Available online at www.sciencedirect.com

ScienceDirect

International Journal of Project Management 32 (2014) 508 – 518

International Journal of Project Management

www.elsevier.com/locate/ijproman

Barriers to effective configuration management application in a project context: An empirical investigation

Usman Ali *, Callum Kidd [1]

Management of Projects, School of Mechanical Aerospace and Civil Engineering, The University of Manchester, Manchester, M13 9PL, UK

Received 25 October 2012; received in revised form 30 May 2013; accepted 4 June 2013

Abstract

Configuration management (CM) is not a new set of ideas, what it does represent is an effective way for project managers to use a formalized methodology in order that they can manage status and changes to it throughout the lifecycle. This research sets out to identify and prioritize the obstacles in the effective implementation of the CM practices, categorize these obstacles into more manageable groups of factors, and analyse the effects of multiple factors on the identification and rating of these barriers. Nineteen barriers are finalized and prioritized on the basis of their criticality and as a result three groups (managerial and organizational barriers, implementation barriers, and planning and process barriers) are extracted with the help of factor analysis. This study will help both configuration management and project management professionals to plan better and avoid the impacts of these key obstacles from much earlier in the definition phase.

Keywords: Configuration management; Project management; Process improvement; Barriers; Aerospace and defence industries

1. Introduction

This paper investigates the obstacles to configuration management (CM) success in both the aerospace and defence industries, from a project management (PM) perspective. Configuration management is a management activity that manages the definition of a product, system or process from its earliest definition all the way through the lifecycle. In many cases, this is also required to be managed post disposal, in cases where access to data or documentation may be required for regulatory purposes. CM helps project professionals ensure that products and systems meet their defined functional and physical requirements and that any changes to these requirements are tightly controlled, carefully identified, and accurately recorded (Samaras, 1988). With clear rewards in terms of reducing product development time, minimizing through life cost, and enhancing overall product quality, CM is an essential part of the project delivery strategy. However, CM initiatives have been undermined and implemented in a haphazard way even in the presence of a sound structured methodology and sufficiently detailed requirements standards (Burgess et al., 2005). CM is based on sound business principles to establish product configurations, identify and manage changes to them through life, account for all incorporated/approved changes, and maintain the integrity of the configuration by validating and verifying compliance wherever required. Turner (1997) very eloquently puts this into a PM perspective as thus 'CM is not a radical discovery that revolutionizes the way the facility is developed and maintained. It is a set of good working practices for coping with uncertainty and change and gaining commitment of the projects participants as the design evolves'.

CM was first formally introduced by the US Department of Defence in the 1950/60's where its need was instigated through lack of data uniformity and change control issues in the race for a successful missile launch in the 1950's (Samaras, 1988). In the 1990s, CM was increasingly evident in more commercially oriented sectors to extend this concept and help them with

* Corresponding author. Tel.: +44 161 306 2368.
E-mail addresses: usman.ali-2@postgrad.manchester.ac.uk, engrusman@hotmail.com (U. Ali), c.kidd@manchester.ac.uk (C. Kidd).
[1] E9, Pariser Building, School of Mechanical Aerospace and Civil Engineering, The University of Manchester, Manchester, M13 9PL, UK. Tel.: +44 161 306 4616; fax: +44 161 306 4646.

0263-7863/$36.00
http://dx.doi.org/10.1016/j.ijproman.2013.06.005

through life management of product and system status. During this period the International Organization of Standardization issued their first guideline on CM in the form of ISO-10007 in 1994 with a major reflection being the inclusion of CM in the requirements based aerospace standards such as AS-9100. CM has remained one of the most critical process areas throughout the process maturity models developed by the Software Engineering Institute. CM is not limited in scope to just the aerospace & defence industries and extends to other sectors for example nuclear, conventional power generation, petrochemical, construction, and shipbuilding (Fowler, 1992; Gonzalez and Zaalouk, 1997) and has played a major part in business process improvements across the board (Gonzalez and Zaalouk, 1997).

CM is considered, by many, to be an integral element of the project management (PM) function which is a barrier to effective application is perhaps in itself. Several studies have identified that the CM process extends beyond the project, across engineering, support and disposal. Use of a common process is critical in ensuring conformance. Effective management of a project requires consistent and repeatable processes and methodologies to manage the constraints of scope, time, cost and quality, and to ensure project success. The PM professional requires CM to actively support the project direction and infrastructure (PMI, 2007). CM is a through life activity, which invariably extends beyond the traditional project lifecycle, and is encapsulated in a variety of engineering, project management and manufacturing management methods (Burgess et al., 2003). It is an on-going and repetitive activity to establish and maintain integrity of an evolving product/system throughout the lifecycle, whether it be at product, asset, system or project level, while PM is specifically concentrated on the definition and execution of the lifecycle at a project level. CM is an integral part of the system engineering function (Team, 2006; Sage and Rouse, 2009) whereas PM, quality management, engineering management, and logistics management are principal stakeholders in the ownership of the CM process (Kidd and Burgess, 2007).

The academic literature in the field of configuration management is unexpectedly and extremely limited with no formal study to date on the barriers to configuration management success. Several studies for example Burgess et al. (2003), Burgess et al. (2005), Huang and Mak (1999), Fowler (1996), have addressed several of the issues but have specific limitations on their own, namely in terms of their focus, and their scope of the discipline. The majority of studies focus purely on change management, and not CM in general. On the other hand extensive studies in allied professional activities such as quality management (Bhat and Rajashekhar, 2009; Sebastianelli and Tamimi, 2003), knowledge management (Riege, 2005; Sun and Scott, 2006), and project management (Atkinson et al., 2006) show the importance of research in the understanding of barriers. Studies on the topic highlight the core issues which facilitate the development of a road-map towards maturity of a process (Niazi et al., 2005; Yeo and Ren, 2008). This current research will not only help in organizational enhancement of the configuration function but also facilitate the exploration of ways to avoid obstacles and devise frameworks to establish excellence in CM practices for project management.

Configuration management is not practised to its full potential and is perceived in a similar way to that of quality management in Western organizations prior to its increased level of awareness in the 1980's (Burgess et al., 2005). Indeed, there is a common path for the development in that quality rose from a culture of quality control, through assurance and then on to management. CM, similarly, is very much entrenched in a culture of control/assurance. Burgess et al. (2005) further confirmed that achieving a highly performing CM system is not simple and needs further study to investigate the obstacles involved in implementing high-grade CM systems. To further investigate that very issue, this research is designed with the aim of highlighting the main barriers in the effective implementation of the CM process in both aerospace and defence industries. This study identify barriers associated with managing configuration management application, prioritize them with the help of differential statistics, categorize them into more manageable groups of factors through factor analysis, and analyse the effects of multiple factors e.g. academic education, gender differences, CM experience and types of organization on the perception of CM practitioners in the process of application and finally rating these factors through the application of inferential statistics.

