

49th CIRP Conference on Manufacturing Systems (CIRP-CMS 2016)

A Novel Methodology for Manufacturing Firms Value Modeling and Mapping to Improve Operational Performance in the Industry 4.0 era

Tonelli, F.^a; Demartini, M.^a; Loleo, A.^b; Testa, C.^{b*}^a DIME - Department of Mechanical Engineering, Energetics, Management and Transportation, Polytechnic School, University of Genoa, ITALY^b Siemens Italy S.p.A., Via Enrico Melen 83, 16152, Genoa, ITALY* Corresponding author. Tel.: +39 010 3532888; fax: +39 010 317750. E-mail address: flavio.tonelli@unige.it

Abstract

In recent years there has been appreciable academic activity in manufacturing value creation resulting in that the ability to create value is based on the competence to make decisions and implement strategies; even though this evidence it is still difficult to understand where the company's weak points are located so value modeling approaching is arising. In this study Authors first report a qualitative review on value creation and modeling based on the identification, selection and analysis of about 100 papers, then specify the value concept within manufacturing companies. Within this context the Authors describe a novel methodology for manufacturing value modeling from strategic level down to operational improvements. The methodology and the related mapping and analysis tools have been co-developed with Siemens MES division within Industry 4.0 context. The Manufacturing Value Modeling Methodology (MVMM) is based on 5 steps: Value Map, Maturity Model, Gap and Process Analysis, Validation and Improvement Areas Definition. Through this methodological approach, a series of structured interviews allowing to construct the value map accordingly to the current company maturity model and the relationships between the strategic objectives and operational practices, capabilities, and methods. Combining the assessments interview with the Company' resources, infrastructure and IT structures, it is possible to establish a current level of the company. The mapping step is followed by a gap and process analysis, assessing most relevant areas for the creation of value aiming at constructing an interventions roadmap, setting out priorities and activities to be improved. The selection of the improvement areas defines process initiatives, KPIs and interventions to improve business alignment. To provide a practical view of the methodology a sample of the Value Modeler tool is presented and discussed.

© 2016 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license

[\(http://creativecommons.org/licenses/by-nc-nd/4.0/\)](http://creativecommons.org/licenses/by-nc-nd/4.0/).

Peer-review under responsibility of the scientific committee of the 49th CIRP Conference on Manufacturing Systems

Keywords: Manufacturing Value Creation, Value modelling and mapping, Manufacturing Maturity Model, Gap and Process Analysis, Operational Improvement

1. Introduction

Value creation is a complicated and various concept [1] that is fundamental to implement strategies that allow taking decisions; a company's capability to create value rely on its competence to develop strategies that "respond to market opportunities by exploiting their internal resources and capabilities". Because it is difficult to understand where the company's weak points are located so value modeling approaches are arising "since managers need to understand what are the key internal resources and drivers of performance in their organisations" [2].

Traditionally the value creation was considered as a financial measure that was created when a business earns revenues that exceeds expenses or the cost capital. In today's

company, value creation is characterized by intangible drivers like process improvements, innovation, knowledge and people. In fact for [2] tangible resources are becoming continuously "transient and rarely provide a long-term competitive advantage".

In the last years, and now thanks also to Industry 4.0, that emphasize the concept, value creation supported by ICT represents a key driver to analyze and evaluate the intangible drivers and process improvements of manufacturing company.

Decision making is becoming increasingly complicated as a result of the enormous number of alternatives and multiple conflicting goals. These complications affect several decision variables and sophisticated constraints and in many cases problems are penetrated by uncertainty and subjectivity. In order to accelerate the value creation processes while at the

same time ensuring higher quality, industry has in the meantime also begun to fully support its decision by using software tools [3]. Tools are needed to know how the activities and firms should do to improve this value creation. The competitiveness of companies will in future mostly be determined by the scope and penetration of these technologies and how professionally they are utilized [4].

