Disponível em: http://periodicos.ufes.br/BJPE/index

ISSN: 2447-5580

Brazilian Journal of Production Engineering
BJPE - Revista Brasileira de Engenharia de Produção

Campus São Mateus
UNIVERSIDADE FEDERAL DO ESPÍRITO SANTO

ARTIGO ORIGINAL OPEN ACCESS

BIBLIOMETRIC ANALYSIS AND SYSTEMATIC REVIEW FOR ENGINEERING CHANGE MANAGEMENT

ANÁLISE BIBLIOMÉTRICA E REVISÃO SISTEMÁTICA DA GESTÃO DA MUDANÇA DE ENGENHARIA

Paola Pimentel Barroso[1]*; Pedro Paulo de Andrade Júnior[2]

[1] Mestranda no programa de Pós-Graduação em Engenharia e Ciências Mecânicas na área de Desenvolvimento de Sistemas de Engenharia da Universidade Federal de Santa Catarina. barroso.paola@gmail.com
[2] Doutor em Engenharia de Produção na Universidade Federal de Santa Catarina. UFSC, 2006. Florianópolis – SC. pp.andrade@ufsc.br

ARTIGO INFO.

Recebido em: 30/09/2018

Aprovado em: 07/10/2018

Disponibilizado em:10/10/2018

PALAVRAS-CHAVE:

Gestão de Mudança de Engenharia; PLM; desenvolvimento de produto.

KEYWORDS:

Engineering Change Management; PLM; product development.

***Autor Correspondente**: Paola Pimentel Barroso.

RESUMO

Este artigo desenvolveu uma análise bibliométrica seguida de revisão sistemática no tópico Gestão da Mudança de Engenharia, que consiste em gestão de modificações dos componentes do produto após início da produção em massa. Uma metodologia de 5 passos reduziu 33970 resultados a 62 documentos altamente relevantes para o desenvolvimento de método para melhor controle da gestão de mudança de engenharia. Uma revisão sistemática dessas publicações baseada em leitura integral usando estratégia de classificação em Sistema, Método e Fora do Escopo permitiu a identificação de estudos focados em Método e com tema central "gestão da mudança" e "controle da gestão da mudança de engenharia". Isso resultou em 12 principais documentos para compor um referencial teórico acerca do estudo para controle da gestão da mudança de engenharia.

ABSTRACT

This paper developed a bibliometric analysis followed by a systematic review on the topic engineering change management, which is the modification of product's components after product entered mass production. A five-step methodology narrowed 33970 results to 62 documents highly relevant for developing a method for better control of engineering change management. A systematic review of those publications based on full reading and using System, Method and Out of Scope classification strategy allowed the identification of publications focused on Method and with core theme "change management" and "ECM control". This resulted on 12 main relevant documents to compose a theoretical referential on engineering change management control study.

Citação (APA):BARROSO, P. P. & ANDRADE JUNIOR, P. P. de.(2018). Bibliometric analysis and systematic review for Engineering Change Management. Brazilian *Journal of Production Engineering*, 4(3):184-205.

1. INTRODUCTION

Within the past years, Engineering Change Management (ECM) has seen increased interest within engineering research. For years, studies like Huhtala et al (2014) considered changes mean more money and more time spent on the product and for this reason, the lack of structured studies regarding ECM control was notable.

Most part of rare ancient publications focus on improving new product development (NPD) to eliminate modification on product's components after product entered mass production and consequently seek to eliminate ECM. On Ouertani et al (2004) state of art analysis for engineering change process on 2004 identified 20 documents in which merely 14% considered improving ECM process. Ullah et al (2016) on 2011 identified only 247 publications related to the core field of engineering change management.

Considering that Li e Moon (2012) highlights effective engineering change management as an important competitive advantage, Tavčar e Duhovnik (2005) explains the need of enlarging product lifecycle because it increases product profitability since developing a new product family is associated to considerable cost and Fiedler e Kampa (2016) emphasis the criticality of adapting product development to mass customization, the scenario has changed and now studies related to managing properly the ECM to adjust development process for producing customer variants are taken as a driving force to overcome hard competition on the marketplace.

For this reason, this paper performs a bibliometric analysis followed by a systematic review to identify the main relevant documents to compose a theoretical referential on ECM control study.

2. METHODOLOGY

In order to identify the aspects important to this research, a bibliometric analysis was conducted using a method comparable to Jonkers e Derrick (2012).

In the first moment, Scopus was defined as research base considering publications until March 31st, 2018. Later the title, abstract and keywords were considered to locate bibliometric publications. The topic search started from a large scope and was narrowed according to research objectives. With a five-step structure described on sub item 2.1 to 2.5 it was possible to identify appropriate search string and resulted on 62 documents to be evaluated.

After that, a systematic review conducted with full reading of the documents provided information to identify the 12 main relevant documents to compose a theoretical referential on ECM control study.

2.1 STEP ONE

A general search using "ECM or Engineering Change Management" resulted on 33970 documents according Table 1. Those results involved multiple study areas such as Biology, Medicine, Engineering, Material Sciences and Agricultural sciences.

Table 1 - General search on Scopus using "ECM or Engineering Change Management" on March 31st, 2018

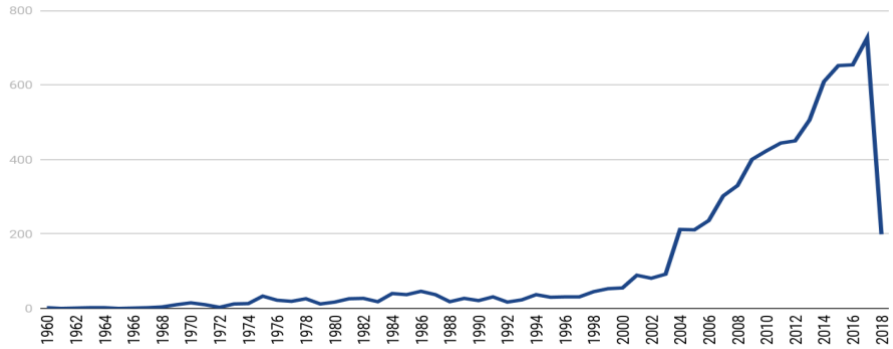
SUBJECT AREA	Percentage
Biochemistry, Genetics and Molecular Biology	43,9%
Medicine	36,0%
Engineering	22,0%
Materials Science	12,4%
Agricultural and Biological Sciences	7,8%
Chemical Engineering	7,6%
Immunology and Microbiology	5,6%
Neuroscience	4,8%
Others	34,3%

Source: BARROSO & ANDRADE JUNIOR, 2018

2.2 STEP TWO

Since only topics related to Engineering are related to modifying product's components after product entered mass production, a new search considering only this area resulted on 7472 documents.