With in-depth interviews and questionnaire surveys, nineteen (19) barriers were finalized and prioritized on the basis of their mean values which are grouped into three groups namely 'managerial and organizational barriers', 'planning and process barriers', and 'implementation barriers'. Significance is found in the CM practitioner's perceptions based on the typology of organizations in which they work.

2. Literature on barriers to CM implementation

CM barriers refer to those potential actions, phenomenon, or influences which impede and prevent effective implementation of the process in achieving its objectives. Detailed searches of peer reviewed journals and practitioner literature highlights that research based study on the topic is unexpectedly and extremely scare in comparison with other allied processes such as quality management and knowledge management, and no formal study is found with the aim to explore barriers to CM success. However, allied studies in the areas of quality management (e.g. Bhat and Rajashekhar, 2009; Sebastianelli and Tamimi, 2003), knowledge management (e.g. Riege, 2005; Sun and Scott, 2006), project management (e.g. Atkinson et al., 2006), and business process management (e.g. Da-Silva et al., 2012) provided a great deal of scope in this area of study.

Burgess et al. (2003), Huang and Mak (1999), and Burgess et al. (2005) could be considered the most influential studies to date which have supported the need for this research in many aspects but have specific limitations on their own. Instead of targeting CM as a holistic and generic process, these studies have targeted specific elements of CM execution. For example the study of Burgess et al. (2003) is related primarily to configuration status accounting while that of Huang and Mak (1999) deals with configuration change control and hence can't be considered a representative view of the CM process as a whole. Burgess et al. (2005) is a comprehensive research on current CM practices within one multi-national aerospace programme which highlighted some of the obstacles to CM implementation.

The Burgess et al. (2003) research study highlights the implementation performance of configuration status accounting within the aerospace sector. According to the research, CM planning – the most influential aspect of the process – is rarely given due credence and is considered generally a main obstacle. Other factors having significant effects on the outcome are lack of dedicated CM staff, perceived lack of CM value, and an engendered belief that CM is not a cost effective process. The study is based on the assumption that international/national standards for CM are widespread and well understood which could be considered a major limitation of the study. This as a whole is believed to be one of the most critical areas in CM implementation (Samaras, 1988) which can largely affect the overall performance of the process and hence cannot be ignored. A more recent study by Wu et al. (2012), states that CM standards are not well understood or adopted, especially where there is no contractual requirement to do so.

The Huang and Mak (1999) study is a detailed representation of the influential factors of engineering change management. According to the authors, the most influential factors to effective change implementation are a reluctance and indifference toward the process, poor communication, high uncertainty in planning and priorities, an overly bureaucratic process infrastructure, complex and confusing organizational structures, lack of simplicity, lack of cooperation, scarce resources that are exacerbated by constant fire fighting, lack of involvement from stakeholders, isolated automation of the process, lack of engagement of CM practitioners in decision making, and by no means least, a narrowing of human skills.

The Burgess et al. (2005) research is an overview of the current CM practices in the aerospace sector, from the perspective of one major collaborative programme, which highlights some major obstacles to CM success. It purports that CM is not considered a vigorous discipline, having poor recognition, and instead of a single process it is viewed as the interaction of many processes all embedded within other functions. According to the study, the lack of CM as a generic process across the full life cycle is missing at present. The lack of poor recognition of CM is linked inextricably with lack of management support, lack of CM education and training, and lack of CM career progression.

Fowler (1996) has also highlighted some major concerns in the implementation of CM within shipbuilding organizations. He emphasized that although CM is considered a potentially powerful tool focusing on quality, waste-reduction and the preservation of design intent, the problems associated with CM implementation should not be underestimated even in the presence of defined CM principles, practices, and standards. Even though some aspects may vary according to the nature, structure, function and objectives of a particular organization; there are some general soft skill issues with CM implementation. These behavioural issues include lack of sufficient human resource to introduce CM concepts, unfamiliarity with CM concepts, the existence of a diverse range of perceptions, and hesitation in accepting the ownership and commitment to CM principles and practices.

Other studies on multiple issues within CM – although quite few and very fragmented – have highlighted barriers to CM application e.g. lack of standardization, lack of resources, lack of management support, and lack of user's acceptance and involvement (Gonzalez and Zaalouk, 1997), lack of communication, cooperation and coordination (Jarratt et al., 2011), and lack of user friendly software tools (Guess, 2006).

The literature outlined above does not reflect one singular study dedicated to CM implementation barriers. These individual studies do reflect some barriers but critical review suggests that several highlighted barriers are based on a particular researcher's own perception since they believe that the process is not practised to its full potential because of a variety of perceived reasons. Little cross industry research based on collected data has been undertaken in some of these studies. This is a major failing of a phenomenological approach to research, and reflects a particular bias, especially where the outcome is to promote a particular methodology. It is also important to note that many barriers presented in this research have not been reflected before, for example lack of flexibility in CM process, extreme project pressures, lack of authority to implement CM principles/policies, poorly defined CM requirements and process, lack of CM awareness in Customer worlds, and outdated CM process. This highlights a major gap in the literature. This is the only study on the topic which presents a holistic view of the issue and presents a sound methodology to identify barriers to CM implementation, group them into more manageable factors, and prioritizes them based on their mean values with the help of experienced CM professionals working in both aerospace and defence industries. Furthermore, it is also believed that multiple factors such as academic education, gender differences, CM experience and type of organization may influence the identification and rating of these factors which again has never been explored previously. To investigate this issue, the following hypothesis was developed which is then verified by using inferential statistics.

Hypothesis. 'The identification and ranking of barriers to configuration management acceptance and application, from the perspective of a CM practitioner, will be directly influenced by their academic education, gender difference, CM experience, and typology of organization'.

3. Research methodology

This research is based on mixed method research which refers to the use of more than one method for the collection of data (Creswell and Clark, 2007). Mixed method research is used to validate our results through triangulation which is primarily to increase the reliability and validity of the research (Hussey and Hussey, 1997). Multiple research techniques were followed where data is collected by talking to people, either face to face, by means of telephone, over internet or by written questionnaire which are the effective means of performing survey research (Jankowicz, 2004).

