Formalizing the practice of Configuration Management in the MTR

F. Fabbian & K. Lam

Mass Transit Railway Corporation Limited, Hong Kong.

Abstract

Configuration Management (CM) includes four main activities: Configuration Identification, Change Control, Status Accounting and Configuration Audits. During the construction or maintenance of a system, we usually arrange information in a structured manner and put identifying codes on objects or documents (i.e. Configuration Identification). We authorize and manage changes to the system (i.e. Change Control). We report the status of a system and previous changes carried out on the system (i.e. Status Accounting). We carry out audits to check if works are carried out according to the procedures (i.e. Configuration Audit). Configuration management activities are carried out but it is a practice that is seldom formalized. This paper discuss the organization, software tools used, approach and development process that leads to the successful implementation of CM.

1 Introduction

1.1 Development of Configuration Management

When the missiles were being developed in the 1950, the successful prototypes were unable to be reproduced because critical last minute changes were not documented. In 1964, NASA published the first configuration management manual for the Apollo program to address the safety consideration of the manned mission [1]. The whole concept of CM focuses on preventing erosion of functionality and safety of a product.

Configuration management (CM) is a management discipline and a set of processes to ensure effective asset management and change control to a product during its life cycle. Classical CM emphasis its disciplined approach and surveillance aspects of CM and downplays, in some cases ignores, the technical aspects of CM, it was also administrative and labor intensive. With the evolution
of CM tool technology, the latest practice requires less clerical effort and reinforces the belief that CM is beneficial and that it is part of the solution, not part of the problem.

Although Configuration Management is not specified in ISO 9001, it is one of the Key Process Areas in Level 2 of the Capability Maturity Model [2] developed by the Software Engineering Institute. It is an important function to achieve the Repeatable Level defined in CMM and essential to the successful completion of software development projects.

While CM is developed from NASA and used extensively managing spare parts in the hardware industry such as automotive industry, it is more important for the software industry to adopt CM. Incorrect hardware can usually be identified by some of its characteristics. However different versions of old software or information may exists at the same time. Moreover, improper version of software may remain undetected until major system-wide failure occurs. It was confirmed in a recent MTRCL survey that all successful companies in UITP have CM in place.

1.2 Introduction to MTRCL

The Mass Transit Railway (MTR) in Hong Kong was constructed through the most densely populated area of the territory. The Urban Lines system consists of three lines and a total of 38 stations, 28 of which are underground. The overall route length is 43.2km, with trains operating at a maximum speed of 80 km/hour. The average waiting time for trains is less than 2 minutes during peak hours. The MTR carries over 2.2 million passengers everyday, making it one of the most highly utilized urban metros in the world.

The recently opened Airport Express Railway is a seven-station, 34-kilometre line completed in June 1998. Two new services are provided: the Airport Express Line (AEL) and the Tung Chung Line (TCL). The AEL travels at a speed of 135 km/hour and transport passengers from Hong Kong Station in the Central business district to the new airport in 23 minutes with high-quality business-class style seating. The TCL provides much-needed relief to the congestion on the Nathan Road corridor as well as establishes the first commuter railway link between Lantau Island and Hong Kong Island.

With the advance of technology, systems have become very complex and interconnected to achieve the desired productivity required. System failures usually lead to total disruption of services and therefore are less tolerable. Other issues such as frequent changes in system requirement, company reorganization, increased use of contractors, use of more software, increase in interfaces between sub-systems, increased number of changes required and the chance of major disruptions. Improvement in accountability, reproducibility, traceability and coordination is required to ensure the reliability of complex systems.

MTRCL is neither a system developer nor an IT company, most of the software based systems were supplied by contractors. MTRC is only responsible to operate and maintain these systems after hand-over from the contractors. Its expertise falls on the maintenance side and it is not surprising that technical staff do not have sufficient understanding of CM. Although a departmental procedure
was in place for configuration management [4], the degree of implementation on
different systems varies.

MTRCL decided to formalize and rollout CM in the engineering systems in
late 1999. A working group was setup to lead the process of applying CM to 123
software systems used in the operation of the railway. There are some common
characteristics of these systems, the design complexity is high and they are
software intensive. Substantial changes to the systems are required from time to
time. CM is an important element on the construction and maintenance of
software systems.