Graphic 1 - "ECM or Engineering Change Management" limited to Engineering study area on March 31st, 2018



Source: Barroso & Andrade Junior, 2018

It is notable the increasing interest on the topic from 2002 on. This is consistent with Pikosz e Malmqvist (1998) affirming in 1998 that product lifecycle was decreasing mainly due to hard competition and engineering change was the key to fast adopt changing customer needs. In the early 2000 the ECM subject gained visibility.

In 2018 the number of publications is lower than 2017 not because it decreased, but because only first quarter of the year was considered. Projecting the first quarter number to the full year expectation results on almost 800 documents regarding the topic on Engineering area for 2018.

However, performing a detailed evaluation of the documents title and keywords an unexpected outcome was noticed. Within Engineering area the acronym ECM may refer not only to Engineering Change Management but also to "ElectroChemical Machining", “ElectroChemical Migration”, “Electrochemical Membrane”, “Electrochemical Metallization”, "ExtraCellular Matrix ", "Environmentally Conscious Manufacturing", “Eco-Care-Matrix”, “Eco-design Concept Manual”, “Error Correction Model”, “Expectation Confirmation Model”, “Enterprise Content Management”, “Engine Control Module”, “Engine Condition Monitoring”, “Energy-Corrected Milk”, “Equivalent Circuit Model”, “Electronic Control Module”, “Electrets Condenser Microphones”, “Engineering Chain Management”, “Equilibrium Constant Method” and “Eddy Current Microscope”.In order to avoid documents not related to Engineering Change Management, at step 3 a review was conducted on steps 1 and 2 to remove ECM from search.

2.3 STEP THREE

Reviewing steps 1 and 2 to consider only Engineering Change Management and after that reducing to the area Engineering, the results are shown below.

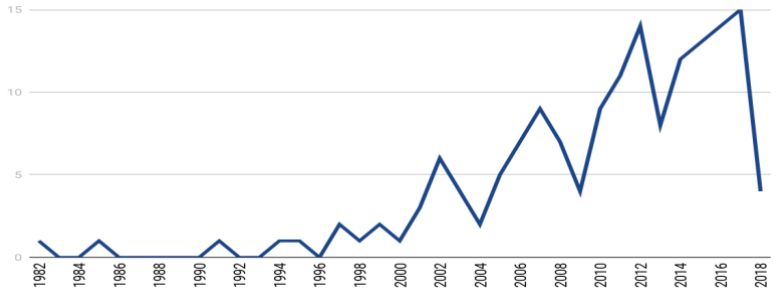
Table 2 - General search on Scopus using “Engineering Change Management” on March 31st, 2018

SUBJECT AREA	Percentage
Engineering	74,2%
Computer Science	43,2%
Business, Management and Accounting	19,7%
Decision Sciences	16,0%
Mathematics	16,0%
Others	11.7%

Source: BARROSO & ANDRADE JUNIOR, 2018

Removing ECM from the search, the study areas were narrowed to exact sciences such as Engineering, Computer and Mathematics. The biomedical sciences such as Biology and Medicine were removed indicating the documents are more related to product development. Despite that, focusing on Engineering is still necessary as showed on Graphic 2.

Graphic 2 - “Engineering Change Management” limited to Engineering study area on March 31st, 2018



Source: Barroso & Andrade Junior, 2018

Removing ECM also removed results before 1980 which considering Padalkar e Gopinath (2016) comment that from early ‘60s till early ‘80s the focus for project management lied upon scheduling and only from mid ‘80s on began a shift towards explanation for other phenomena, than ECM studies starting on 1982 is reasonable.

The increased importance on the last eighteen years can be associated to market scenario change as pointed out by Karthik e Reddy (2016) in which manufacturers are pushed to produce a high quality product at the lowest cost with the minimal lead-time making change management of vital importance.

In 2018 the number of publications is lower than 2017 not because it decreased, but because only first quarter of the year was considered. Projecting the first quarter number to the full year expectation results on about 16 documents regarding the topic on Engineering area for 2018.

2.4 STEP FOUR

In order to narrow down the 158 results from step 3, a series of cross search was performed considering keywords identified as main related to the research purpose. The references are shown on Table 3.

Table 3 - Cross search from step 3 to relevant keywords using data from March 31st, 2018

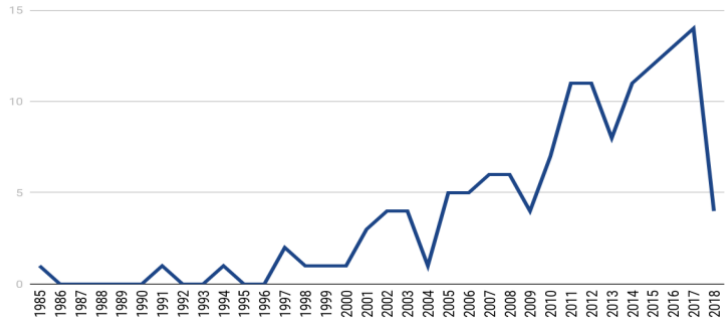
Keyword	Query	Results
Product	(TITLE-ABS-KEY("Engineering change management" and product) AND (LIMIT-TO (SUBJAREA,"ENGI")))	113
PMBOK	TITLE-ABS-KEY ("Engineering change management" AND pmbok)	0
SCRUM	(TITLE-ABS-KEY ("Engineering change management" AND scrum) AND (LIMIT-TO (SUBJAREA,"ENGI")))	0
CANVAS	TITLE-ABS-KEY ("Engineering change management" AND canvas)	0
Methodology	TITLE-ABS-KEY ("Engineering change management" AND methodology) AND (LIMIT-TO (SUBJAREA , "ENGI"))	14
Method	TITLE-ABS-KEY ("Engineering change management" AND method) AND (LIMIT-TO (SUBJAREA , "ENGI"))	55
Framework	TITLE-ABS-KEY ("Engineering change management" AND	24

framework) AND (LIMIT-TO (SUBJAREA , "ENGI"))