It was a challenging task to highlight the list of barriers which impede the effective implementation of CM process. The task was accomplished by dividing data collection process in three different phases. In the first phase, research participants were asked through an open question to identify factors which they believe are the most obvious barriers in the implementation of configuration management. This open question was part of a questionnaire for our previous research study on 'critical success factors for the implementation of configuration management'. The replies received through 64 questionnaires (320 sent out) were grouped into multiple factors for further analysis. In the second phase of the research seven semi-structured interviews with CM experts of four different industries were conducted. Each interview was recorded for later analysis. Interviews were analysed several times and highlighted barriers were downloaded where cross comparison was done with identified barriers through questionnaire study. The data was grouped and analysed carefully to avoid possibilities of ignoring or repeating factors where nineteen factors (Ali and Kidd, 2012) were finalized for our final survey.

The third phase of this research was based on a questionnaire survey to validate our findings and verify the established hypothesis. The questionnaire was divided into two sections. The first section focussed on gathering background information whereas the second part was related to barriers where respondents' opinions were asked on a series of statements. Respondents of the questionnaire survey were asked to mark trueness of each statement based on their organization by using a five-point scale (1 = not at all true, 2 = slightly true, 3 = somewhat true, 4 = mostly true, 5 = completely true). A pilot study was conducted to ensure that the questionnaire was phrased correctly, ensure no problem while answering, and provision of measures for what it was designed. In the first phase five CM professionals were asked to comment on the readability, comprehensiveness, and accuracy of the questionnaire. With some minor changes, in the second phase, questionnaire was send to fifty-two CM professionals where a total of thirty-five questionnaires were received without any changes. The Cronbach's Alpha coefficient was calculated to check the reliability of the questionnaire by using internal consistency method which is 0.91 after thirty-five responses. The questionnaire survey was continued since the Cronbach Alpha of 0.7 and above conform the test of internal consistency (Pallant, 2010), meaning that the scale is free from any random error and is reliable for research. The overall Cronbach Alpha coefficient is 0.904 (after 187 responses) which is well above the recommended value of 0.7 shows a high internal consistency between nineteen items within our research questionnaire.

To facilitate respondents and improve the response rate, a web based questionnaire was designed and the link was sent by email to all respondents. To maintain a high degree of legitimacy of received data, judgemental sampling is used where only identified CM professionals were contacted to provide their views on the issue. 211 questionnaires were received out of 550 with a response rate of 38% where 187 questionnaires were used for further analysis while 24 questionnaires were dropped for their incompleteness in many aspects. It is important to note that the research participants targeted in this research were CM professionals from aerospace and defence industries.

4. Data analysis, findings, and discussion

4.1. Barriers to CM implementation

On the basis of questionnaire survey followed by semi structured interviews, nineteen barriers are finalized which were further validated through our second questionnaire survey. Since configuration managers perceive the existence of barriers to CM, in general, the responses suggest that adverse consequences of these barriers are not widespread. It is understandably true and validates our interview findings since it is believed that in industries like defence where CM is being realistically followed while its performance is monitored from the top which is also evident from the fact that most of the CM standards have been issued from defence contracts and hence suit their environment. It is observed that aerospace businesses have rated CM barriers more than any other business, meaning that there may be additional significance for CM issues.

The list of nineteen barriers is a composition of both previously highlighted and newly identified barriers which are shown in Fig. 1. The previously highlighted barriers (e.g. lack of management support, lack of training, lack of communication, lack of resources, and lack of stakeholder's support) are endemic in nature which are not only reflected in the literature of CM but also in other allied fields like quality management and knowledge management. The newly identified barriers (e.g. lack of flexibility, extreme project pressures, lack of authority to implement CM principles, poorly defined CM requirements and process, lack of CM awareness in Customer worlds, and outdated CM process) are presented for the first time and will need special attention to address. In-depth analysis suggest that most of the barriers are closely related while some are considered the root cause for many other barriers e.g. lack of management support, lack of training, lack of CM planning etc. and hence need special attention to address.

4.2. Ranking of the barriers to CM

Descriptive statistics is used to rank all nineteen barriers on the basis of their mean values which are shown in three groups (obtained through factor analysis in Section 4.3) in Fig. 1, with factors having high mean values being at the top of each group. The barriers having the same mean values are ranked first based on their high marking as either mostly or completely true received through the questionnaire survey. "Lack of CM training across organizations" is ranked first (mean = 3.41) while "outdated CM process" is ranked 19th (mean = 2.36). It can be seen that mean values are very close to each other and hence suggest that there are no major differences in the perception of professionals for these factors as barriers to CM implementation.

4.3. Factor analysis

Factor analysis is a data reduction technique which explores and detects the underlying relationships among a large set of variables and summarize them into smaller sets of factors based on their inherent relationship. Factor analysis is an ideal

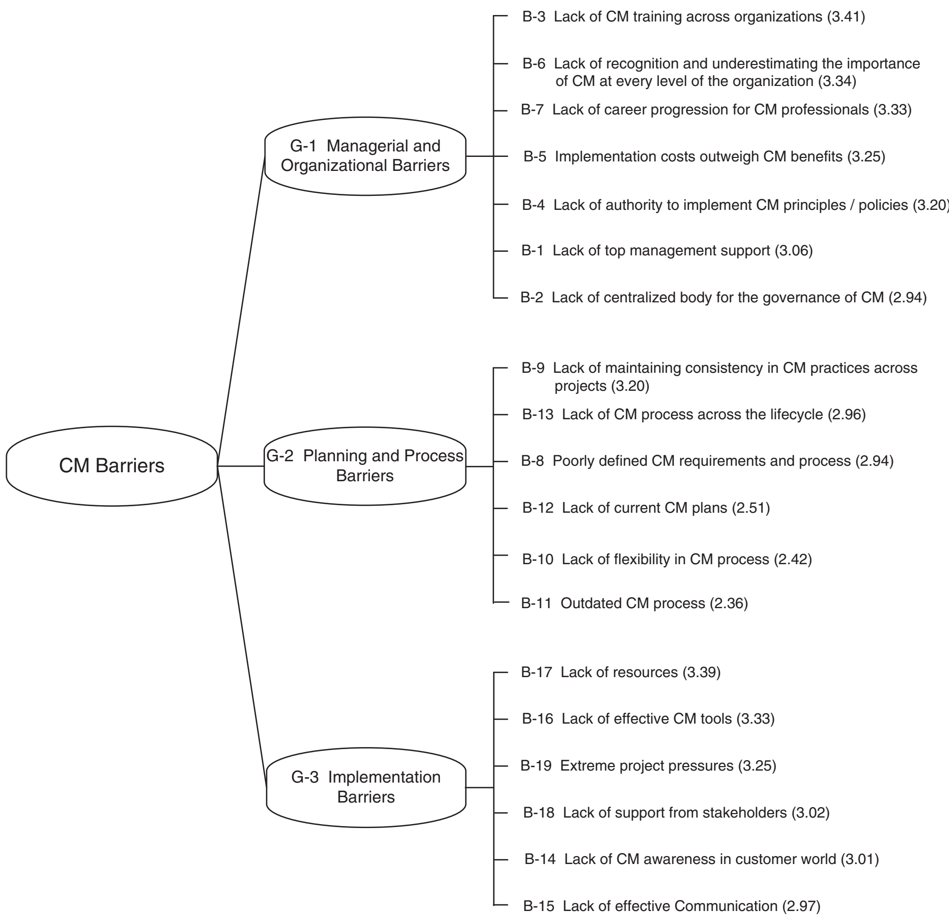

Fig. 1. Barriers to CM transformation.

