Conquering Configuration Management Conundrum

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C. Suresh kumar
Indian Space Research organization
(c_sureshkumar@lpsc.gov.in)

Suresh Subramoniam
Kerala University
(sureshsubramoniam@gmail.com)

Configuration management (CM) is a tool for product data management. Over a period of time the nature and function of CM has changed to an active component of product development and applied throughout the product lifecycle. The initial applications of CM is seen in complex military projects and aerospace programs followed by the evolution of standards and application of CM in other projects too. The CM application in present day product development, especially R&D projects, needs better understanding to resolve complex issues related to continuous changes in requirements, technology, environment or relevance of the project. Change management is the dynamic component in CM which involves decision making to optimize system performance. An attempt is made in this paper to formulate the decision making problem in CM as a decision matrix. The feasibility of obtaining an analytical solution to this problem using Multi-Criteria Decision Making (MCDM) methods is explored. Possible solutions to resolve challenges faced during CM implementation, and constraints are also briefly discussed here.

1. Introduction

The nature and relevance of Configuration Management (CM) has changed a lot since its introduction in the 1950's.CM is developed to resolve the issues in complex military projects and aerospace programs, wherein the product development starts with a vague (technically) definition and components undergo a lot of change as part of system development. The situation is similar in most of the Research and Development (R&D) projects. Now, Configuration management is applied throughout the life cycle of the product, viz. development, production, deployment, operation and disposal [1]. The CM application in R&D projects needs better understanding to resolve complex issues related to continuous change in requirements, technology, environment or relevance of the project. It is high time to refine or evolve an analytical approach to solve decision making problem in CM.

The decision making problem in CM is to select the best alternative to substitute an existing component, so that the overall system performance is optimized. Often this is done in a subjective manner. An attempt is made in this paper to formulate the decision making problem in CM as a decision matrix. The feasibility of solving this problem, using Multi-Criteria Decision Making (MCDM) methods, is also explored. The issues associated with identification of criteria and difficulty in expressing all the criteria in the same unit is also highlighted. In addition, the challenges faced during CM implementation, possible solutions and constraints form the topic of discussion here.

2. Configuration Management: An Overview

Configuration Management (CM) originated in 1950's as part of product management system, when the product complexity was in the increasing trend. The concept is developed in military systems and other defence oriented (aerospace) areas. As a result, a good number of standards are generated on how to practice CM.

Configuration management is defined as "Configuration Management is a management discipline that applies technical and administrative direction to the development, production and support lifecycle of a configuration item. The discipline is applicable to hardware, systems, processed materials, services and related technical documentation. Configuration management is an integral part of life cycle management" [2].

Over a period of time the scope of CM has increased in product realization and in the last two decades the concept of CM found its place throughout the product life cycle. Systematic procedure for the application of CM is already developed and available in almost all CM standards.

Generally, CM is applied as a passive mechanism which gives high priority for systematic recording and storage of data pertaining to a product during its evolution. This passive mode was sufficient to meet the CM requirements when the product development was taken up by a single agency in a sequential manner. In the present world of Concurrent Engineering (CE), configuration management needs to be redefined as an active data analysis and decision making system rather than a passive data recording and storage system.

Though, CM is introduced for products which are hardware oriented, of late the software industry has benefited a lot from the configuration management concept. This is mainly due to the modularity in software development. The subsystems (modules) are designed and developed by different System Development Agencies (SDA's) and this necessitated centralized control over the design, especially the interfaces (both physical and functional). CM takes up this role and it does the configuration control on an integrated level.

CM also plays an important role in streamlining the product life cycle. Agile Configuration Management is proposed as an approach to simplify and stream line the procedure to carry out the CM requirements [4] so that it gets aligned with the overall product development activities. Over a period of time, the CM approach is elevated to a management process to establish, monitor and achieve consistency of a product's physical and functional requirements with its design and operational information throughout its life.

The MIL-STD-973 (1992) [5] defined configuration management activities as:

Identify and document functional and physical characteristics of Configuration Items(CIs);

a. Control charges to a CI and its related documentation;
b. Record and report information needed to manage CI's effectively;
c. Audit CI's to verify conformance.

As a product data management system, CM needs to follow the above activities systematically to avoid losing track of product development and also to evaluate the "as designed" and "as realized" conditions of a product. It is obvious that the role of CM was passive in product development and generally, it was treated as a subset of quality control activities.