Source: BARROSO & ANDRADE JUNIOR, 2018

Considering all those references from Table 3 together, it is obtained 137 documents distributed along the years according to Graphic 3.

Graphic 3 - "Engineering Change Management" and Keywords limited to Engineering study area on March 31st, 2018



Source: Barroso & Andrade Junior, 2018

The tendency on Graphic 3 is the same as Graphic 2 because only 21 documents were removed once they didn't have any relation to the keywords listed on Table 1 and therefore no relevance to compose a theoretical referential on ECM control study. The same is valid for the comment related to 2018, on a full year expectation the number of documents would achieve 16.

2.5 STEP FIVE

Since main relevant information is considered from last 5 years, the appropriate string requires step 4 to be restricted from 2013 to 2018 resulting on 62 documents relevant to compose a theoretical referential on ECM control study.

Table 4 - Research string using data from March 31st, 2018

Query	Results
((TITLE-ABS-KEY ("Engineering change management" AND product)) OR (TITLE-ABS-KEY ("Engineering change management" AND plm)) OR (TITLE-ABS-KEY ("Engineering change management" AND methodology)) OR (TITLE-ABS-KEY ("Engineering change management" AND method))) OR (TITLE-ABS-KEY ("Engineering change management" AND framework)) AND (LIMIT-TO (SUBJAREA , "ENGI")) AND (LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013))	62

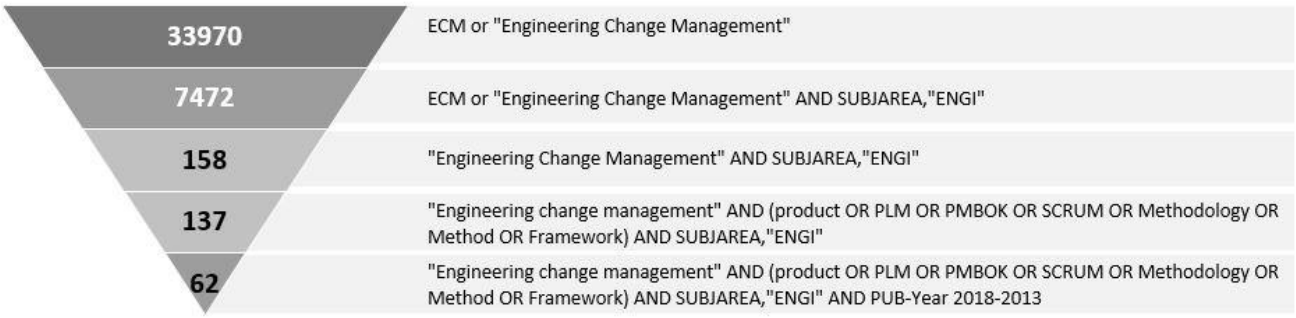
Source: BARROSO & ANDRADE JUNIOR, 2018

3. RESULTS AND DISCUSSION

3.1 BIBLIOMETRIC ANALYSIS

Using the Methodology described, the initial 33970 documents were narrowed to 62 aligned with research purpose.

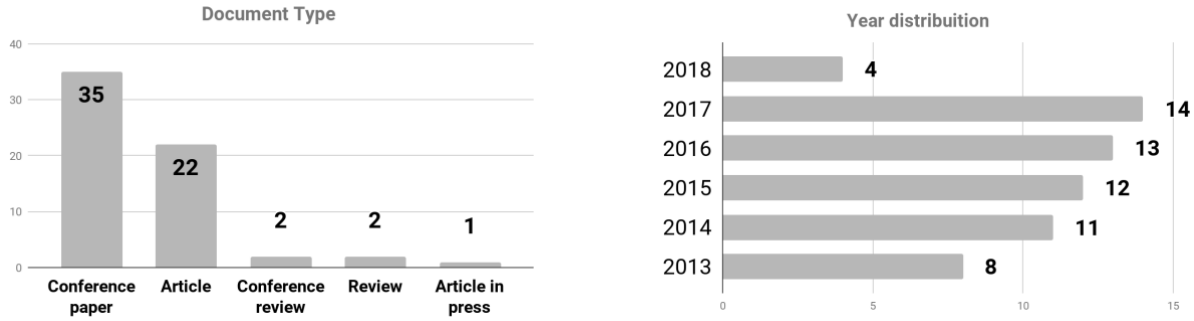
Figure 1 - Summary of methodology use



Source: Barroso & Andrade Junior, 2018

These 62 documents were evaluated according its characteristics as below.