technique for reducing numerous items into more manageable frameworks (Norusis, 2008) which can also be used in hypothesis testing or finding relationship within a group of variables (Bartholomew et al., 2011).

Principal component analysis, one of the important methods of factors analysis; is used to group the nineteen barriers into small sets of factors based on their inherent relationship followed by varimax rotation. Principal component analysis is most commonly used in factor analysis where original variables are transformed into smaller sets of linear combinations, with all of the variance in variables being used as compared to other factor analysis approaches where factors are estimated through mathematical model by only analysing the shared variance (Pallant, 2010).

It is important to perform some mandatory checks before opting for factor analysis. The first important check is to have a large sample size where little agreement is made among researchers (Pallant, 2010) but according Tabachnick and Fidell (2001) reliable results could be obtained in most cases if the sample size is 5 to 1 ratio: i.e. 5 cases for each item to be factor analysed. After suitable sample size it is important to confirm the suitability of data for factor analysis by using three compulsory checks (Pallant, 2010). Firstly, inspection of the Pearson Product–moment Correlation Coefficient Matrix is important which revealed the presence of many coefficients of 0.3 and above as shown in Table 1. Secondly, the Bartlett's Test of Sphericity which is used to detect if variables are uncorrelated is significant (significance value needs to less than 0.05 which is 0.000 in this study). Thirdly, the Kaiser–Meyer–Olkin (KMO) value is 0.893 which exceeds the recommended value of 0.6 meaning that factor analysis is highly recommended for the sample data.

Principal component analysis shows the presence of three components with eigenvalues exceeding 1, presenting 36.919%, 10.305%, and 6.401% of the variance respectively. Similarly an inspection of the screeplot as shown in Fig. 2 highlights a clear break after the third component which suggests the retention of three components for further investigation i.e. managerial and organizational barriers, planning and process barriers, and implementation barriers. Both Kaiser's criterion which suggests retaining of factors having eignvalues of 1.0 or above and Catell's scree test which recommends retaining all factors above breaking in the plot as shown in Fig. 2 (Pallant, 2010) confirm that the three-factor-model should be sufficient for our research analysis.

Finally, varimax rotation was applied on the derived data to present the pattern of loadings for easy interpretation. The data in Table 2 shows that extracted loadings after varimax rotation is consistent where each of the barriers weighs heavily on only one of the three groups and hence verified our decision to

Table 1
Correlation matrix for CM barriers.

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19
B1	1.000																		
B2	.461	1.000																	
B3	.622	.517	1.000																
B4	.537	.505	.562	1.000															
B5	.395	.440	.434	.529	1.000														
B6	.571	.517	.585	.581	.621	1.000													
B7	.272	.354	.369	.330	.358	.381	1.000												
B8	.137	.315	.256	.363	.356	.340	.363	1.000											
B9	.284	.380	.332	.315	.378	.372	.390	.631	1.000										
B10	.175	.200	.239	.254	.217	.225	.200	.420	.386	1.000									
B11	.182	.284	.336	.309	.275	.369	.284	.465	.326	.395	1.000								
B12	.135	.293	.237	.283	.301	.261	.162	.467	.415	.398	.459	1.000							
B13	.231	.336	.285	.155	.290	.299	.221	.376	.401	.408	.285	.438	1.000						
B14	.189	.300	.215	.302	.366	.335	.213	.283	.253	.233	.297	.434	.328	1.000					
B15	.166	.248	.205	.304	.200	.328	.255	.356	.397	.233	.302	.354	.218	.451	1.000				
B16	.117	.171	.180	.137	.118	.160	.212	.247	.288	.376	.266	.236	.263	.312	.384	1.000			
B17	.278	.290	.358	.259	.347	.320	.274	.348	.376	.278	.297	.303	.287	.323	.280	.464	1.000		
B18	.233	.325	.354	.282	.376	.380	.396	.327	.350	.300	.287	.373	.355	.437	.418	.391	.556	1.000	
B19	.230	.328	.302	.366	.324	.376	.257	.338	.393	.272	.258	.388	.371	.344	.362	.297	.453	.613	1.000

maintain only three groups of factors. The final statistics of principle component analysis after varimax rotation in Table 3 show that the three factors extracted comprise 53.631% of the variance. To avoid any possible confusion between the extracted factors and barriers during interpretation, extracted factors are renamed as “group” for clarity in our results interpretation.

4.4. Inferential statistics

Mann–Whitney-U and Kruskal Wallis Tests are carried out to analyse participant perceptions based on their academic education, gender differences, CM experience, and types of organization on three groups of CM barriers. Mann–Whitney-U and Kruskal Wallis Tests are non-parametric tests which give reliable results if the data is not normally distributed (Pallant, 2010) or the data received is ranked or discreet (usually the case with Likert scale) (Motulsky, 1995). The normality of data can be decided on the basis of Sig. value calculated by using Kolmogorov–Smirnov or Shapiro–Wilk Tests which if greater than 0.05 show that the data is normally distributed (Pallant, 2010). Since the data is ranked or discreet and also not normally distributed (since the sig. value is zero for all three groups) hence non-parametric tests are used for inferential statistics.

