A Review of Enterprise Modelling Studies

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Abstract: This paper aims to provide a basis for the improvement of enterprise modelling research through a review of previous work published in literature. The review identifies 198 enterprise modelling papers in 49 journals and classifies the papers according to: research topic, modelling approach, research approach, study context and type of validation set. A database of these enterprise modelling papers is provided to ease the identification of relevant research results. The review results are combined with other knowledge and provide a support for modelling strategy recommendations for future enterprise modelling research, including: identification of relevant papers within a carefully selected set of journals when completeness is essential; need of conducting more studies on modelling methods commonly used from the software industry; and increase the awareness of how the properties of the case studies impact on the results when evaluating modelling methods.

1 INTRODUCTION

Enterprise modelling is aimed to achieve a comprehensive picture of an enterprise. The model is a snapshot of the company at a particular moment that incorporates all the knowledge regarding an organization, including resources, products, and the way the organization communicates.

Enterprise modelling is often used to create representations applied in information technology planning. In this case, the model looks at how technology is being currently used in a company, how the company structure supports the use of information technology and the way in which information technology can be integrated. For example, the modelling is useful when an enterprise evaluates the adoption of a new software system. In this case, enterprise modelling determines whether the acquisition of a new computer system is compatible with the stated goals and needs of the company.

Enterprise modelling is also used for improving the business strategy and organization. By providing a complete picture of the entire organization, enterprise modelling allows companies to see how their systems might be refined to better meet the goals, counter external threats and eliminate internal weakness (Ulrich 2002), (Gustas and Gustiene, 2003), (Dietz, 2006). This knowledge can be used to improve management techniques, develop internal procedures, and assume long term quality for the business.

Business organizations also use enterprise modelling for projecting the future, looking at the changing relationships between a company and its external environment. This type of enterprise modelling considers what types of products the company could develop to expand, how the market is going to change, and how the expansion of the company could be made smooth and efficient.

Enterprise modelling promotes and efficient, well-run company by building a comprehensive and integrated picture of it along its goals, resources, and climate.

This paper proposes a literature review of enterprise modelling research studies. The performed review follow the guidelines defined in literature (Petersen, 2008) (Kitchenham, 2007).

The main difference of the conducted review respect to other reviews is the different goal. Indeed, this paper reviews journal articles on enterprise modelling with the goal of supporting and directing future enterprise modelling research, differently from traditional literature reviews that principally aim at introducing novice researchers to the variety of approaches, models, and tools. This difference in goal leads to a different focus as this review focuses on the research methods and does not include a

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comprehensive description of the different enterprise modelling approaches.

The analysis is mainly based on a systematic search of journal papers. The study classifies the enterprise modelling papers with respect to the topics, research approaches, study contexts and used data.

The following section described the issues that have been identified as interesting. The motivation for inserting the analysed questions was the improvement of the enterprise modelling research. The considered issues guided the design of the review process. The remaining part of this paper is organized as follows: Section 2 describes the review process; Section 3 reports the review results; Section 4 summarizes the main threats to validity; Final remarks are given in the last section.

2 REVIEW PROCESS

This section outlines the review steps that have been followed for conducting the study.

2.1 Scope Definition

The first activity that has been performed is the definition of the issues to be addressed. To this aim, after a preliminary reading of the most relevant papers, the following issues have been defined for the analysis:

- Analysis of the paper distribution among journals, proceedings and other type of publications.
- Analysis of the main publication sources for the Enterprise Modelling research studies.
- Quantification of the articles published over the years by the most relevant authors.
- Analysis of the effort, measured as number of the papers concerning this topic over the years.
- Classification of the papers based on the most relevant research topics.
- Classification of the articles based of the category they belong.
- Analysis of the used Modelling Languages.
- Analysing at which extent enterprise modelling researches are applied
- Analysis of the used quantitative approaches.

2.2 Inclusion Criteria

The main criterion that was followed for including a journal paper in the performed review was that it described research on enterprise modelling. Papers concerning software modelling, assessment of enterprise complexity, or identification of factors correlated with enterprise modelling, were only included if the main purpose of the study was the improvement of the enterprise modelling research.

Examples of papers basically describing a similar study in more than one journal paper were found. Fortunately, the number of such cases was small and would not lead to important changes in the outcome of the analysis. In any case, we decided, to exclude these papers.

2.3 Identification of Papers

The proposed literature review was obtained by analysing enterprise modelling papers selected from the literature. In particular, a full investigation of the research papers concerning this topic was performed and the scientific databases were queried. Numerous journal and conference papers were identified. Therefore, it was decided to concentrate the attention on journal papers as they should publish more mature research results. With this in mind, the Science Direct, IEEE and ACM database was taken into consideration and queried.