In 21st century, Business Process Improvement (BPI) [5] is becoming a relevant activity in fact processes are an important differentiation factor in competition, and company try to struggle to quickly deliver new products to market on time, on cost, and on quality [6]. Cost and time concerns are symptoms of overlying issue, inefficiencies in the process and companies who run the development in this field in a systematic, innovative and consistent manner create advantages for themselves that cannot in the short term be equalled by their competitors. This has much to do with processes that do not appear on the market and are therefore not able to be subjected to quick analysis by competitors. Measuring process improvements involve an assessment of “how activities within an end-to-end business process will be impacted,” this could be done through the context of process maturity. The competitiveness of company processes, will in future also be measured against how well they have been freed from the constraints of location, time and end device through mobile IT support [7]. Several methodologies and frameworks exist for evaluating process performance from the perspective of process maturity as well as decomposition and hierarchical approaches to performance measurement [8]. The support of process maturity models belong to the concept that company capabilities develop in a stage-by-stage approach and that each of these levels can be certainly managed, assessed, and led [10]. Academics, practitioners, and international consortia have expanded various maturity models [11], furthermore many of these models arise from the Capability Maturity Model (CMM) [12] and its consequent Capability Maturity Model Integration (CMMI) [12]. Maturity models are relevant for the organizational level and they are appropriate for creating a roadmap for improvements [13]. Authors suggest defining a business model applicable to a manufacturing company in order to develop it following an implementation roadmap. “A business model articulates how the company will convert resources and capabilities into economic value” [14], and the usage of a roadmap enables the prioritization of the activities needed to achieve the goal. In addition to maturity model, methods such as process analysis are very useful to perform a value analysis.

The proposed approach evaluates the potential application of a value-based technique using Business Process Model and Notation (BPMN) [15] as a standard methodology for process analysis. BPM's (Business Process Modelling) [16] methods are used to increase integration between business and manufacturing levels.

Standards as ANSI/ISA-95 Enterprise/Control System Integration should be evaluated to support a model for business integration. The international standard ISA-95 has been developed to address the problems encountered during the development of automated interfaces between enterprise and control systems. This standard has been covered all kinds

of manufacturing environments, all over the world, due to its hierarchical functional model [3]. Also diagnostic tools to evaluate manufacturing systems improvements have been developed [9].

Within this context the Authors starting from a qualitative literature review on value creation and value modeling in Section 2, within Section 3 they describe a novel methodology for manufacturing value modeling from strategic level down to operational improvements, in Section 4 Authors illustrate an application of the methodological approach on a real case. Finally Section 5 shows the consequences and issues of Author's work and conclusions are discussed.

2. Literature Review

The qualitative literature review process was composed by two parts [1]: first, an explorative and unstructured part that had a number of different origins providing inputs from project management and other areas; and second, a more structured review process involving searching databases using search strings and dashboards. Academic papers were selected through a computer search from four databases: ScienceDirect, Scopus, Emerald and Web of Science. Authors chose these databases for their ample covering of articles in the field of value creation and process improvement. They offer search combinations using “AND” and the possibility to search for keywords. Authors' strategy used to search was to identify articles that included “Value creation”, “Process Improvement”, “Maturity Model” or “Business Model” as main subject headings or text words in the title or in the paper. To collect the broadest array of relevant studies, Authors included keywords directly related to their research, as well as synonyms of each concept. Additionally, Authors took into account various synonymous of each of these terms. A single search consisted of a keyword combined with the term “value creation” or synonyms of this term using “AND”.

Our literature search identified 105 empirical academic papers that were published between 2000 and 2015. Their titles, abstracts and texts were reviewed in detail by two of the authors for relevance to the study. As a result, a literature review was carried.

The distribution of publications over years (Figure 1) displays an interesting sharp growing trend of articles on this subject over the past decade. The trend line illustrates the average number of articles published until the previous year. It reveals a significant increase from 2013.

In terms of geographical distribution (Figure 2), the publications contributing to this research area originate from many different countries around the world, based on the main author's university affiliation. A few countries stand out: the US, Italy, The UK, and Spain. Hence, it might be argued that project value creation is primarily rooted in these countries, and partially in countries throughout the rest of Europe.