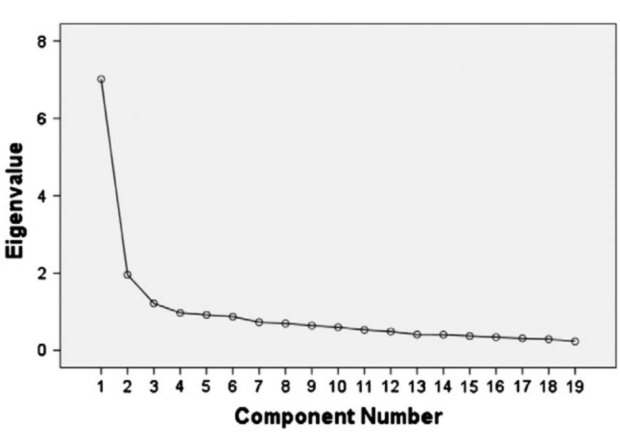

Fig. 2. Screeplot, total variance associated with each barrier.

Results of the Mann–Whitney-U and Kruskal Wallis Tests about participants' perceptions regarding CM barriers in three groups based on the gender differences, academic education, CM experience, and types of organization are summarized in Table 4. The significance value (Asymp. Sig) shows the statistical significance of the three groups and their average. If the significance value is below the threshold value i.e. 0.05, it presents a statistically significant difference in the perception of CM professionals over three groups of barriers. Since the significance values are less than 0.05 as shown in Table 4 based on types of

Table 2
Group of matrix after varimax rotation.

	Group 1	Group 2	Group 3
B1	.789		
B6	.781		
B3	.773		
B4	.751		
B2	.666		
B5	.658		
B7	.439		
B8		.770	
B12		.675	
B10		.663	
B9		.634	
B11		.633	
B13		.547	
B18			.778
B17			.680
B16			.672
B19			.643
B14			.560
B15			.560

Table 3
Final statistics of principle component analysis.

Groups	Eigenvalues	Percentage of variance	Cumulative percentage of variance
1. Managerial and organizational barriers	7.015	36.919	36.919
2. Planning and process barriers	1.958	10.305	47.224
3. Implementation barriers	1.217	6.406	53.631

organizations, meaning that professional's from different organizations perceive the barriers differently in their setups hence we accept the hypothesis for types of organization as highlighted in Section 2. Since the significance value for all other parameters i.e. academic education, gender differences, and CM experience is greater than 0.05 as shown in Table 4, meaning that no differences exist in the perceptions of CM professionals on CM barriers based on these parameters hence we reject the hypothesis for all these parameters as highlighted in Section 2.

The outputs in Table 4 can be further explained with the help of mean rank values generated by the same test. Since the outputs for all the three groups (G-1, G-2, and G-3) and the average of nineteen barriers (Avg) bears similar explanation, only the mean rank values for the group of nineteen barriers are discussed. It is important to know that when the significance value is less than 0.05 the difference between the mean rank values is greater between categories and the category with greater mean rank value shows its significance over others. Since the significance value for the types of organization is 0.000 (which is less than 0.05) hence a considerable difference is seen between the mean rank values of aerospace (109.92) and defence industries (77.24). Furthermore the mean rank value for the aerospace industries is greater than that of defence industries meaning that professionals in aerospace industries perceive these barriers more significant in the implementation of CM than those of defence industries. This means that aerospace industries would need special attention to plan actions and avoid these barriers to improve their CM practices.

On the other hand the significance values for the other three groups i.e. gender differences, academic qualification, and experience in CM are 0.990, 0.558, and 0.911 respectively which are more than 0.05 meaning that there is no significant difference in the perception of professionals in the identification and ranking of barriers based on these factors. This means

Table 4
Mann–Whitney-U and Kruskal Wallis Test results.

Parameters	Asymp. Sig			
	G-1	G-2	G-3	Avg
Significance of barriers with participants gender differences	0.508	0.971	0.757	0.990
Significance of barriers with participants academic qualification	0.106	0.704	0.683	0.558
Significance of barriers with participants experience in CM	0.105	0.794	0.118	0.911
Significance of barriers with participants types of organizations	0.000	0.045	0.000	0.000

that there will be no considerable differences in the mean rank values between the different categories in each group. The mean rank values for two categories based on gender differences i.e. male and female are 93 and 94 respectively while that for academic qualification of employees having PhD, Master, Bachelor, and HND/HNC degrees are 83, 85, 76, and 71 respectively which are too close to each other. Similarly for experience in CM the mean rank values of employees having different years of experience in the implementation of CM are in the range of 92 and 99 which are again too close to each other and hence can be assumed no significant differences in the perceptions of employees for these parameters.

4.5. Interpretation of CM barriers groups

4.5.1. Group 1: Managerial and organizational barriers

The seven extracted barriers related to managerial and organizational barriers includes lack of top management support, lack of centralized body for the governance of CM, lack of CM training across organizations, lack of authority to implement CM principles/policies, implementation costs outweigh CM benefits, lack of recognition and underestimating the importance of CM at every level of the organization, and lack of career progression for CM professionals.

4.5.1.1. Lack of top management support (B_1). It is believed that management doesn't fully understand the role, importance, and criticality of the process and hence ignores it. It looks true after its reflection as one the most frequently highlighted barriers in this research which is also considered a root cause for many other barriers. Management support is believed to play a crucial part in establishing CM as a core business process (Guess, 2006) but on the other hand lack of management support is a major concern towards CM application (Burgess et al., 2005; Gonzalez and Zaalouk, 1997). Lack of management support is one of the major concerns to any business process management (Da-Silva et al., 2012).

4.5.1.2. Lack of centralized body for the governance of CM (B_2). It is observed that decentralization of the process has greatly affected the implementation of CM across the business. CM is often considered a secondary role with only a very few organizations having a senior manager with overall specific CM responsibility (Burgess et al., 2003). It is further observed that project teams often have differing approaches as to how they use the CM process, making their level of engagement inconsistent across the organisation.

Since projects are often multi-disciplinary endeavours which cross many boundaries, specific disciplines have developed their own versions of CM strategies and procedures (PMI, 2007). This has fragmented the CM process across the organization of the project and instead of one generic practice we can often observe a diluted view of the process across a broad array of functions. In the past decade, the notion of Project Based CM has become increasingly popular. In fact, PMI have been quite explicit in their definition of project versus domain specific CM (PMI, 2007). This has become increasingly challenging for the project manager trying to maintain a high level of control over the ‘configuration items’ within his/her project. In such situations, it is hard to integrate the relevant policies and insure harmonization of the CM process across the project/domain divide. For many organizations, CM at project level is focussed solely on change control, which is only part of CM. It is believed that in organizations like aerospace and defence, a functionally centric (domain) view of CM is more appropriate which will not only ensure the implementation of a focussed set of CM guidelines but also minimizes the dilution of the practices across projects.