1.3 A Complete Concept of Configuration Management

There is a lot of international literature on CM, and standards were developed by
NASA, IEEE and US Department of Defence. Based on ISO 10007:1995(E) [3],
CM is said to be complete if and only if it includes configuration identification,
configuration control, status accounting and configuration audit.

1.3.1 Configuration Identification

Configuration identification defines what types of item require CM. A method
shall be developed to identify and collect the items in a structured way. An
unique naming and versioning convention shall be designed to identify each
item.

1.3.2 Configuration Control

Configuration control is a system to govern the changes to configuration items. It
defines the sequence of work flow, input requirements to each control process
and the quality of the deliverables. It also describes how each control process
would change the inputs into the deliverables. A typical configuration control
process starts from change request, to evaluation, approval, development, testing
and installation.

1.3.3 Status accounting

Status accounting is the recording and the reporting of the configuration data of a
product (or a system) under management. The data captures all the history of
changes to a product, and together with the system baseline, the entire system
can be re-constructed whenever necessary. The configuration data and status can
also be used to reveal the effectiveness of the CM and form the basis for process
improvement.

1.3.4 Configuration Audit

There are 3 types of configuration audits, functional, physical and external audit.
1. Functional configuration audit authenticates the actual performance of a
configuration item and the compliance to the requirement specifications. It is
accomplished by evaluating the test methods, procedures, reports and other
engineering and design documentation. Functional audit is performed by
internal CM practitioners or system owners, and is usually completed before
factory acceptance test and it forms part of a phase ending review.
2. Physical configuration audit is a formal examination to the as-built version of a configuration item (CI) against the baselined technical documentation defining the CI. It ensures all the required changes are included in the as-built version. Same as functional configuration audit, this is executed by internal CM practitioners or system owners, and is usually completed before factory acceptance test and it forms part of a phase ending review.

3. External audit is a formal evaluation of the configuration management process. It authenticates the organization, CM procedures and all documentation against the configuration management plan. It is performed by independent party (can be in house or external) at any point of the CM life cycle.

1.4 Benefits of CM

The benefit of CM is listed as follows:

1. Better asset management – A complete picture of configuration items is available to enhance the management of the intellectual asset.

2. Improve efficiency – Consistent and easy to use naming and numbering system enhance the efficiency in locating and working with the information required.

3. Increase accountability – The roles and responsibility of each member are spell out clearly and there shall be no confusion as to who’s responsibility for what.

4. Improve communication within team members – The storing and retrieval of configuration item ensure the latest information is available for use.

5. Better project/vendor control - Unique and consistent version control of configuration items prevents placing incorrect order, avoid modifying a bug-free software module or install a non up-to-date version item.

6. Restrain the introduction of non-essential changes – The management practice also shows the evolution of the software system through the development and maintenance.

7. Avoid use of out-of-date information – Latest and approved version of information is always available. The use of out-of-date information during project development can be avoided.

8. Reduced software problems - Software problems are documented for future development reference. This serves as very useful knowledge base to minimize the risk of producing bugs.

9. Enhance auditability - Improve transparency and allow process improvement easily. Audit trails are captured to reflect all CM activities.

1.5 Necessary evil

While there are a lot of benefits in implementing CM, it is usually done in an ad hoc or fragmented manner. This is because the introduction of a disciplined and change management process can be viewed as a hindrance by most stakeholders involved in the process. They will be impacted by immediate addition of administrative workload before the benefits can be seen.
As the introduction of CM to an organization is very similar to the introduction of a quality system, successful introduction of CM requires all the success factors that is required to implement a quality management system. They are senior management support, proper organization structure, careful planning and effective implementation process, supported by tools, training and promotions. Therefore CM shall be carefully considered and justified with business case before full commitment to the implementation.

2 Status of CM before formalization

Before a detail action plan was prepared, a survey was conducted in March 2000 for 50 of the MTRCL systems to gauge the present coverage and implementations.