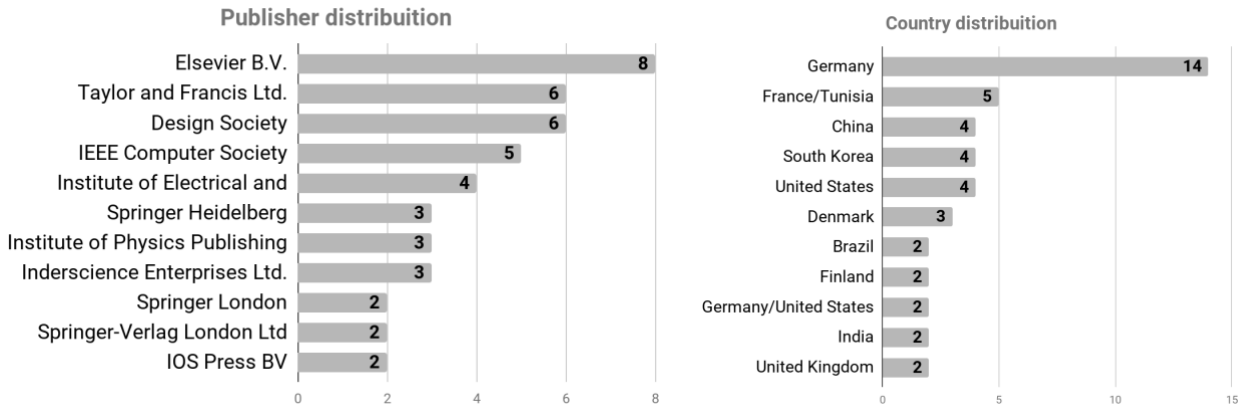
Graphic 4 - Document type and Year distribution



Source: Barroso & Andrade Junior, 2018

Considering the trend for the past 5 years it's notable the increased importance of ECM and coherent considering the industry competitiveness scenario but theme is still stronger on conference papers, that responds for over 56% of total. This indicates the need for structured research on the topic.

Graphic 5 - Main Publisher and Country

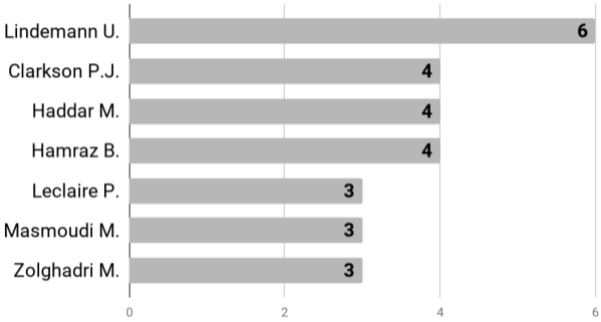


Source: Barroso & Andrade Junior, 2018

The concentration on few publication and countries is common on topics with recent increased importance such as ECM control. Eleven publishers respond for 71% of all documents and five countries accumulate 50% of the total. This indicates that studies are centralized on few institutions and need a worldwide spread.

The same pattern is presented when comparing authors and sources on Graphic 6 and Table 5. Nine sources respond for 61% of documents while 7 authors published 43% of the total reinforcing the idea that studies are centralized on few institutions.

Graphic 6 - Main authors (more than 2 publishes)



Source: Barroso & Andrade Junior, 2018

Table 5 - Main source with more than one publishing

Source title	Qty
Proceedings of the International Conference on Engineering Design, ICED	8
Procedia CIRP	6
Research in Engineering Design	4
International Journal of Production Research	4
IEEE International Conference on Industrial Engineering and Engineering Management	4
Lecture Notes in Mechanical Engineering	3
IOP Conference Series: Materials Science and Engineering	3

Journal of Engineering Design	3
International Journal of Product Lifecycle Management	3
Computers in Industry	2
PICMET 2017 - Portland International Conference on Management of Engineering and Technology: Technology Management for the Interconnected World, Proceedings	2
Concurrent Engineering Research and Applications	2

Source: BARROSO & ANDRADE JUNIOR, 2018

Regarding keywords, the 62 documents presents high similarity in the point that 13 keywords appears more than twice as showed on Table 6 and the couple words "Engineering Change Management (ECM) and Product Lifecycle Management (PLM)" appears 6 times. Other pairs also repeat as shown on Table 7.

Table 6 - Keywords that appear more than twice

Keyword	**Qty**	**Keyword**	**Qty**
Engineering Change Management (ECM)	43	Design management	4
Change propagation	10	Change prediction	3
Product life cycle management (PLM)	9	Design Structure Matrix(DSM)	3
Change management	6	Engineering changes	3
Engineering Change	5	Functional reasoning	3
Decision making	4	Product data management	3
Dependency	4		

Source: BARROSO & ANDRADE JUNIOR, 2018

Table 7 - Main keywords combination (more than twice)

Keyword 1	**Keyword 2**	**Qty**
Engineering Change Management (ECM)	Product life cycle management (PLM)	6
Engineering Change Management (ECM)	Change propagation	5
Engineering Change Management (ECM)	Engineering Change	5
Engineering Change Management (ECM)	Dependency	4
Engineering Change Management (ECM)	Change management strategy	3
Engineering Change Management (ECM)	Change Prediction	3
Engineering Change Management (ECM)	Decision making	3
Engineering Change Management (ECM)	Product data management	3

Source: BARROSO & ANDRADE JUNIOR, 2018

Therefore, it is possible to conclude that despite increase interest on ECM within engineering research, there is still a gap on structured studies and most part of knowledge is centralized on few institutions and need a worldwide spread. Besides that, there is a strong correlation between "Engineering Change Management (ECM) and "Product Lifecycle Management (PLM)" that can be explored on future studies.

3.2 SYSTEMATIC REVIEW

After the bibliometric analysis, a systematic review was conducted to evaluate the content of publication in order to identify the group highly relevant for developing a method for better control of Engineering Change Management. In this phase, the 62 documents resulted from bibliometric analysis were read in full and main contributions are listed on Tables 8, 9 and 10.

Based on the contributions it is possible to classify them according to main focus and core themes:

- System: Documents related to change propagation simulation through computer system, system development to support change feasibility calculation and computer alternatives to improve Engineering Change Management record and control;

- Method: Documents that review Engineering Change Management research, evaluate expanding application of Engineering Change Management literature to other change control or propose methods and frameworks to control or analyze changes cause and feasibility;

- Out of Scope: Documents not directly related to Engineering Change Management or duplicated.