4.5.1.3. Lack of CM training across organizations (B_3). It is believed that lack of training is one of the core issues to any business process management (Da-Silva et al., 2012) and is considered a serious issue for the effective implementation CM process (Burgess et al., 2005; Fowler, 1996). On the other hand, professionals having CM certification/training understand the limitations of the CM process and play a key role in its overall implementation (Ali and Kidd, 2013). It is believed that CM should be part of the core skills training programme across organizations to ensure that individuals have a high level of understanding of the use and benefits of the CM process. Lack of training has remained an issue for most of the allied fields which could play a crucial part for organizational development and success.

4.5.1.4. Lack of authority to implement CM principles/policies (B_4). It is observed that project managers can undermine CM principles by not following a core CM process and believe that they can manage their projects without domain specific CM assistance (PMI, 2007). Often PM will manage change, for instance, through the governance of a project change board, not a domain specific CM change control board. In theory CM managers own the CM process but in reality they are mere custodians and have no say in the decision making process. It is a major concern since lack of authority to implement CM creates risk to poor quality processes and poor quality deliverables.

4.5.1.5. Implementation costs outweigh CM benefits (B_5). Research on cost versus benefit analysis – one of the weak areas in the limited CM literature – may answer many concerns including “implementation cost outweighs CM benefits”. It is a major issue since CM is often not realistically followed in companies because of the overall cost overhead related to the specialized CM process (Burgess et al., 2003) just like quality management was ignored (Bhat and Rajashekhar, 2009). The reason observed behind this perception is the lack of CM training and education across organizations where CM has not only neglected by academia but also by organizations which have limited the knowledge on CM benefits and its role in reducing product development time, increasing quality, and reducing cost.

4.5.1.6. Lack of recognition and underestimating the importance of CM at every level of the organization (B_6). The acceptance of ownership and commitment to CM principles are major concerns in organizations (Fowler, 1996). It is obvious to see lack of recognition and underestimating the importance of CM within organizations in the presence of lack of management support, lack of centralized CM function, and lack of authority to implement CM. It is believed that CM is just tolerated but not embraced since top management doesn’t understand its role while others believe that they can manage their products without its assistance. CM is only seen a necessary evil and has no importance within facilities until something really goes wrong.

4.5.1.7. Lack of career progression for CM professionals (B_7). Lack of career progression – linked with poor recognition of the process – is mainly linked again with education and training and is considered a major failing for developing CM as a process (Burgess et al., 2005). It is observed that retaining talented human resource; the major requirement for effective process implementation; is a hard task in fields having no career progression.

4.5.2. Group 2: Planning and process barriers

The planning and process barriers group constitutes of six barriers i.e. poorly defined CM requirements and process, lack of maintaining consistency in CM practices across projects, lack of flexibility in CM process, outdated CM process, lack of current CM plans, and lack of CM process across the lifecycle.

4.5.2.1. Poorly defined CM requirements and process (B_8). CM guidelines are not fully understood and implemented at different levels of organization. It is believed that the available standards are complex and lack explanation. It is hard to implement a successful CM process if the boundaries are vague, have an unclear role, and their benefits are not widely accepted. In such situations it is right to observe multiple issues e.g. inadequate workflow design, substantial mistakes in data interpretation, and cumbersome and voluminous change implementation methodologies.

4.5.2.2. Lack of maintaining consistency in CM practices across projects (B_9). Maintaining consistency in CM application is a major concern which is mainly caused by the lack of proper CM planning, lack of communication, lack of centralized body for the governance of CM, and lack of authority to implement the CM process. It is believed that organizations have little or no legislative requirements for CM and instead of having one generic CM process, projects tend to adopt a project specific configuration management practice often resulting in a diluted view of the process. Harmonization of the CM process which emphasizes on maintaining consistency in CM practices across organization (PMI, 2007) is a major issue in aerospace and defence industries.

4.5.2.3. Lack of flexibility in CM process (B_{10}). The research participants believe that CM policies are not effectively followed since they are quite rigid and inflexible, which irritates users. Lack of flexibility is considered a risk for overall CM effectiveness. It is observed that CM policies should be equally poised because when the process is too flexible and then tightened, it becomes difficult to implement due to different project requirements. The requirements of complex projects like the space shuttle cannot be matched with small development products e.g. ball point pens, hence CM process should never be too rigid and users may provide a room of flexibility to decide on CM requirements according to the nature of the products (Ali and Kidd, 2013).

4.5.2.4. Outdated CM process (B_{11}). The CM standards have remained unchanged for many years and possibly never aligned with other processes which are optimized over the years to cope with technological advancements. Many of these standards are either not explicit or detailed enough and need changes in line with new ideas and concepts. It is observed that some of the process standards give references to specific templates for CM which are never used.

4.5.2.5. Lack of current CM plans (B_{12}). CM planning is the backbone of CM process (Lyon, 2008) which builds on the foundation established by an enterprise for similar products (EIA-649, 2011) and plays an essential part in the success of projects with a major contribution in productivity and effectiveness (Sachs, 2009). Based on the outcome of this research, CM plans are often identified as unavailable/not effectively generated/not updated through-life; hence creating difficulty in the implementation of CM activities. The level of motivation of companies towards CM planning can be seen from the fact that 72% of the companies have CM plans where as only 41% of the companies refer to those plans (Burgess et al., 2003).

4.5.2.6. Lack of CM process across the lifecycle (B_{13}). The late involvement of CM in the project/product lifecycle is also considered a major concern in the effective implementation of the CM process. It is observed that CM practices are missing in the concept, allocation, and maintenance/modification phases of the projects which might be the aftermath of multiple uncertainties in the project life cycle as highlighted by Atkinson et al. (2006). Majority of the standards have no explicit CM guidelines related to maintenance/modification phase which might be a reason for its ignorance. In many contracts, historically, these phases of the lifecycle represented follow-on work.

4.5.3. Group 3: Implementation barriers

The third group of CM barriers is formed with the combination of six factors i.e. lack of CM awareness in customer world, lack of effective communication, lack of effective CM tools, lack of resources, lack of support from stakeholders, and extreme project pressures.

4.5.3.1. Lack of CM awareness in customer world (B_{14}). CM facilitates customers by ensuring their requirements throughout product-life-cycle and assuring product quality to achieve their objectives. With extensive knowledge proliferation and people's understanding of managing requirements, there is still a lack of CM awareness in the customer world. It is believed that many customers are unaware of the importance of CM which could ensure the development/production of quality products against their requirements.

