendors. As a cautionary note, the analysis of Big Data, if improperly used, may pose

significant issues specifically in the following areas: data access and policies, industry structure, and techniques. Because large amounts of unstructured data may require different storage and access mechanisms combined with more sensitive data assembled together, Big Data will be more attractive to potential attackers. Application of Big Data requires the issuing of specific rules and regulations as well as the associated control mechanisms to become useful and fruitful.

6. Summary

In this paper, concurrent engineering has been depicted as an encompassing concept that matches current approaches to current forms of innovation in which many different actors from different stages of a product lifecycle and different context are involved. Many different technologies have been developed to support collaboration and information and knowledge exchange in an innovation process. Many systems and system ideas have been listed to show the different approaches and their relevance for particular stages in a development process. However, many challenges still exist and many new technologies are underway. We have indicated the most important challenges and technologies that are underway to solve some or most of the challenges.

Nevertheless, CE is also a process involving many people who need to be open to collaboration. Organisational arrangements need to support and enable such collaboration. These arrangements and their challenges need further exploration.

References

[1] N. Wognum and J. Trienekens, The System of Concurrent Engineering, in J. Stjepandić et al (eds): *Concurrent Engineering in the 21st Century,* Springer International Publishing, Switzerland, 2015, pp. 21-50.

[2] W.J.C. Verhagen, J. Stjepandić and N. Wognum, Challenges of CE, in J. Stjepandić et al (eds): *Concurrent Engineering in the 21st Century,* Springer International Publishing, Switzerland, 2015, pp. 807-834.

[3] M. Wever, P.M. Wognum, J.H. Trienekens and S.W.F. Omta, Supplu chain-wide consequences of transaction risks and their contractual solutions: towards and extended transaction cost framework, *Journal of Supply Chain Management*, Vol. 48, Issue 1, 2012, pp. 73-91.

[4] J. M. Denolf, *Critical success factors for implementing supply chain information systems. Insights from the pork industry*, PhD Thesis, Wageningen University, Wageningen, The Netherlands, 2014.

[5] J. Stjepandić, H. Liese, and A.J.C. Trappey, Intellectual property protection, in J. Stjepandić et al (eds): *Concurrent Engineering in the 21st Century,* Springer International Publishing, Switzerland, 2015, pp. 521-554.

[6] J. Stjepandić, N. Wognum and W.J.C. Verhagen (eds.), *Concurrent Engineering in the 21st Century. Foudations, Developments and Challenges*, Springer International Publishing, Switzerland, 2015.

[7] A. Bahmiou, Systems Engineering, in J. Stjepandić et al (eds): *Concurrent Engineering in the 21st Century,* Springer International Publishing, Switzerland, 2015, pp. 221-254.

[8] C.E. Dikerson, D.N. Mavris, *Architecture and Principles of Systems Engineering*, CRC Press, Boca Raton, 2008.

[9] C. Zheng, M. Bricogne, J. Le Duigou, B. Eynard, Survey on mechatronic engineering: A focus on design methods, *Advanced Engineering Informatics*, Vol. 28, pp. 241–257, 2014.

[10] J. Stark, *Product Lifecycle Management – Volume 1: 21st Century Paradigm for Product Realisation*, 2rd ed, Springer, Cham, 2015.

[11] N. Figay, C. Ferreira da Silva, P. Ghodous, R. Jardim-Goncalves, Resolving Interoperability in Concurrent Engineering, in: J. Stjepandić et al. (eds.): *Concurrent Engineering in the 21st Century:*