Table 8 - Main contribution split within the themes - System

SYSTEM		
Core theme	**Author**	**Main Contribution**
Change feasibility	Hesselmann et al (2017)	Micro-meso-macro coordination architecture to represent and reconcile opposing interest and conflicting requirements on changes
Change Propagation	Eltaief et al (2018)	CAD management model for change propagation impact analysis
Change Propagation	Hein et al (2018)	Identification of requirements most relevant for change propagation impact analysis
Change Propagation	Masmoudi et al (2017)	Novel classification of ECM methods according dependency model
Change Propagation	Yin et al (2017)	Method to acquire product changes automatically and evaluate design change propagation
Change Propagation	Lee e Hong (2017)	Use of Bayesian Network to model and analyze change propagation
Change Propagation	Masmoudi et al (2017)	Two steps method to predict approach for changes in two dimensional geometrical product model
Change Propagation	Kattner et al (2017)	Model that combine a matrix-based approach of modeling interrelations with knowledge of expert to identify change propagation

Change Propagation	Lee e Hong (2015)	Use of Bayesian Network to model and analyze change propagation
Change Propagation	Masmoudi et al (2015)	Approach to map dependency links among components of products
Change Propagation	Mahmoud et al (2015)	Regression analysis to identify type of dependencies between two dimensions
Change Propagation	Hamraz et al (2015)	FBS Linkage Method for modelling and analyzing engineering changes
Change Propagation	Reddi e Moon (2013)	Interaction between new product development and ECM
Change Propagation	Hamraz et al (2013)	Enhanced change prediction method incorporating interface information
ECM control	Yan (2016)	System to solve asynchronism between product data management and quality systems in case of changes
ECM control	Hamraz e Clarkson (2015)	FBS Linkage Method for modelling and analyzing engineering changes
ECM control	Sonzini et al (2015)	Ontology to capture product changes
ECM control	DO (2015)	Product data management database to support engineering change analysis
ECM control	Ganesan (2015)	Data base to prioritize, select and manage scope and resources for cost reduction and value improving ideas
ECM control	Sriram et al (2014)	IT based collaborative decision support framework
ECM control	Hamraz et al (2013)	Enhanced ECM method based on change prediction management

Source: BARROSO & ANDRADE JUNIOR, 2018

Table 9 - Main contribution split within the themes - Method

METHOD		
Core theme	**Author**	**Main Contribution**
Change during project development	Schuh et al (2017)	Framework for adaptive ECM to enable agile product development
Change during project development	Kattner et al (2016)	Performance metrics in ECM
Change during project development	Han et al (2015)	Model to capture design changes and share with stakeholders during product development
Change during project development	Alblas e Jayaram (2015)	Categorization of design resilience in relation to organizational resilience
Change during project development	Wickel et \l (2013)	Approach to support determination of optimal checkpoints to detect deviation during product development
Change feasibility	Rebentisch et al (2017)	Multilayer network model to identify most cost-effective solution in cases of change request

Change feasibility	Gebhardt (2017)	Model for predicting indirect process cost in ECM based on a task characteristic perspective
Change feasibility	Gebhardt et al (2016)	Model for predicting indirect process cost in ECM
Change feasibility	Kurdve et al (2016)	Evaluation of manufacturing impact in cases of changes
Change feasibility	Bueno e Borsato (2014)	Decision-making support method for identifying opportunities for product improvement
Change management	Stekolschik (2016)	Framework for controlling engineering changes at mechanical engineering companies
Change management	Wilberg et al (2015)	Approach based on Viable System Model to improve the as-is ECM
Change management	Mutingi et al (2015)	ECM framework based on critical success factors
Change management	Wu et al (2014)	Advanced CMII-based ECM framework
Change management	Sommer et al (2013)	Process model for customer-driven product development
Change management	Yu et al (2013)	Model for ECM at small and medium-sized companies
Change management	Storbjerg et al (2013)	ECM capability framework
Change management	Obidallah et al (2013)	Framework and methodology to manage changes in virtual organizations
ECM analysis	Kattner e Lindemann (2017)	Procedure to support project management in investigating ECM
ECM analysis	Jokinen et al (2017)	Reasons for engineering change requests to vary processing times
ECM analysis	Grieco et al (2017)	Self Organizing Map to clustering text of engineering requests
ECM analysis	Storbjerg et al (2016)	Maturity framework to guide improvement on ECM and critical success factors for efficient ECM
ECM analysis	Kukulies et al (2016)	Approach for improving inspection planning and controls based on engineering changes lessons learned
ECM analysis	Subrahmanian et al (2015)	Support system to reduce cognitive load of design engineer in case of changes
ECM analysis	Wickel e	Indicators to sign best engineering change strategy

	Lindemann (2014)	based on past data
ECM control	Shivankar et al (2015)	ECM process to communicate through all supply chain
ECM control	Hollauer et al (2014)	Framework to manage and cultivate knowledge from ECM
ECM control	Huhtala et al (2014)	Technique to handle engineering change using product data management system
ECM control	Elezi et al (2013)	Systematic approach to coordinate communication in ECM
MCM	Koch et al (2016)	Design of Manufacturing Change Management based on ECM concepts
MCM	Koch et al (2016)	Context model for a process-oriented Manufacturing Change Management
Review	Serapelo et al (2017)	ECM Systematic review listing frameworks available
Review	Karthik e Reddy (2016)	Overview about ECM and it's implication in product design
Review	Ullah et al (2016)	Systematic review highlighting methods and tools proposed by previous researches

Source: BARROSO 31st, 2018

Table 10 - Main contribution split within the themes - Out of scope

OUT OF SCOPE		
Core theme	**Author**	**Main Contribution**
IoT	Zdravković et al (2017)	List of scientific disciplines to support resolution for IoT implementation problems
ERP	Comuzzi e Parhizkar (2017)	Methodology to identify impact on enterprise systems in cases of changes on enterprise resource planning systems
PLM	Bricogne et al (2014)	Collaborative PLM platform
3D-CAD	Brière-côté et al (2013)	Evaluation trials upon commercially available 3D-CAD model comparison tools
Conference review	(no author available) (2018)	Conference review
Conference review	(no author available) (2016)	Conference review
Duplicated	Bueno e Borsato (2014)	Repeated with BUENO E BORSATO (2014) but presented at different conference

Source: BARROSO & ANDRADE JUNIOR, 2018

Considering the scope is to identify document to compose a theoretical referential on Engineering Change Management control study, better adherence to the theme may be identified within the 12 documents from Method focus with core theme change management and ECM control. List of these articles is presented on Table 11.