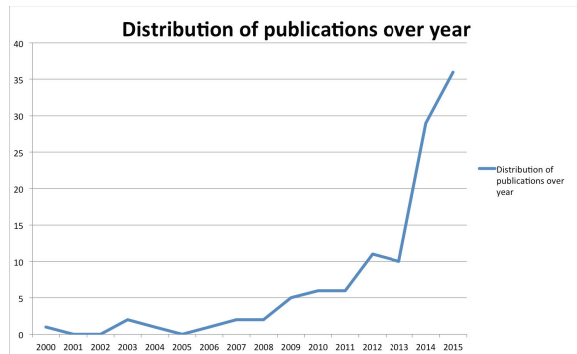


Fig.1 Distribution of publications over year

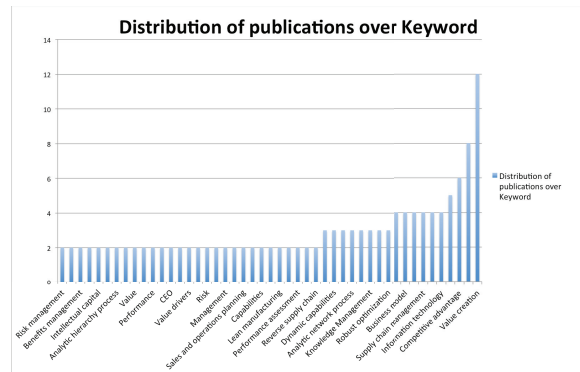


Fig. 4 Distribution of publication over keyword

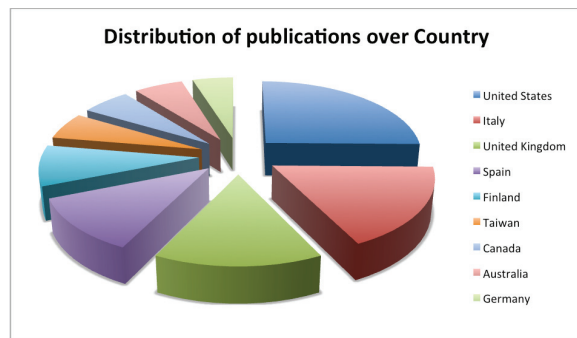


Fig.2 Distribution of publication over country

Furthermore, this paper proceeds with an analysis in order to verify on what journals the selected articles are published. Authors analyze the number of publications in core journals that are where most articles of a research field are published. The top three journals, the International Journal of Project Management, International Journal of Production Economics and International Journal of Information Management can be considered the core journals in the field. Figure 3 gives an overview of journal frequencies and types for the identified publications.

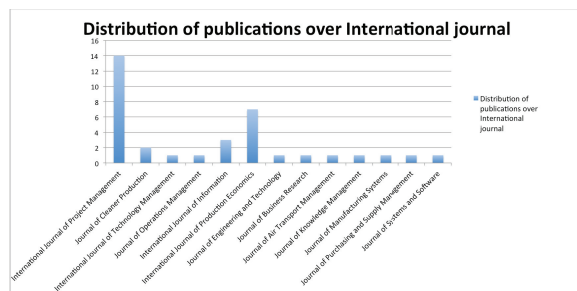


Fig. 3 Distribution of publication over International Journal

Author's analysis concludes with the distribution of publications over keyword. The top five keywords are "value creation", "competitive advantage", "information technology", "supply chain management" and "business model".

Based on the findings of this review, it is possible to establish an overview of the predominant Value Strategy characteristics. For [2] the ability to create value for a company is based on the capacity to develop strategies that respond to market opportunities but the Author also underlines the complexity "to understand the key internal resources and drivers of performance".

[3] pays attention on the need "of flexible and adaptable platforms which enable technology and internal integration between ERP and MES levels of manufacturing industry". This concept has been analysed by also [4], the Author sustains that there is the need of "tools to discuss what the project itself and the base organization should do to enhance this value creation" owing to the increasingly complexity of the manufacturing processes.