In 1998 when ANSI/EIA 649 [6] National consensus standard is written to replace MIL-STD-973, CM got identified as an essential part of product development with better clarity to CM activities. The role of CM as per ANSI/EIA-649 is to maintain consistency between, the product definition and product configuration, and, the configuration management records. In this definition CM transformed as an 'active system' to form part of successful product development. As a consequence, the change management and its importance got emphasized. The economic aspect of product development is one important consideration in the CM process. Maintaining consistency as demanded in the definition is a big challenge when everything is in a state of change. Unless, CM is remodelled as a dynamic system with continuous interaction in product development this cannot be achieved. The success of CM application in the product life cycle management is to be viewed in this scenario. Studies indicate that proper implementation of CM achieves reduction in time for design, development and production of the system [7].

3. Product Life Cycle and Changes

A typical project by definition is constrained with cost, schedule and quality (triple constraints). The fundamental requirement of achieving project goal, satisfying the constraints is firm planning and executing the plan as defined, originally. Any change in the due course, may lead to the violation of any one of the constraints. Example ranges from construction of a house to multi-billion establishments like oil refineries, Airports and more.

A deviation from this classical project structure is necessitated even in early days (though very limited examples) due to reasons which are beyond the scope of thinking at the planning stage. In those days, these deviations got treated as exceptions. Let us consider the most ambitious and successful project in the recent human history, the Moon Mission, charted out by US President John F. Kennedy "landing a man on the Moon and returning him safely to the Earth" by the end of the 1960s, which he proposed on a May 25, 1961. When he set this goal, neither technology nor infrastructure nor expertise exists with any certainty. The project has under gone plenty of changes during the development. In fact, the systems are evolved through a series of iterations, yet it achieved the goal. One may think that this is an exceptional case for that point of time, but now this is the order of the day. In high-tech product development, ranging from rocket systems to mobile phones with fast changes in requirements, the design rules, process, materials, technology, environmental requirements and the like undergoes continuous change.

Now, let us consider the reasons for change. Peter F Drucker [8] explained the following points as the reasons for change in any system.

a. Process needs
b. Change in industry and market structure
c. Change in demographics
d. Change in meaning and perceptions
e. New knowledge

Every industry which is involved in the product development faces these problems in an increasing manner. All the reasons that can be quoted for change can be classified under any one of the above five. The original requirements keep on changing due to different reasons and these changes in requirements need to be controlled and documented throughout the life cycle. Figure 1 illustrates the evolution of requirements.

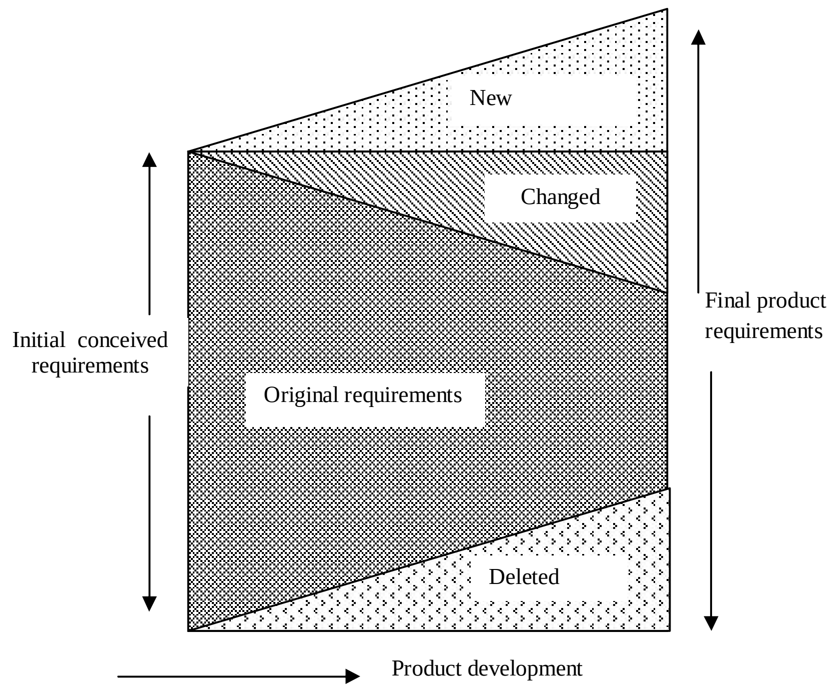

Figure 1 *Evolution of requirements [9]*

4. Configuration Management and Importance to Life Cycle

Notwithstanding the changes during the product life cycle, the basic constraints should be honoured to ensure project success. CM can play a major role in achieving this diverse objective. The present day design concepts like Concurrent Engineering (CE) or modularity aims to achieve optimal subsystem, but this local optimum may not yield a global optimum at product level. Every subsystem definition need to be oriented and controlled during the evolution so that it does not lose its integrity with other subsystems in terms of performance, interface (both physical and functional) quality, schedule or cost as the case may be. The relevance of CM in product life cycle is identified here. When a change is proposed in one subsystem due to any of the reasons as explained in the last section, the suitability of this change is to be assessed on a platform different from that of what the designer uses. This role is presently assigned to the CM team.