Table 11 - Documents to support ECM study

Title	Focus	Core Theme
Stekolschik (2016)	Method	Change management
Wilberg et al(2016)	Method	Change management
Mutingi et al (2015)	Method	Change management
Shivankar et al (2015)	Method	ECM control
Wu et al (2014)	Method	Change management
Hollauer et al (2014)	Method	ECM control
Huhtala et al (2014)	Method	ECM control
Sommer et al (2014)	Method	Change management
Yu et al (2014)	Method	Change management
Storbjerg et al (2013)	Method	Change management
Obidallah et al (2013)	Method	Change management
Elezi et al (2013)	Method	ECM control

Source: BARROSO & ANDRADE JUNIOR, 2018

With this articles resulted from a bibliometric analysis followed by a systematic review it is possible to compose a theoretical referential on ECM control study using highly relevant documents for the theme.

4. CONCLUSION

During the bibliometric analysis and systematic review it was notable that despite its great importance as competitive advantage for companies because it is the alternative to become more flexible and satisfy customer needs, the ECM is not being given the right attention on researches.

The publications only increased on the past 18 years and the studies are still concentrated on few publishers and countries.

The systematic review performed on the 62 documents from the bibliometric analysis resulted:

- 34% relates to change propagation simulation through computer system, system development to support change feasibility calculation and computer alternatives to improve Engineering Change Management record and control. This group was considered as System focus.

- 55% concentrates on review Engineering Change Management research, evaluate expanding application of Engineering Change Management literature to other change control or propose

methods and frameworks to control or analyze changes cause and feasibility. This group was considered as Method focus.

- 11% were not directly related to Engineering Change Management or were duplicated. This group was considered Out of Scope.

Narrowing the 34 documents that represents the 55% with Method focus, considering core theme “change management” and “ECM control” it was possible to identify 12 publications as the main relevant documents to compose a theoretical referential on ECM control study.

A strong relation between ECM and PLM was evidenced by the keywords analysis and considering the increasing interest on PLM on the company's side, there is a good perspective for developing further studies on ECM.

5. REFERENCE

ALBLAS, Alex; JAYARAM, Jayanth. *Design resilience in the fuzzy front end (FFE) context*: an empirical examination. International Journal of Production Research, 2015. v. 53, n. 22, p. 6820-6838.

BRICOGNE, Matthieu et al. *Concurrent versioning principles for collaboration:* towards PLM for hardware and software data management. International Journal of Product Lifecycle Management, 2014. v. 7, n. 1, p. 17-37.

BUENO, Marcio R.; BORSATO, Milton.*A Method for Identifying Product Improvement Opportunities through Warranty Data*. In: ISPE CE. 2014. p. 122-131.

BUENO, Marcio R.; BORSATO, Milton.*A Method for Identifying Product Improvement Opportunities through Warranty Data*. In Advances in Transdisciplinary Engineering, 2014.

BRIÈRE-CÔTÉ, Antoine; RIVEST, Louis; MARANZANA, Roland. *3D CAD model comparison:* An evaluation of model difference identification technologies. Computer-Aided Design and Applications, 2013. v. 10, n. 2, p. 173-195.

COMUZZI, Marco; PARHIZKAR, Minou. *A methodology for enterprise systems post-implementation change management*. Industrial Management & Data Systems, 2017. v. 117, n. 10, p. 2241-2262.

DO, Namchul. *Integration of engineering change objects in product data management databases to support engineering change analysis*. Computers in Industry, 2015. v. 73, p. 69-81.

ELEZI, Fatos; MAIER, Thomas Georg; LINDEMANN, Udo. *Engineering change management challenges and management cybernetics*. In: Systems Conference (SysCon), 2013 IEEE International. IEEE, 2013. p. 567-573.

ELTAIEF, Ameni; LOUHICHI, Borhen; REMY, Sébastien. *Associations management and change propagation in the CAD assembly*. Computers in Industry, 2018. v. 98, p. 134-144.

FIEDLER, R; KAMPA, J. *Identificação dos motivadores de alterações de produto e seus impactos financeiros no desempenho do PDP*: um estudo em uma empresa montadora de medidores de energia elétrica. Gest. Prod., São Carlos , 2016. v. 23, n. 1, p. 37-47.

GANESAN, A. *Database for sustained product cost reduction*. In SAVE Value Summit 2015 pp. 22–28.

GEBHARDT, Marcel. *Predicting indirect process costs of engineering change based on a task characteristic perspective*. In: DS 87-4 Proceedings of the 21st International Conference on Engineering Design (ICED 17), 2017. Vol 4: Design Methods and Tools, Vancouver, Canada, 21-25.08.

GEBHARDT, Marcel; SCHMIED, Christian; MÖRTL, Markus. *Ex-anteQuantifizierungindirekterÄnderungskosten*. ZWF Zeitschrift für wirtschaftlichen Fabrikbetrieb, 2016. v. 111, n. 7-8, p. 434-438.

GRIECO, Antonio; PACELLA, Massimo; BLACO, Marzia. *On the application of text clustering in Engineering Change process*. Procedia CIRP, 2017. v. 62, p. 187-192.

HAMRAZ, B., HISARCIKLILAR, O., RAHMANI, K., WYNN, D., THOMSON, V., & CLARKSON, P. *Change prediction using interface data.* Concurrent Engineering Research and Applications, 2013. v. 21(2), p. 141–154.

HAMRAZ, Bahram et al. *FBS Linkage ontology and technique to support engineering change management*. Research in Engineering Design, 2015. v. 26, n. 1, p. 3-35.

HAMRAZ, Bahram et al. *Requirements-based development of an improved engineering change management method*. Journal of Engineering Design, 2013. v. 24, n. 11, p. 765-793.