The identification of relevant studies was based on an examination of papers found through a manual inspection of the papers resulting by querying the database. The first query aimed to recover papers including the term ‘enterprise modelling’. Then, the selection was refined applying the ‘business management’, ‘computer science’, and ‘modelling’ subject terms , from 2003 to present, and including also journals. In total, 1483 paper were found, in the first phase all papers was examined by using a manual inspection of titles, and if unsure, the abstracts. After this primary study, 198 papers distributed within 49 peer-reviewed journals written in English were selected as potentially relevant.

In spite of the high number of identified journals, it was possible that there were, national or company-specific journals with enterprise modelling papers that have been missed. In any cases, following the first analysis, the journal that was discovered to be the most representative of the enterprise modelling, topic was Computer in Industry from Elsevier. For this reason, some of the analysis are mainly concentrated on this journal.

2.4 Classification of Papers

For addressing the analysis, the identified papers were classified according to their typology. Four

typologies were considered: Research papers, proposing innovative strategies for enterprise modelling; Practice papers, describing experiences for experimenting defined strategies; Industrial survey, those ones describing interviews performed within operative organizations for understanding if and how they were facing problems and/or adopting approaches regarding the enterprise modelling; and Reviews, describing literature studies, even if few journals published this kind of study. The aim of this classification was to understand the formalism and practical aspects the papers analysed and their maturity level. The considered papers were distributed as it follows: 85 papers belonged to the Practice category; 162 papers were classified as Research; 11 papers were Review; and 13 papers were Industrial survey. Some papers belonged to more than one type.

A preliminary exploration of the papers allowed the extraction of the properties and categories to be considered in the analysis. They were based on categories of research works commonly adopted in journals and international conferences by IEEE, and adapted to the needs of our analysis. Specifically some categories were added with reference to enterprise concepts. In the performed analysis the classification was used to assess the interest of authors for the different research topics. The chosen research topics and categories addressed the purpose of our review and do not have to be intended to represent a general-purpose classification of enterprise modelling studies. We also believe that the classification may be useful for other researchers while searching for relevant papers on, for example, a particular modelling approach.

3 ANALYSIS

The classification of research papers provided a general picture of the characteristics of the Enterprise Modelling research. It represented for the authors a starting point for a deeper investigation and suggested important short comings in Enterprise Modelling research and possibilities for improvement. In the following, the considered issue, listed in the scope definition section, will be analysed and results will be described.

Analysis of the paper distribution among journals, proceedings and other type of publications

The aim of this analysis was to investigate the editorial collocations where research papers concerning the Enterprise Modelling topics are mainly published. Specifically, journal papers and book chapters were considered.

Table 1: Paper distribution among the work type and publisher.

Type	#Number	Publisher
Book Chapter	12	ACM
Book Chapter	2	IEEE
Journal	162	Elsevier
Journal	1	IEEE
Journal	19	Springer

Table 1 shows that 198 research works concerning the Enterprise Modelling were found. These works were distributed in 14 book chapters and 182 journals. In particular, as regards the book chapters, 12 papers have been published by ACM while IEEE published the remaining 2 papers. Concerning the journals, Elsevier has published 162 papers, 1 paper by the IEEE and 19 by Springer.

Analysis of the principal publication sources for the Enterprise Modelling research studies

The goal of this analysis was to check which source was predominant in the modelling studies on Enterprise Modelling and in which venues they were published. Specifically, it goes to consider the placement of the items, the total number of items according to the locations and how this affects the percentage of the total number of articles. For reasons of space, only the results greater than 1 are reported in the results description.

Analysing the data reported in Table 2 it emerges that the predominant journal publishing enterprise modelling papers is Computer in Industry, published by Elsevier, which comprises about 30% of the total papers published in this area; followed by: Information Systems with 6.3%; Expert Systems with Applications with 5.7%, and Data & Knowledge Engineering with 5.2%.

Quantification of the articles published over the years by the most relevant authors

Table 3 shows the results of this analysis and indicates that the researchers that have been interested in enterprise modelling studies from 2004 to 2014. In particular, it emerged that Wil MP van der Aalst is one of the most active researcher in this area with five articles between 2007 and 2008; followed by Jeongsoo Lee with 4 items between 2010 and 2014; and Kwangsoo Kim Lee with 4 items between 2010 and 2014.

Analysis of the effort measured as number of paper dedicated on this topic over the years

The aim of this analysis was to observe how many articles have been written in the different countries

Table 2: Predominant Journal for Enterprise Modelling.