As the project progresses the subsystems are getting firmed up in design, process, material, testing and so on. At that point of time, change in another subsystem need to be viewed in a different perspective. Though the change may be positive in one of the constraints, it may have negative impact on another. The constraints on yet another subsystem may have a different impact level. This is the situation that leads to subjectivity in decision making in CM. It is observed that as the complexity of the system is increased the changes occurred during development is increased in exponential manner.

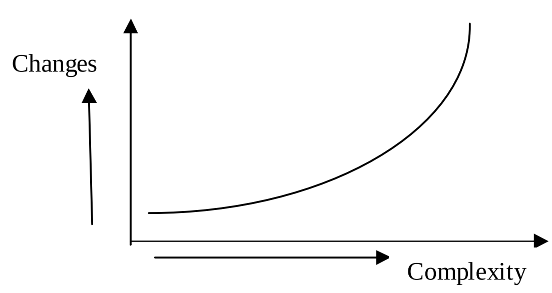

Figure 2 *Changes Vs Complexity*

In this scenario CM needs to act as a facilitator than as a passive onlooker and it needs to interact on a continuous manner during the product life cycle.

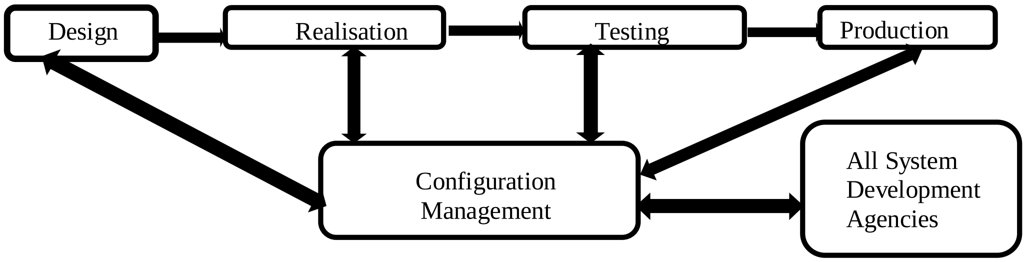

Figure 3 *CM as A Facilitator*

5. Role of CM and Challenges

The basic functions of CM as defined in the standards or hand books remains unchanged, but the role changes. The change management becomes more and more relevant. In fact, in high-tech systems like aerospace systems development, the final authorization for a design to go for metal cutting is given by a CM team. In view of this CM needs a better systematic approach in dealing with changes and its management. At each stage of product development, the changes need to be discussed and accepted /rejected based on different criteria. At present this change management is practiced on a subjective manner. It needs a lot of expertise; even then bias cannot be eliminated. Research need to be focused on eliminating the subjectivity to a great extent so that the decision can be made with firm backup of analysis.

CM has a greater role in product development in terms of controlling changes in different phases of product development. However, it does not have any design responsibility. Though CM is aimed to improve the product performance, it does not involve in any of the quality control process. This intricate nature of CM makes management to think it as a complex system to be implemented. Often this led to identify CM as part of quality assurance [10] or integrated with project management [11]. However, slowly CM is evolving as an independent function and tries to achieve minimum difference between what is aimed and what is achieved when the system evolves through continuous changes.

A comprehensive review of CM practiced in the aerospace industry [12] indicates that the below par performance of CM in certain industry is due to the reason that the simple practice of standard CM solutions cannot achieve a high performance CM. The challenges in successful CM implementation is discussed elaborately in a white paper on CM[13].

The product configuration identification or base-lining and recording of change history are not an easy task. This challenge can be tackled by preparing a detailed system break down structure (SBS) to identify all Configuration Controlled Items (CCI) and then base-lining each of them using requirement documents, design documents and interface documents. The success of base-lining depends on the completeness of the above documents. Tracking of changes will become effective when a proper Configuration Control Data Base is established. Above all a dedicated CM team with properly identified position in the organisation structure is a must to have effective CM functioning.

Defining and establishing a reliable change process and change control mechanism in the fast changing environment with an integrated approach is difficult to achieve. This challenge can overcome only with the implementation of an effective change control system. The system should have the capability to take decisions on change proposals in an objective manner and a procedure to implement the changes throughout the system wherever it is applicable. Unlike other functions of CM, change control is dynamic in nature. A change in one system aimed to improve its performance may have an adverse effect in another system. Also yet another alternative may give a better performance when the overall system is considered. The change control system should be able to select the best suited change among the alternates available. The attributes to be considered while taking the decision are very critical. Till now, in CM this decision making is done in a subjective approach, wherein decision is taken by experts based on the available information. This subjectivity can cause bias and may affect the overall system performance. To eliminate this subjectivity a new approach is suggested in later part of this paper.