Like [7] explains in his work, business process and process performance improvements have a relevant role in the value creation, since business process "describes how something is done in an organization" and precisely "processes are composed of a collection of interrelated tasks or activities which solve a particular issue. In the context of business process management, a business process is defined as end-to-end work which delivers value to customers".

Finally Authors highlight the importance of the Industry 4.0 project that addresses the evolutionary changes that will be brought about by the merging of modern information and software technologies with classic industrial processes and the revolutionary effects that this transformation will have on industry. It is, however, reasonable to suspect that broad penetration of industry with these technologies will, in spite of their revolutionary effects, take a considerable amount of time. This aspect should always be taken into consideration when planning the corresponding investments.

Starting from these findings Authors have identified and developed a Manufacturing Value Modelling Methodology (MVMM) with the aim to create value for manufacturing company through a structured model based on 5 steps: Value Map, Maturity Model, Gap and Process Analysis, Validation and Improvement Areas Definition.

3. Methodological Approach

In this section Authors explain the methodological and structured approach. The model is based on 5 steps: Value Map, Maturity Model, Gap and Process Analysis, Validation and Improvement Areas Definition. The first one is Value Map where the scope is to create knowledge about the specific manufacturing company, analysing trends, implications and possibilities about its market, environment, and operational level, revealing the business conditions and problems that exist. In this phase is necessary to develop a thorough understanding of the specific pressures, behaviours and demands of the vertical or micro vertical target industry, explaining the business strengths/weaknesses, goals and objectives, future outlooks, profitability, adaptability to change.

The goal of the company Value Map's construction is to develop and align industry initiatives and impediments with solution capabilities that support the market. To build the company Value Map is relevant to comprehend which are the market and business drivers of the company contextualize to its specific strategic objectives.

After having analysed the strategic view of the company and its market's conformation, it proceeds with the analysis of the specific capabilities of the company, in particular it analyses company activities and processes.

All information gathered on a industry should be captured and convert into the Value Map of the company, to do this Authors summary all contents into four items:

1. Market Trends that represent the tendency of the market and the specific environmental in which company works;
2. Company Objectives that show the company specific strategy or goals an organization would like to achieve;
3. Practices that present all the essential features of processes necessary to improve standard operating procedures in a consistent manner;
4. Business Domain a collection of related, structured company activities or tasks that show where improvements can be applied.

The second phase of the MVMM is the Maturity Model in which Authors measure the current state of the company. To do this is necessary to face the company's stakeholders who are guided to evaluate a structured maturity model and assess the current company processes. In this phase stakeholders bring out company strengths/weaknesses starting from the Value Map and developing strategic business requirements, identifying impediments to their strategies and then capturing these needs in the maturity model. The Maturity Model used is "Gartner Maturity Model" to measure the current state of the company is based on 5 increasing maturity levels that describe how an operation can be performed: Stage 1 React companies focus on operational activities and plan at a factory or distribution level, with all locations focusing on their own objectives; Stage 2 Anticipate the objective of supply planning evolves from covering existing orders to attempting to match projected supply to forecast demand. Stage 3 Integrate as organizations evolve into Stage 3 maturity, they

seek to fully integrate their demand and supply plans to create a volume and service-oriented response to anticipated demand. Stage 4 Collaborate organizations that reach Stage 4 maturity have achieved functional excellence in supply planning. Stage 5 Orchestrate the boundaries between demand planning and supply planning become blurred as the three functions work in concert to the support value chain orchestration. Through this maturity model stakeholders measure each process or activity evaluating the current state and the target state with a score from 1 to 5 that reflects the five maturity levels.

Thanks to this phase how the company works, what processes are value-added, what is the company current situation and what are the stakeholders' future outlooks have been captured in the methodology.