2.1 CM Survey result in MTRCL

The result shows a wide spread in uptake and conformance to the departmental procedure, “System Configuration Management and Change Control”. Major findings include:

1. Unclear roles and responsibilities because of the recent evolution of station base maintenance in URL.
2. Most of the staff acknowledges the need to manage the configuration of software and hardware but no systematic approach was developed to handle CM.
3. Master lists of configuration items are missing.
4. Different groups use different naming and versioning scheme to identify configuration items. Although this is not a problem, most of the schemes are not documented.
5. There is little understanding of the concept of “baseline” and this explains why not many people maintain baseline documents.
6. Not many software system have setup and document a formal change control process although they are in place.
7. For most in-house CM activities that are taking place, no CM tool is used. A paper based system exists with a manual work flow.

The above findings suggest that there exist great variance in the compliance on the departmental procedure. Different groups may have different work practices to take care of CM. All in-house CM practitioners are encouraged to deploy the CM tool to capture all the configuration items and reinforce a systematic change control process, making the system configuration more auditable.

2.2 Popular Misconceptions about Configuration Management

Some people believe that configuration management is all about keeping records to show the versions of hardware and software of a system, or the location of these items. The others just think that CM is a documentation system to record all the information about a system. Furthermore, change control and version control are considered to be the same thing.
As CM shall contain technical and organizational activities that include configuration identification, configuration control, configuration status accounting and audits, it is not merely a version control or a documentation system.

CM also means a set of techniques to define, communicate and control the evolution of a product or system through its concept, development, implementation, maintenance and operation phases.

CM identifies in detail the total configuration of a product or a system. This include all hardware, software, firmware, document, drawings, organization structure, work practices, and the complete supplies chain at any given time of a product cycle. Together with the change history applied to the system, the complete system can be re-constructed whenever necessary.

3 CM Implementation

Back in the 3rd quarter of 1999, a briefing paper titled, “Configuration Management System for Operation Division” was approved. The Software Engineering team took the lead to implement configuration management within Operations Division. The team adopted a management approach that addresses the organization, method and tools needed to realize CM.

3.1 CM organization

Figure 1 shows the CM organization. The Software Management Steering Committee oversees and produces overall software engineering policies. The Configuration Control Working Group is a steering group responsible for managing the overall rollout of CM on all the targetted systems. It provides management and decision making for the CM rollout by the Configuration Teams (CT), coordinates, monitors and reviews progress achieved by the CT’s in the implementation of CM.

![CM Organization Diagram](image-url)
The Configuration Board is an approval body, and comprises representatives for the Designer, Implementor, Maintainer and/or Electronic Workshop. The Configuration Team, typically staff of the CB members, is responsible for the hands on implementation of CM for the system. For each system, a CT is required to be setup. All members sit at the regular meeting to review and monitor the all the CM activities progress throughout the configuration management cycle of the system. The CT is also required to produce a configuration management plan to describe the roles and responsibilities, method of configuration item identification, change control procedures, status accounting and audit.

The members of the Configuration Control Working Group consist of representatives from various departments. They were supported by the Software Engineering Team who provided the expertise and drive the implementation of CM.

The role of champion and in-house skill in CM is very import to successful implementation of CM [6]. The Software Engineering Team updates the departmental procedures on CM, prepare sample CM plan documents for CTs to follows, prepares the implementation schedule and provide initial assistance to each CTs during their startup.

3.2 Methods

The implementation covers 75 URL and nearly 50 LAR control systems. A CM framework was developed by the Software Engineering Team to assist individual engineering sections to establish CM within their own groups. This framework includes setting up configuration team, production of departmental procedures, provision of a configuration management plan template as well as deployment of a CM tool. The software engineering team plays the role as advisor and technical support to all the CM practitioners to build up an effective CM system.

A program was developed based on a set of criteria. Priority was set by assessing the following criteria:
1. Frequency of changes required
2. Business impact of the system
3. Existing CM procedure in place

3.3 Use of CM tools

Software CM tools are available in the market. There is no single best tool. In addition to the hardware and software platform restrictions, other factors that shall also be considered including the IT strategy, range and type of projects undertaken, volume of changes for bug-fix and enhancements, match of functionality of tool and requirement and support provided by the suppliers.