Extending CM to partners and at the same time protecting the interest of the industry as well as difficulty in concurrently addressing engineering and manufacturing requirements is yet another challenge. The integration of partners into CM process is a strategic decision and needs strong support from top management. Also the CM process is to be redefined to take care of change requirements from partners. The fundamental requirement of CM is to resolve the contradicting change requirements from different system development agencies involved throughout the product life cycle. A clear end effective change control process with frequent auditing can successfully tackle this issue.

6. Formulation of CM Problem as MCDM

To resolve the subjectivity issue in CM decision making one need to formulate this as an analytical problem. The analytical formulation requires identifying all possible alternatives when a change is proposed. Then each of these alternatives is to be evaluated against certain quantifiable criteria. Once this is done the problem can be solved using Multi Criteria Decision Making **(**MCDM) method. It is an analytical process in which alternatives and attributes are represented as rows and columns of a matrix (decision matrix) with each element a_{ij} represents the value of j^{th} parameter (criteria) for i^{th} alternative.

Three main steps in using MCDM are:

a. Determining the relevant criteria
b. Allocating weights (relative importance) to each criteria

c. Process the decision matrix to determine the ranking of each alternative.

The parameters (criteria) are to be identified carefully so that they have sufficient sensitivity in decision making [14]. Weight for each parameter is to be fixed. Once this is done the problem became amenable for analytical approach. Multi-Criteria Decision Making (MCDM) is best suited for this situation.

Here, the alternatives are the candidates for changing an existing component/system. While doing an analysis the existing component/system will also form as one of the alternatives unless otherwise it is proved that the existing component cannot serve the indented function. Hence, at any point of time of decision making at least two alternatives is available. The parameters are the attributes that make an alternative to stand as a candidate. The finalisation of these parameters is an involved process. Generally, one can consider the three major parameters viz. cost, schedule and compatibility. However, the definition of cost and schedule may not be as straight as in project management. The definition of these parameters needs elaborate discussion. Once the parameters are finalized the weight assigned with each parameter is to be established. Definitely, all parameters do not have equal weight in decision making and the necessary condition is that sum of all weights is equal to unity. Then the decision matrix is as given below:

Parameters (criteria)

Alternative

	P_1	P_2	P_3	....	P_n
	W_1	W_2	W_3	....	W_n
A_1	a_{11}	a_{12}	a_{13}	....	a_{1n}
A_2	a_{21}	a_{22}	a_{23}	....	a_{2n}
A_3	a_{31}	a_{32}	a_{33}	....	a_{3n}
.	.	.	.	....	.
.	.	.	.	....	.
A_m	a_{m1}	a_{m2}	a_{m3}	....	a_{mn}

Figure 4 *Decision Matrix*

Where A_1, A_2, A_3… are the alternatives: P_1, P_2, P_3…..are the parameters and W_1, W_2, W_3….are the weights associated with each parameter. An alternative with highest ranking, derived by MCDM analysis, is to be selected to replace the existing one. The ranking of all the available alternates is also an output of MCDM analysis. The MCDM techniques like Weighted Sum Model (WSM), Weighted Product Model (WPM) or Analytic Hierarchy Process (AHP) can be tried to solve the problem. The advantages of each of these method and issues associated with are explained [14].

WSM can be used only if the units of measure of all parameters are the same. Definitely, it may not be so in real life. AHP analysis is slightly computational intensive. For all practical purposes, WPM is sufficient to elicit the best alternative.

7. Conclusion

CM is an essential component of product life cycle data management system. CM begins with subsystems identification (CCI), change control, accounting and auditing. The role of CM is continuously changing since its introduction and now it plays a vital role in achieving project goals. This is evident from the number of standards evolved and the frequent updating on this. CM is identified as the management process, which keeps the product development on target in the dynamic environment.

In order to equip CM with analytical tools, than procedural tools, a lot of research is to be done. A new approach to resolve the change management issue in CM is proposed in this study. The selection of best alternative, when a proposal comes for changing an existing component/system is formulated as a decision matrix. The feasibility of solving this problem using MCDM is also established. The selection of appropriate parameters (criteria) is an involved activity. The issues associated with unit of measurement of criteria also need further research. The proposed analytical approach can reduce to a great extent the subjectivity of decision making in CM.

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