The next phase, Gap and Process Analysis, is based on the review and comprehension of the previously collected data; the scope is to define what activities or processes need interventions, evaluate the tactical and business skills that the market asks for, compare requirements to the current skill sets, and identify the differences. Understand "As Is" operational barriers and the gaps of value added processes can also involve a process formalization in some standard (such as Business Process Model and Notation - BPMN). To determine impact to the business requirements is necessary to proceed with the Value Analysis. In this phase is crucial to review all information in detail with regard to company financial status, profitability, business issues, competitive advantage and capabilities. Companies business challenges are also analysed accordingly to the benchmarks of the industry segment the company belong to.

The following phase is called Validation and is a crucial step in which all information gathered are harmonized and application solution prioritized as defined in the analysis based on strategies and company requirements. Validation phase is the building block in delivering a qualitative and quantitative output with which the organization can utilize in its decisions making process. It is useful to review the Gap and Process Analysis, the current/future initiatives of the company, the value-added process and the driving forces of its business. For this reason, it is very helpful to prepare a report to be presented to the validation team to confirm the concrete alignment to the company strategy. Stakeholders who have performed the assessment do not belong to the validation team that is composed by company's representatives that make decisions at corporate level.

The last phase of proposed MVMM is the Improvement Areas Definition; starting from contents validated, the roadmap of interventions is defined by identifying areas of the value, value of the opportunities, and total opportunity value. This phase also addresses to how this can be accomplished with the associated potential risk and value. Aligning the strategic requirements of the company to the solution that overcomes the business issues barriers is fundamental to determine the resources required and associated with the implementation of each specific action. Applicable solution prioritization is translated in the generation of an implementation roadmap that takes in account both company objectives and budgetary constraints and whose aim is to

create a tangible improvement for the company. Finally to conclude the value proposition expressed by the roadmap determines quantifiable value in the resolution of operational and business barriers.

4. Methodology implementation

In this section Authors illustrate an application of the Manufacturing Value Modeling Methodology to a real case using the Value Modeler tool co-developed with Siemens MES Division. The case study has been accomplished on a real industrial plant for the realization of the practical aspects of the value methodology presented in this paper.

The company is an Italian global leader manufacturing company in design, development and production of mechanical components for the automotive industry. The company guarantees the utmost safety and comfort and improved product performance thanks to process integration and optimization of the entire production cycle, from the initial design and cast-iron or aluminum casting to assembly, testing and simulations on the bench, track and road. They have been delivery their equipment all over the world.

The value analysis started with the study of the mechanical components industry segment and in particular with the study of the company context, it proceeded with the stakeholders' interview in which they explained both their strategic view through the business strengths/weaknesses, goals and objectives, and the most relevant operational activities and processes. These contents have been organized into the Value Map of the company through ISA 95 Pillars (Figure 5).

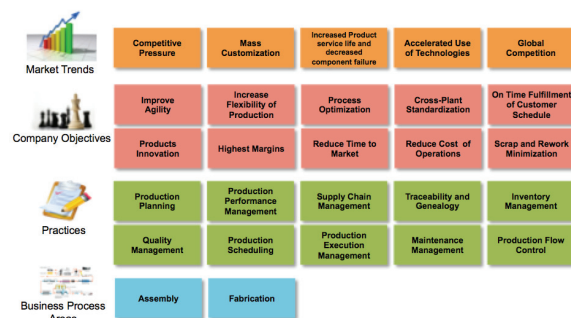


Fig. 5 Value Map of the mechanical component company build with Value Modeler Tool

Starting from the Value Map of the case, stakeholders assessed the current and the target state of the company through the Maturity Model, explaining their definition of value to be achieved, the following list represents the most important statements:

- Address new emerging markets, opening new plants;
- Practises and processes standardization;
- Seamless interconnected system (people, process, knowledge) through the Enterprise;
- Being able to track the products along their whole lifecycle;

- Implement analytics to help making tactical and strategic business decisions.

After the Maturity Model phase the Gap and Process Analysis was performed, it allowed to understand what activities or processes need interventions defining the current and the target state of the company and explaining strengths and opportunities that are summarized in the list below:

- Strengths:
 - Great attention to quality of the products;
 - Very dynamic company;
 - Top-class products and brands.
- Opportunities:
 - Quality data should be available into an integrated quality system, to react in real-time and to make root-cause analysis;
 - Operations shall be supported by a better integration of all the existing ICT tools;
 - Scheduling is not yet adequately supported by ICT solutions/tools.