Foundations, Developments and Challenges, Springer International Publishing, Switzerland, 2015, pp. 133–164.
[12] Sobolewski, M., (2015). Technology Foundations, in J. Stjepandić et al (eds): *Concurrent Engineering in the 21st Century,* Springer International Publishing, Switzerland, 2015, pp. 67-99.
[13] M. Peruzzini, M. Germani, Design for sustainability of product-service systems, *Int. J. Agile Systems and Management* **7** (3/4) (2014) 206-219.
[14] S. Bondar, J. Hsu, J. Stjepandić, Network-Centric Operations during Transition in Global Enterprise, *Int. J. Agile Systems and Management* 8 (3/4) (2015) in press.
[15] S.Wiesner, M. Peruzzzini, J. Baalsrud Hauge, K.-D. Thoben, Requirements Engineering, in J. Stjepandić et al (eds): *Concurrent Engineering in the 21st Century,* Springer International Publishing, Switzerland, pp. 103-132, 2015.
[16] A. McLay, Re-reengineering the dream: agility as competitive adaptability, *Int. J. Agile Systems and Management* 7 (2) (2014), pp. 101-115.
[17] R. C. Beckett, Functional system maps as boundary objects in complex system development, *Int. J. Agile Systems and Management* 8 (1) (2015), pp. 53-69.
[18] F. Behmann, K. Wu, *Collaborative Internet of Things (C-IOT): For Future Smart Connected Life and Business*, John Wiley & Sons, Chichester, 2015.
[19] I. Ng, K. Scharf, G. Pogrebna, R. Maull, Contextual variety, Internet-of-Things and the choice of tailoring over platform: Mass customisation strategy in supply chain management. *Int. J. Production Economics*, Vol. 159, 2015, pp. 76-87.
[20] S.K. Chandrasegaran, R. Ramani, R.D. Sriram, I. Horvath, A. Bernard, R.F. Harik et al., The evolution, challenges, and future of knowledge representation in product design systems. *Computer-Aided Design*, Vol. 45, Issues 2, pp. 204-228, 2013.
[21] Y. Jiang, X. Zhang, Y. Tang, R. Nie, Feature-based approaches to semantic similarity assessment of concepts using Wikipedia, *Information Processing and Management*, Vol. 51, 2015, pp. 215–234.
[22] T.W. Mak, L.H. Shu, Using descriptions of biological phenomena for idea generation, *Res Eng Design* (2008) 19:21–28.
[23] W. Wang, A. Duffy, I. Boyle, R. Whitfield, Creation dependencies of evolutionary artefact and design process knowledge, *Journal of Engineering Design*, (2013) 24:9, 681-710.
[24] F. Rosa, E. Rovida, R. Viganò, E. Razzetti, Proposal of a technical function grammar oriented to biomimetic, *Journal of Engineering Design*, (2011) 22:11-12, 789-810.
[25] B.R. Moser, R.T. Wood, Design of Complex Programs as Sociotechnical Systems, in J. Stjepandić et al. (eds): *Concurrent Engineering in the 21st Century,* Springer International Publishing, Switzerland, 2015, pp. 197-220.
[26] D. Chang, C.H. Chen, Understanding the Influence of Customers on Product Innovation, *Int. J. Agile Systems and Management*, Vol. 7, 2014, Nos 3/4, pp 348 – 364.
[27] S. Alguezaui, R. Filieri R, A knowledge-based view of the extending enterprise for enhancing a collaborative innovation advantage, *Int. J. Agile Systems and Management*, Vol. 7, 2014, No. 2, pp 116–131.
[28] C. Argyris, *Knowledge for Action: a Guide to Overcome Barriers to Organizational Change,* Jossey Bass Inc., San Francisco, USA, 1993.
[29] J.M. Denolf, J.H. Trienekens, P.M. Wognum, J.G.A.J. van der Vorst, S.W.F. Omta, Towards a framework of critical success factors for implementing supply chain information systems, *Computers in Industry*, vol. 68, 2015, pp. 16-26.
[30] M.S. Scott Morton (ed.), *The corporation of the 1990s: Information Technology and Organizational Transformation,* Oxford University Press, New York, NY, 1991.
[31] D. Chang, C.H. Chen, Exploration of a Concept Screening Method in a Crowdsourcing Environment. In: J. Cha et al. (eds.) *Moving Integrated Product Development to Service Clouds in Global Economy. Proceedings of the 21st ISPE Inc. International Conference on Concurrent Engineering*, IOS Press, Amsterdam, 2014, pp. 861-870.
[32] A.W. Colombo, T. Bangemann et al., *Industrial Cloud-Based Cyber-Physical Systems: The IMC-AESOP Approach*, Springer International Publishing, Switzerland, 2014.
[33] N. Bessis, C. Dobre, Big Data and Internet of Things: A Roadmap for Smart Environments. Springer International Publishing Switzerland, 2014.
[34] R. Wallis, J. Stjepandić, S. Rulhoff, F. Stromberger, J. Deuse, Intelligent Utilization of Digital Manufacturing Data in Modern Product Emergence Processes, In J. Cha et al. (eds.) *Moving Integrated Product Development to Service Clouds in Global Economy*. *Proceedings of the 21st ISPE Inc. International Conference on Concurrent Engineering*, IOS Press, Amsterdam, 2014, pp. 261-270.
[35] E. Tsui, W.M. Wang, L. Cai, C.F. Cheung, W.B. Lee, Knowledge-based extraction of intellectual capital-related information from unstructured data, *Expert Systems with Applications*, Vol. 41, 2014, pp. 1315–1325.