HAMRAZ, Bahram; CLARKSON, P. John. Industrial evaluation of FBS Linkage–a method to support engineering change management. Journal of Engineering Design, 2015. v. 26, n. 1-3, p. 24-47.

HAN, Jinteck; LEE, Soo-Hong; NYAMSUREN, Purevdorj. *An integrated engineering change management process model for a project-based manufacturing.* International Journal of Computer Integrated Manufacturing,2015. v. 28, n. 7, p. 745-752.

HEIN, Phyo Htet; VORIS, Nathaniel; MORKOS, Beshoy. *Predicting requirement change propagation through investigation of physical and functional domains*. Research in Engineering Design, 2018. v. 29, n. 2, p. 309-328.

HESSELMANN, Carsten et al. *Decentralized handling of conflicts in multi-brand engineering change management*. In: DS 87-4 Proceedings of the 21st International Conference on Engineering Design (ICED 17), 2017. Vol 4: Design Methods and Tools, Vancouver, Canada, 21-25.08.

HOLLAUER, Christoph; WICKEL, Martina; LINDEMANN, Udo. *Learning from past changes—Towards a learning-oriented engineering change management*. In: Industrial Engineering and Engineering Management (IEEM), 2014 IEEE International Conference on. IEEE, 2014. p. 1081-1085.

HUHTALA, Merja; LOHTANDER, Mika; VARIS, Juha.*Product Data Management Systems as a Tool in Engineering Change Management*. In: Advanced Materials Research. Trans Tech Publications, 2014. p. 1134-1140.

JOKINEN, Lauri; VAINIO, Ville; PULKKINEN, Antti. *Engineering Change Management Data analysis from the perspective of Information Quality*. Procedia Manufacturing, 2017. v. 11, p. 1626-1633.

JONKERS, K; DERRICK, G. *The bibliometric bandwagon:* Characteristics of bibliometric articles outside the field literature. Journal of the American Society for Information Science and Technology, 2012. v. 63(4); p. 829–836.

KARTHIK, K.; REDDY, K. Janardhan. *Engineering Changes in Product Design-A Review.* In: IOP Conference Series: Materials Science and Engineering. IOP Publishing, 2016. p. 012001.

KATTNER, Niklas et al. *A method for the expert-based identification of engineering change propagation.* In: DS 87-4 Proceedings of the 21st International Conference on Engineering Design (ICED 17) Vol 4: Design Methods and Tools, 2017. Vancouver, Canada, 21-25.08. 2017.

KATTNER, Niklas; LINDEMANN, Udo. *Performance Metrics in Engineering Change Management:* Towards a Methodology to Investigate the Efficiency of Handling Engineering Changes. In: Management of Engineering and Technology (PICMET), 2017 Portland International Conference on. IEEE, 2017. p. 1-8.

KATTNER, Niklas; WANG, Tianyi; LINDEMANN, Udo. *Performance metrics in engineering change management-Key Performance Indicators and engineering change performance levels.* In: Industrial Engineering and Engineering Management (IEEM), 2016 IEEE International Conference on. IEEE, 2016. p. 1180-1184.

KOCH, J.; GRITSCH, A.; REINHART, G. *Process design for the management of changes in manufacturing:* Toward a Manufacturing Change Management process. CIRP Journal of Manufacturing Science and Technology, 2016. v. 14, p. 10-19.

KOCH, Jonas; MICHELS, Nicolas; REINHART, Gunther.*Context model design for a process-oriented manufacturing change management.* Procedia CIRP, 2016. v. 41, p. 33-38.

KUKULIES, Jan; FALK, Bjoern; SCHMITT, Robert. *A holistic approach for planning and adapting quality inspection processes based on engineering change and knowledge management.* Procedia CIRP, 2016. v. 41, p. 667-674.

KURDVE, Martin et al. *Production System change strategy in lightweight manufacturing.* Procedia CIRP, 2016. v. 50, p. 160-165.

LEE, Jihwan; HONG, Yoo S. *A Bayesian network approach to improve change propagation analysis.* In: DS 80-5 Proceedings of the 20th International Conference on Engineering Design (ICED 15) Vol 5: Design Methods and Tools-Part 1, 2015. Milan, Italy, 27-30.07. 15.

LEE, Jihwan; HONG, Yoo S. *Bayesian network approach to change propagation analysis.* Research in Engineering Design, 2017. v. 28, n. 4, p. 437-455.

LI, W; MOON, Y. *Modeling and managing engineering changes in a complex product development process.* The International Journal of Advanced Manufacturing Technology, 2012. v. 63, n. 9-12, p. 863-874.

MAHMOUD, Masmoudi et al. *Modelling dependencies in engineering change management (ecm).* In: Design and Modeling of Mechanical Systems-II. Springer, Cham, 2015. p. 161-168.

MASMOUDI, Mahmoud et al. *Change propagation prediction:* A formal model for two-dimensional geometrical models of products. Concurrent Engineering, 2017. v. 25, n. 2, p. 174-189.

MASMOUDI, Mahmoud et al. *Dependency identification for engineering change management (ecm):* an example of computer-aided design (cad)-based approach. In: the 20th International Conference on Engineering Design (ICED 15), 2015.

MASMOUDI, Mahmoud et al. *Engineering Change Management (ECM) Methods: Classification According to Their Dependency Models*. In: International Conference Design and Modeling of Mechanical Systems. Springer, Cham, 2017. p. 1169-1178.

MUTINGI, Michael; MBOHWA, Charles; MAPFAIRA, Herbert. *An alternative framework for managing engineering change.* In: Industrial Engineering and Operations Management (IEOM), 2015 International Conference on. IEEE, 2015. p. 1-5.

OBIDALLAH, Waeal J. et al. *Service oriented virtual organizations:* A service change management perspective. In: Electrical and Computer Engineering (CCECE), 2013 26th Annual IEEE Canadian Conference on. IEEE, 2013. p. 1-6.