Publisher	Collocazione	#	%
Elsevier	Computers in Industry	54	27,22%
Elsevier	Information Systems	12	6,28%
Elsevier	Expert Systems with Applications	11	5,75 %
Elsevier	Data & Knowledge Engineering	10	5,23 %
ACM	ACM Computing Surveys	8	4,18 %
Elsevier	The Journal of Systems and Software	8	4,18 %
Elsevier	Information and Software Technology	7	3,66 %
Elsevier	Robotics and Computer-Integrated Manufacturing	7	3,66 %
Elsevier	Science of Computer Programming	6	3,14 %
Elsevier	Computers & Industrial Engineering	5	2,61 %
Elsevier	Procedia Computer Science	4	2,09 %
Elsevier	Advanced Engineering Informatics	4	2,09 %
Springer	Int J Adv Manuf Technol	4	2,09 %

Table 3: Authors more active over the years.

Authors	Article number	Years
Wil M.P. van der Aalst	**5**	2007, 2008
Jeongsoo Lee	4	2010, 2011
Kwangsoo Kim	4	2010, 2011
Marlon Dumas	2	2011
Guy Doumeingts	2	2008

over the years. Then, the papers were considered with reference to the countries in which the researches were conducted. For reasons of space, the description of the results considers only results greater than 1. The considered years go from 2004 to 2014.

Figure 1 shows the graphic distribution of articles written during the considered period with reference to countries. Results shows that European countries, such as France and Spain, are the most active in this research field and produced the higher number of articles in the considered period. In particular, a large part of the papers were published by France Institutions (89) and Spain published 72 papers. Just 25 items were found for Italy.

Classification of the papers based on the most relevant research topics

The goal of this analysis was to identify the research topics regarding enterprise modelling mainly investigated, and how they changed over time. Figure 2 reports the number of papers

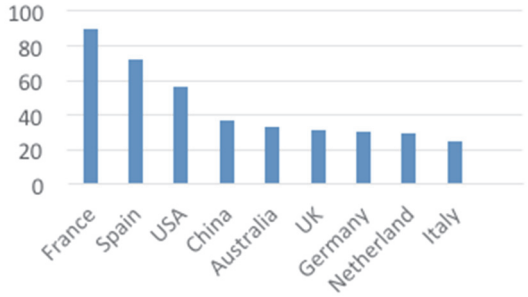

Figure 1: distribution of research paper for countries.

concerning the main research topics from 2004 to 2014. It is possible to observe that a large part of papers discusses enterprise modelling with reference to: Enterprise architecture; Interoperability; Business process modelling and Unified Modelling Language.

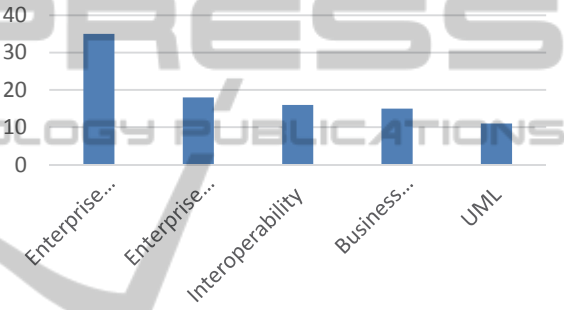

Figure 2: Principal area investigating Enterprise Modelling.

Classification of the articles based of the category they belong

The goal was to analyse what are the research topics of enterprise modelling more studied with reference to the category they belonged and how these changed over time. The categories were: Software Engineering, Business Management and Artificial Intelligence. Specifically, the categories were analysed over the period going from 2004 to 2011, sorted by ascending order. Figure 3 shows the results of this analysis and indicates that Software Engineering, with 175 papers, and Business

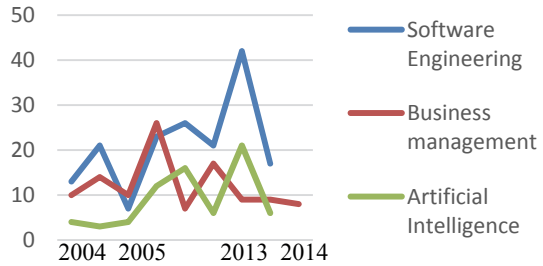

Figure 3: Main research categories investigating Enterprise Modelling.

Management, with 119 papers are the most relevant categories.

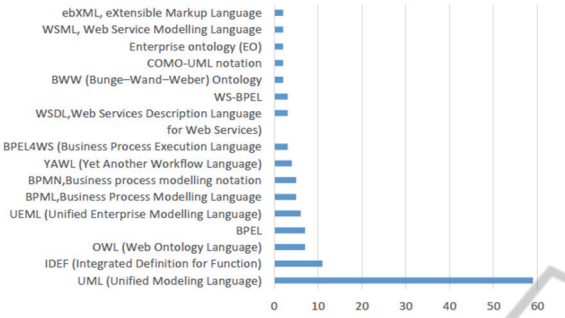

Figure 4: Modelling language mainly used.