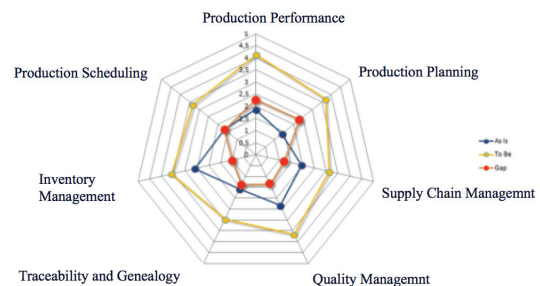


Fig.6 Gap Analysis respect Practices

The Validation phase was then realized with the company executives. They agreed with all the contents and underlined the issue of Data Collection and ICT integration as it emerged from the Gap Analysis through discussing the practice called Production Performance Management (Figure 6).

Finally the roadmap of interventions is built and activities are scheduled on the basis of the priorities and improvement areas emerged from the Gap Analysis (Figure 7).

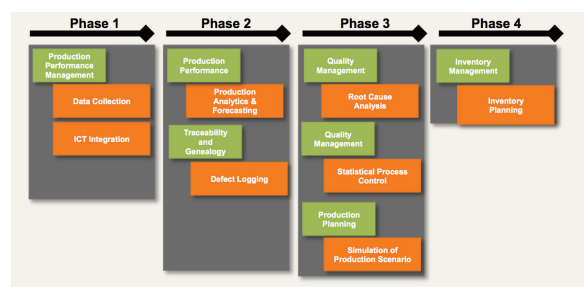


Fig. 7 Roadmap of Intervention and Improved Areas

5. Discussion and Conclusions

Authors' purpose was to examine evidence of value creation and value modeling. To accomplish this, Authors realized a structured Manufacturing Value Modeling Methodology and then analyzed their model through a real case using Value Modeler tool. This allows analyzing the complexity of value drivers and value creation of organizations. Starting from a qualitative literature review on value creation and related research fields of process improvement, strategic management, value management, project management and benefit management, Authors identified different aspects that can be understood to create added value, competitive advantage or a manner of reducing risk and costs. Starting from this assumption a methodological approach has been provided.

The MVMM is a structured approach with the scope of bringing out business strengths/weaknesses, goals, objectives and future outlooks; the related methodology aims to have a clear overview of the company both on a strategic level and on an operational level. The approach is based on four items that compose the Value Map and that are hierarchically linked: Market Trends, Company Objectives, Practices and Business Domains. The Value Map represents the linkage among the characteristics of the environment and the market in which the company works, the strategic view of the company and its specific processes. The innovative aspect of the proposed approach is full correlation. It is relevant to underline that the model has a closed loop approach (Figure 8), in fact starting from a market trend, it is possible to know what activities and what business areas need to be improved to achieve the company objective linked to that path. It is also possible starting from a business domain go back to the related market trends and company objectives. This allows controlling and monitoring constantly all processes. Another relevant aspect of the MVMM is that interviews within Maturity Model phase are carried out both with stakeholders and the executive accomplishing the result of aligning two different views of the company strategy. In fact, as [17] explained in his work "we did not interview corporate stakeholders which can lead to a subjective perspective of value creation. Future studies could include primary and secondary stakeholders into data collection" since "these sample characteristics influence the strategic success factors".

Finally Authors recognise that methodology needs some improvements, one of them is represented by the introduction of metrics as proposed by [18]. A potential development is to introduce metrics within the closed loop approach with the aim to tangibly control and measure the evolution of the proposed solutions trying to implement this functionality within the tool Value Modeller. To sum up, the purpose of MVMM is to create a clear framework of the interventions that the company should follow to develop its business and to achieve its strategic objectives.

References

- [1] Laursen M, Svejvig P. Taking stock of project value creation: A structured literature review with future directions for research and practice. *International Journal of Project Management*; 2015.