4.5.3.2. Lack of effective communication (B_{15}). It is hard to deny the importance of communication in every field of life. Lack of communication is considered a major problem in processing engineering changes (Huang and Mak, 1999). About 40% of time in the implementation of configuration changes could be reduced through effective communication (Tavcar and Duhovnik, 2005; Wasmer et al., 2011) whereas two thirds of the changes could be prevented through better communication because failure in this could result in a number of changes through decisions on obsolete data (Jarratt et al., 2011).

4.5.3.3. Lack of effective CM tools (B_{16}). One of the most influential areas is the availability of appropriate software tools which has gained much attention over the last few years. These tools have increased individual capabilities in work and facilitated organizations with enhanced data and information (Cantamessa et al., 2012) but the majority of them are still not user friendly (Guess, 2006). It is believed that lack of CM knowledge of individuals involved in the design and development of these tools and lack of standardization of the CM practices are responsible for the uncertain behaviours of these tools in different environments. It is crucial to have a standardized body of knowledge to set an agreed CM boundary and come up with uniform practices at lowest levels of the process.

4.5.3.4. Lack of resources (B_{17}). Resource limitation is one of the major issues in the CM implementation (Gonzalez and Zaalouk, 1997) which is also highlighted a major concern in the implementation of other allied fields (e.g. Anthony and Desai, 2009; Bhat and Rajashekhar, 2009; Riege, 2005; Sebastianelli and Tamimi, 2003). The most obvious barrier in terms of resources for CM implementation is the lack of human resources which often ties in with lack of funds. It is observed that CM is always under resourced in comparison with design and development activities.

4.5.3.5. Lack of support from stakeholders (B_{18}). Support from stakeholders plays a leading role in the implementation of CM which is evident from its traditional role highlighted by Watts (2008, 2010) i.e. "CM is the communication bridge between design engineering and the rest of world". Lack of commitment severely affects the communication process among stakeholders and has a great effect on the implementation of CM process. It is also highlighted as a major obstacle by Huang and Mak (1999) that change management – an important part of the CM process – has not received the due importance and the kind of support from stakeholders.

4.5.3.6. Extreme project pressures (B_{19}). It is believed that many project managers don't adhere to domain centric CM process requirements and either bypass them or follow project specific variants of them to achieve their short-term objectives. It is believed that 'extreme project pressures' which is highlighted as a barrier is not supposed to be a barrier in the presence of a well defined and flexible CM process. It is a barrier only because the importance of CM is not understood which frequently causes failure to the process.

5. Research limitation and its implications for academics

There are a few limitations with this study which should be acknowledged for further research. Firstly, this study is limited to aerospace and defence industries which are both linked with high levels of understanding of CM and also with one of the author connections in these industries. Secondly, our target population were from aerospace and defence industries of Europe and USA which is a limitation by design in restricting the study to a particular region as well as its industry grouping.

The focus on aerospace and defence industries raises the related question of what is the current situation in commercial sectors. It is believed that commercial sectors have either limited understanding of CM as a holistic practice, or fragment it through several business processes. Further research could be done for commercial sectors to investigate the implementation status of CM, cost versus benefit analysis, factors that have limited the implementation of the process, and areas which can contribute in the effective implementation of the CM process.

6. Conclusions

This study was carried out to identify and prioritize barriers to effective implementation of a configuration management process in both aerospace and defence industries. A list of nineteen barriers is identified which is further extracted into three groups (managerial and organizational barriers, planning and process barriers, and implementation barriers) based on their inherent relationship to facilitate professionals in targeting specific areas for improvements. Emphasis is drawn in revealing any significant differences in the perceptions of CM practitioners on the basis of gender, academic qualification, CM experience, or types of organization. While configuration managers perceive the existence of these barriers in both aerospace and defence sectors, in general, the responses suggest that these barriers are more evident in the commercial aerospace sector. It is validated through the use of inferential statistics that significant difference is observed in the perception of CM professionals on the basis of the organization in which they work. These results are quite significant since CM is well understood in the defence sectors and is contractually mandated through the meeting of the required defence standards evoked by the customers.

This research contributes to existing knowledge by identifying critical barriers to CM application to facilitate CM practitioners in planning ahead and minimizing potential consequences. The research outcome is quite significant since it highlights obstacles related to areas such as management support, governance, training, principles and policies, planning, authority to implement, stakeholders support, communication, and resource requirements which are not only considered the most influential factors for the successful implementation of configuration management (e.g. Ali and Kidd, 2013) but also for other allied fields such as project management (e.g. Belassi and Tukel, 1996; Fortune and White, 2006), and knowledge management (e.g. Wong, 2005). This study should attract the attention of many organizations to in giving special importance to these factors which could in turn lead them to a more effective implementation of the CM process.

It is believed that several of these barriers have not only affected the organizational image of the process but have also impacted the implementation of the process over the years. These barriers require special attention since it is obvious that some of the factors which are believed to be the root cause for many other barriers may substantially affect the effective implementation of the CM function. It is observed that the delivery of effective training and education programmes across the organization will not only help to get the required support from top management but may also help to alleviate the lack of recognition and perceived importance of the CM process across the organization. Effective CM planning, on the other hand, may take control on other aspects like lack of maintaining consistency in CM practices across the projects and lack of flexibility in CM practices. Organizations need to pay special attention to these barriers, and target areas of concern in order to establish an action based strategy providing focussed, value added solutions.

There is a growing body of knowledge evolving in CM, with several new or revised standards having been, or about to be, delivered. This initiative will undoubtedly be slowed down if organizations cannot, or fail to, identify critical barriers prior to them attempting to meet the requirements of such documents. The study of Ali and Kidd (2013) provides baseline guidelines on process improvement methodologies in the form of a CM activity model. The study emphasized the need for understanding and documenting requirements based on CM methodologies defined in the latest international standard(s).

The outcome of this research is already influencing ongoing research in the group at University Manchester. A new study on the governance of CM across the supply chain will use the critical success factors and barriers from this study, and apply them in a different context down the supply chain tiers. Holistically, this will make a much needed step change in our understanding of how we manage CM in our projects and systems.

References

Ali, U., Kidd, C., 2012. Understanding the obstacles to configuration management success. 26th IPMA World Congress, 29–31 October 2012, Greece.

Ali, U., Kidd, C., 2013. Critical success factors for configuration management implementation. Industrial Management & Data Systems 113 (2), 250–264.

Antony, J., Desai, D.A., 2009. Assessing the status of six sigma implementation in the Indian industry: results from an exploratory empirical study. Management Research News 32 (5), 413–423.

Atkinson, R., Crawford, L., Ward, S., 2006. Fundamental uncertainties in projects and the scope of project management. International Journal of Project Management 24 (8), 687–698.