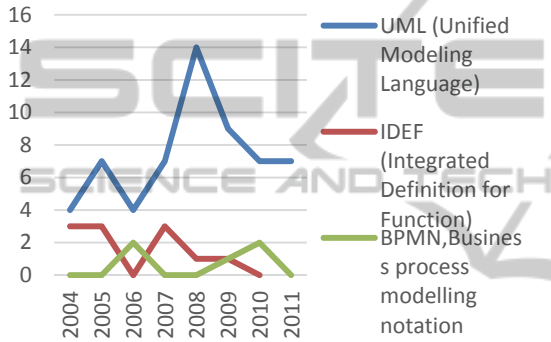

Figure 5: Trend of the modelling language mainly used over the years.

Analysis of the used Modelling Language

The goal of this analysis was to see what are the modelling languages most studied and applied to enterprise modelling, and how they changed over time. Figure 4 shows the results of the analysis by considering and indicates that the modelling languages most studied and applied is UML (Unified Modelling Language), followed form IDEF (Integrated Definition for Function). In addition, Figure 5 reports the trends of the modelling language mainly used in the considered period of time.

Analyse to what extent enterprise modelling research are applied

The goal was to analyse at which extent the research enterprise modelling techniques were applied and in which context of study (e.g., case studies, on the field, etc.). Then, the type of their application was considered. The analysis showed that the investigations of enterprise modelling techniques was mainly performed through examples. In particular, 105 articles concerned examples, 52 papers treated case studies, just 7 papers concerned empirical studies, 2 articles regarded applications on the fields, and 27 concerned other kind of applications. Figure 6 shows graphically the count of items in the various contexts of application.

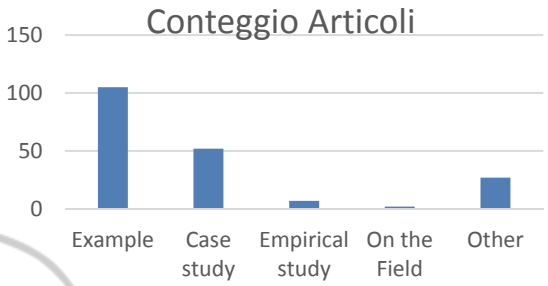

Figure 6: Papers distribution for application type.

Analysis of the Quantitative approaches used

The goal of this analysis was to observe what were the most studied and quantitative approaches used and how this changed over time. Therefore, the quantitative approaches were analysed in different years. The analysis showed that few paper considered quantitative approaches. In particular, among the most studied and applied quantitative approaches KPIs, Key performance indicators, were used.

4 THREATS TO VALIDITY

The main threats to the validity of the proposed review are described in the following.

The publication bias regards the exclusion of conference papers and reports is based mainly on practical concerns, including workload; e.g., the problems of identifying all relevant conferences and the amount of analysis needed to handle the fact that many journal papers are improvements of previously published conference papers. This exclusion of conference papers would be more difficult to defend if the study concerned a particular modelling approach, such as UML Business Extensions. In that type of studies, all relevant papers should be identified and reviewed, regardless the type of source. A small selection of Enterprise Modelling papers published at conferences was analysed and it was found that their research topics, methods, study designs, and study contexts were similar to those of the journal papers. However, the study concerned executed research into Enterprise Modelling and the journal papers are those ones with a high scientific quality. An important difference between conference and journal papers was that research scientists did

not write modelling experience reports; that were typically published at industry conferences. Therefore, large part of the analysed papers was written by academics. This means that probably information about the software industry's experience has been excluded and needs to be further investigated.

Another potential publication bias is that significant enterprise modelling research results have not been published, such as company-confidential results, or results that did not yield the desired outcomes or conducted on topics that did not fit into the common enterprise modelling journals. It could be interesting to study size and effect of the potential publication biases, but this would require a study design different from ours, and can fit our research work.

5 CONCLUSIONS

Enterprise modelling is a growing relevant research topic in the last years. This research issue was addressed in several researches proposing numerous methods, techniques and tools. This paper proposes a literature review of different research studies with the aim of discovering interests, limits, maturity, models, and types in the performed researches. The presented kind of investigation is aimed to support and address future research concerning the enterprise modelling topic.

Indeed, it is necessary to understand which are the aspects considered in the literature of this area with a quantitative approach. Because the field is wide and concerns different aspects, the aim of the presented study is to help practitioners, students and researchers to focalize the attention on a particular interested issue.

The proposed review was applied to the research works regarding the enterprise modelling topics published in primary international journals and the results of the review are presented. The results for this preliminary application emphasize that the enterprise modelling approaches are not adequately addressed.

Obviously, the results obtained in this preliminary study need to be confirmed in a wider investigation involving more and more research approaches. This will be one of the main future work involving the authors. As further future work, the review proposed can be used to make a survey of the studies presented in the literature, and understand how to better address the research issues in the enterprise modelling area. The aim will also regard the classification of different modelling, measurement, and quantitative approaches addressing this issue at different abstraction level, and the understanding of which of them better address a specific problem.

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