OUERTANI, M; YESILBAS, L; LOSSENT, L. *Engineering change process:* state of the art, a case study and proposition of an impact analysis method. In: 5th International Conference on Integrated Design and Manufacturing in Mechanical Engineering, IDMME 2004. AN Bramley, et al., Eds.

PADALKAR, M; GOPINATH, S. *Six decades of project management research:* Thematic trends and future opportunities. International Journal of Project Management, 2016. v. 34, n. 7, p. 1305-1321.

PIKOSZ, P; MALMQVIST, J. *A comparative study of engineering change management in three Swedish engineering companies.* In: Proceedings of the DETC98 ASME design engineering technical conference. 1998. p. 78-85.

REBENTISCH, Eric et al. *Assessment of changes in engineering design using change propagation cost analysis.* In: DS 87-4 Proceedings of the 21st International Conference on Engineering Design (ICED 17) Vol 4: Design Methods and Tools, 2017. Vancouver, Canada, 21-25.08. 2017.

REDDI, Krishna R.; MOON, Young B. *Modelling engineering change management in a new product development supply chain*. International Journal of Production Research, 2013. v. 51, n. 17, p. 5271-5291.

SCHUH, Günther et al. *Enabling agility in product development through an adaptive engineering change management.* Procedia CIRP, 2017. v. 63, p. 342-347.

SERAPELO, Thabisho Eric; ERASMUS, Louwrence; PRETORIUS, Jan-Harm. *Engineering change management impact on project success within a South African petrochemical company.* In: Management of Engineering and Technology (PICMET), 2017 Portland International Conference on. IEEE, 2017. p. 1-8.

SHIVANKAR, Sudhir D.; KAKANDIKAR, Ganesh M.; NANDEDKAR, V. M. *Implementing engineering change management through product life cycle management in automotive field.* International Journal of Product Lifecycle Management, 2015. v. 8, n. 2, p. 132-141.

SOMMER, Anita Friis; DUKOVSKA-POPOVSKA, Iskra; STEGER-JENSEN, Kenn. *Activity-based process model for customer-driven product development.* In: Industrial Engineering and Engineering Management (IEEM). IEEE, 2013. p. 1259-1264.

SONZINI, María Soledad; VEGETTI, Marcela; LEONE, Horacio.*Towards an ontology for product version management.* International Journal of Product Lifecycle Management, 2015. v. 8, n. 1, p. 80-97.

SRIRAM, Pavan Kumar; ALFNES, Erlend; KRISTOFFERSEN, Steinar. *Collaborative engineering:* A framework for engineering-to-order companies. In: Collaboration Technologies and Systems (CTS), 2014 International Conference on. IEEE, 2014. p. 252-258.

STEKOLSCHIK, Alexander. *Engineering Change Management Method Framework in Mechanical Engineering.* In: IOP Conference Series: Materials Science and Engineering. IOP Publishing, 2016. p. 012008.

STORBJERG, Simon Haahr et al. *Development of an engineering change management capability framework for enterprise transformation*. In: DS 75-3: Proceedings of the 19th International Conference on Engineering Design (ICED13) Design For Harmonies, Vol. 3: Design Organisation and Management, 2013. Seoul, Korea 19-22.08. 2013.

STORBJERG, Simon Haahr; BRUNOE, Thomas Ditlev; NIELSEN, Kjeld. *Towards an engineering change management maturity grid.* Journal of Engineering Design, 2016. v. 27, n. 4-6, p. 361-389.

SUBRAHMANIAN, Eswaran et al. *Managing and supporting product life cycle through engineering change management for a complex product*. Research in Engineering Design, 2015. v. 26, n. 3, p. 189-217.

TAVČAR, J; DUHOVNIK, J. *Engineering change management in individual and mass production.* Robotics and computer-integrated manufacturing, 2005. v. 21, n. 3, p. 205-215.

ULLAH, Inayat; TANG, Dunbing; YIN, Leilei. *Engineering product and process design changes: a literature overview*. Procedia CIRP, 2016. v. 56, p. 25-33.

WICKEL, Martina C.; LINDEMANN, Udo. *A retrospective analysis of engineering change orders to identify potential for future improvements.* DS 81: Proceedings of NordDesign 2014, Espoo, Finland 27-29th August 2014.

WICKEL, Martina Carolina; BEHNCKE, Florian; UDO, Lindemann. *When to check for deviations in the design process–An approach to determine a systematic checkpoint schedule.* In: DS 75-1: Proceedings of the 19th International Conference on Engineering Design (ICED13), Design for Harmonies, Vol. 1: Design Processes, 2013. Seoul, Korea, 19-22.08.

WILBERG, Julian et al. *Supporting the Implementation of Engineering Change Management with the Viable System Model*. In: Systems, Man, and Cybernetics (SMC), 2015 IEEE International Conference on. IEEE, 2015. p. 731-736.

WU, Wen-Hsiung et al. *An advanced CMII-based engineering change management framework: the integration of PLM and ERP perspectives*. International Journal of Production Research, 2014. v. 52, n. 20, p. 6092-6109.

YAN, W. *A cross-system collaboration on engineering change order execution.* In CIE 2016: 46th International Conferences on Computers and Industrial Engineering, 2016.

YIN, Leilei et al. *Engineering Change Management of Product Design Using Model-Based Definition Technology.* Journal of Computing and Information Science in Engineering, 2017. v. 17, n. 4, p. 041006.

YU, Xiaonan et al. *Study on design change review for small and medium-sized enterprises.* In: Industrial Engineering and Engineering Management (IEEM), 2013 IEEE International Conference on. IEEE, 2013. p. 556-560.

ZDRAVKOVIĆ, Milan et al. *Domain framework for implementation of open IoT ecosystems.* International Journal of Production Research, 2017. p. 1-18.

(no author available). *7th Conference on Design and Modeling of Mechanical Systems*, CMSM 2017, 2018.

(no author available). *IOP Conference Series: Materials Science and Engineering*. IOP Conference Series: Materials Science and Engineering, 2016.