Bartholomew, D., Knott, M., Moustaki, I., 2011. Latent Variable Models and Factor Analysis, third ed. John Wiley & Sons Ltd., UK.

Belassi, W., Tukel, O.I., 1996. A new framework for determining critical success/failure factors in projects. International Journal of Project Management 14 (3), 141–151.

Bhat, K.S., Rajashekhar, J., 2009. An empirical study of barriers to TQM implementation in Indian industries. The TQM Journal 21 (3), 261–272.

Burgess, T.F., Byrne, K., Kidd, C., 2003. Making project status visible in complex aerospace projects. International Journal of Project Management 21 (4), 251–259.

Burgess, T.F., McKee, D., Kidd, C., 2005. Configuration management in the aerospace industry: a review of industry practice. International Journal of Operations and Production Management 25 (3–4), 290–301.

Cantamessa, M., Montagna, F., Neirotti, P., 2012. Understanding the organizational impact of PLM systems: evidence from an aerospace company. International Journal of Operations and Production Management 32 (2), 191–215.

Creswell, J.W., Clark, V.L.P., 2007. Designing and Conducting Mixed Methods Research. sage publications, Inc.

Da-Silva, L.A., Damian, I.P.M., De-Pádua, S.I.D., 2012. Process management tasks and barriers: functional to processes approach. Business Process Management Journal 18 (5), 762–776.

EIA-649, 2011. EIA-649, National Consensus Standard for Configuration Management. Electronic Industries Alliance.

Fortune, J., White, D., 2006. Framing of project critical success factors by a systems model. International Journal of Project Management 24 (1), 53–65.

Fowler, A., 1992. Models and applications of configuration management. OMEGA: International Journal of Management Science 21 (4), 425–431.

Fowler, A., 1996. Case experience of implementing configuration management in a UK shipbuilding organization. International Journal of Project Management 14 (4), 221–230.

Gonzalez, R., Zaalouk, M.G., 1997. Configuration Management — Crossing the Boundaries. Illinois Inst of Technology, Chicago IL, USA.

Guess, V.C., 2006. CMII for Business Process Infrastructure, 2nd ed. CMII Research Institute, Scottsdale, AZ (85261–4333).

Huang, G.Q., Mak, K.L., 1999. Current practices of engineering change management in UK manufacturing industries. International Journal of Operations and Production Management 19 (1), 21–37.

Hussey, J., Hussey, R., 1997. Business Research, A Practical Guide for Undergraduate and Postgraduate Students. Macmillan Press LTD.

Jankowicz, A.D., 2004. Business Research Projects. Thomson Learning Publishers, London.

Jarratt, T.A.W., Eckert, C.M., Caldwell, N.N.M., Clarkson, P.J., 2011. Engineering change: an overview and perspective on the literatur. Research in Engineering Design 22 (2), 103–124.

Kidd, C., Burgess, T.F., 2007. Managing configurations and data for effective project management. In: Morriss, Peter W.G., Pinto, Jeffrey K. (Eds.), The Wiley Guide to Managing Projects. John Wiley & Sons, Inc., pp. 498–513.

Lyon, D.D., 2008. Practical CM III: Best Configuration Management Practices for the 21st Century, second ed. Raven publishing company.

Motulsky, H., 1995. Intuitive Biostatistics, first ed. Oxford University Press Inc.

Niazi, M., Wilson, D., Zowghi, D., 2005. A maturity model for the implementation of software process improvement: an empirical study. Journal of Systems and Software 74 (2), 155–172.

Norusis, M., 2008. SPSS 16.0, Guide to Data Analysis, second ed. Prentice Hall Press, USA.

Pallant, J., 2010. SPSS Survival Manual, 4th ed. Open University Press, McGraw-Hill Education, England.

PMI, 2007. Practice Standard for Project Configuration Management. Project Management Institute Inc., Newtown Square, Pennsylvania, USA.

Riege, A., 2005. Three-dozen knowledge-sharing barriers managers must consider. Journal of Knowledge Management 9 (3), 18–35.

Sachs, L., 2009. Personality Matters — CM Planning or Planning for CM. http://www.cmcrossroads.com/cm-journal-articles (downloaded on 1st September, 2011).

Sage, A.P., Rouse, W.B., 2009. Hand Book of System Engineering and Management, second ed. John Wiley & Sons Inc., New Jersey.

Samaras, T.T., 1988. Configuration Management Desk Book, A Modern Approach for Assuring that Products Meet Customer Requirements. Advanced Applications Consultants Inc., North Babylon, New York.

Sebastianelli, R., Tamimi, N., 2003. Understanding the obstacles to TQM success. Quality Management Journal 10 (3), 45.

Sun, P.Y.-T., Scott, J.L., 2006. An investigation of barriers to knowledge transfer. Journal of Knowledge Management 9 (2), 75–90.

Tabachnick, B.G., Fidell, L.S., 2001. Using Multivariate Statistics, 4th ed. HarperCollins, New York.

Tavcar, J., Duhovnik, J., 2005. Engineering change management in individual and mass production. Robotics and Computer-Integrated Manufacturing 21 (3), 205–215.

Team, C.P., 2006. CMMI for Development. (Version 1.2) Software Engineering Institute, Carnegie Millon University.

Turner, J.R., 1997. The Handbook of Project-Based Management: Improving the Processes for Achieving Strategic Objectives, second ed. McGRAW-HILL Publishing, Berkshire, England.

Wasmer, A., Staub, G., Vroom, R.W., 2011. An industry approach to shared, cross-organisational engineering change handling — the road towards standards for product data processing. Computer-Aided Design 43 (5), 533–545.

Watts, F.B., 2008. Engineering Documentation Control Handbook, Configuration Management, third ed. William Andrew Inc., 13 Eaton Avenue Norwich, NY 13815.

Watts, F.B., 2010. Configuration Management Metrices, Product Lifecycle and Engineering Documentation Control Measurements, first ed. Elsevier Inc., Linacre House, Jordan Hill, Oxford OX2 8DP, UK.

Wong, K.Y., 2005. Critical success factors for implementing knowledge management in small and medium enterprises. Industrial Management and Data Systems 105 (3), 261–279.

Wu, W.H., Fang, L.C., Lin, T.H., Yeh, S.C., Ho, C.F., 2012. A novel CMII-based engineering change management framework: an example in Taiwan's motorcycle industry. IEEE Transactions on Engineering Management 59 (3), 494–505.

Yeo, K.T., Ren, Y., 2008. Risk management capability maturity model for complex product systems (CoPS) projects. Systems Engineering 12 (4), 2009.