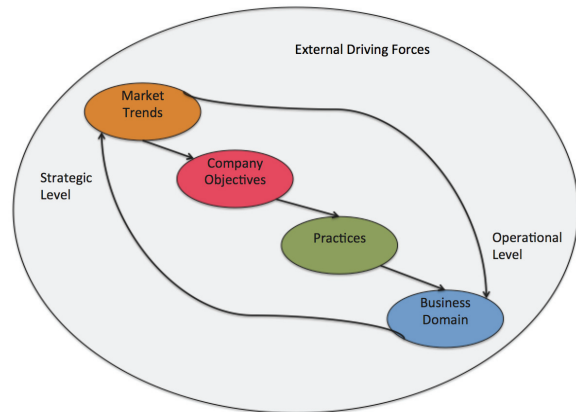


Fig. 8 Closed loop approach

- [2] Carlucci D, Schiuma G. Knowledge assets value creation map Assessing knowledge assets value drivers using AHP. *Expert System with application*; 2007. p. 814-821
- [3] Prades L, Romero F, Estruch A, García-Domínguez A, Serrano J. Defining a Methodology to Design and Implement Business Process Models in BPMN According to the Standard ANSI/ISA-95 in a Manufacturing Enterprise. *Procedia Engineering*; 2013 p. 115-122
- [4] Benítez J, Delgado-Galván X, Izquierdo J, Pérez-García R. Improving consistency in AHP decision-making processes. *Applied Mathematics and Computation*; 2012. p. 2432-2441
- [5] Seethamraju R, Marjanovic O. Role of process knowledge in business process improvement methodology: a case study. *Business Process Management Journal*; 2009. p. 920-936
- [6] Zellner G. "A structured evaluation of business process improvement approaches". *Business Process Management Journal*; 2011. p. 203-237
- [7] Raschke L, Sen S. A value-based approach to the ex-ante evaluation of IT enabled business process improvement projects. *Information and Management*; 2013. p. 446-456
- [8] Cagnazzo L., Taticchi P., Tonelli F. A Decomposition And Hierarchical Approach For Business Performance Measurement And Management. *Measuring Business Excellence*, 2009 Volume 13, Issue 4, ISSN: 1368-3047
- [9] Melioli R., Tonelli F., Piccinino L., 'A Diagnostic Tool To Evaluate Manufacturing Execution Systems Implementation From Operational and Financial Viewpoints', *Proceedings of the European Modeling Simulation Symposium, EMSS 05*; 2005
- [10] Röglinger M, Pöppelbuß J, Becker J. Maturity Models in Business Process Management. *Business Process Management Journal*; 2012.
- [11] Curtis B, Alden J, Weber C.V. The use of process maturity models in business process management. *Borland Software*; 2004.
- [12] Helgesson Y, Host M, Weyns K. A review of methods for evaluation of maturity models for process improvement. *Journal of Software Maintenance and Evolution: Research and Practice*; 2011. p. 436-454
- [13] Parkes A, Davern M. A challenging success: a process audit perspective on change. *Business Process Management Journal* 2011. p. 876-897
- [14] Teece D. Business Models, Business Strategy and Innovation. *Long Range Planning*; 2010.
- [15] Chinosi M, Trombetta A. BPMN: An introduction to the standard. *Computer Standards & Interfaces*; 2012. p. 124-134
- [16] Aguilar-Savén R. Business process modelling: Review and framework. *International Journal of Production Economics*; 2004. p. 129-149
- [17] Schenkel M, Caniels M, Krikke J, Harold van der Laan E. Understanding value creation in closed loop supply chains – Past findings and future directions. *Journal of Manufacturing Systems*; 2015.
- [18] Taticchi, P., Balachandran, K.R., Tonelli, F. (2012) Performance Measurement and Management Systems: State of the art, Guidelines for Design and Challenges. *Measuring Business Excellence*; 2012 Volume 16, Issue 2, pp. ISSN: 1368-3047