Although the use of CM tool is not essential on the implementation of CM, it facilitates standardization of the implementation. MTRCL had chosen Pollytron Version Control System (PVCS) base on the cost-benefit analysis base on a set of criteria developed [5].
Most CM tools provide standard features such as versioning, code comparison, impact analysis, customizing workflow etc. Among various features of the tool, web interface is considered one of the important elements in choosing a CM tool. MTRCL experienced difficulties on installing client software on user workstations. The use of web interface removes such problems.

### 3.4 CM Rollout Process
For each individual system or logical group of systems, the strategy for CM rollout was as follows:
1. Establish a Configuration Board and Configuration Team (2 weeks).
2. Produce a dedicated CM plan (6 weeks).
3. Identify the configuration items (including software, hardware, firmware, documentation) (4 weeks).
4. Establish a change control process/workflow (3 weeks).
5. Customise PVCS tool (1 week)
6. Install PVCS client software on to the users' PC's (2 weeks).
7. Conduct general CM training (1 day)
8. Conduct user training, as required (1 day).
9. Transfer configuration items, workflow process to PVCS (1 week).
10. Implement CM Plan for change control, status accounting and audit (ongoing).

A typical CM rollout for a single system takes 3 months.

### 3.5 Configuration Audits
Audits are essential to ensure that quality functions such as CM are carried out properly. 4 external and 2 internal audits were conducted and findings can be summarised as being combinations of the followings:
1. Incomplete CM Plan
2. Incomplete identification of Configuration Items eg hardware missing
3. Incomplete change control procedures
4. Errors in configuration records
5. Functional/Physical Audit is not being conducted

For the contractors staff, this was the first time they have attempted to implement CM. While corporate CM procedure existed, the work was not to the individual involved.

### 3.6 Issues on Implementing CM

#### 3.6.1 Understanding CM
The greatest barrier to overcome when introducing CM is to change the people's perception on CM. People may perceive the CM model as intrusive, and have little understanding of the disadvantages of not following configuration management practices. To put CM on the road to success, the first thing to do is to promote the awareness of CM.
3.6.2 Managing Changes
Adoption of CM could be interpreted as changing existing work practice and working culture. Resistance to change is normally the first reaction and not until various rounds of explanation and debates, people begin to accept and admit the essence of CM.

Although a lot of selling of CM has been done and commitment was obtained at senior management level, insufficient internal communication within sections also slows down the implementation progress. This is a communication problem among different internal groups. More appreciation workshops are recommended to promote CM within an organization.

3.6.3 Resources
MTRCL is re-organizing to streamline the corporate structure and improve its business efficiency. Some staff have been relocated and the rest have taken up more works than before. Resources become the basic problem to every group. What we could do is to make good use of the resources that we currently have, prioritize the urgency of systems which require CM, and kick off the CM program to cover those urgent systems in order to prevent loss of expertise.

3.6.4 Clarifying Roles and Responsibilities
CM could not be successful if the roles and responsibilities are not clearly defined. The evolving station based maintenance organization has created uncertainty in roles and responsibilities, and in turn caused delay to the implementation program. On the other hand, the rollout of CM assisted in speeding up the clarification of roles and responsibilities in the new organization. The configuration board members for each system has to agree and document their roles and responsibilities in a CM plan.

3.6.5 Identifying the pilot project
A big bang approach to implement a new tool on all systems is extremely difficult to manage and usually resulted in failure. A phased approach is always recommended. Therefore choosing the pilot project properly is very important. The project shall be able to represent the size and complexity of most of the systems in general with short duration so that results can be evaluated quickly and the benefits applied to other systems.

3.7 New Projects
The use of CM existed on all procurement contracts where system development is required. However the degree of use may be different on various contracts depending on the interpretation of the contractors. The CM clauses were strengthened in the General Specification of the contract documents so that the requirements are clearly listed.

A template is also setup for the project managers to use. The template listed the type of configuration items required by MTRCL when the project is handed over. This also assisted the contractor to identify and assemble the documents and software code required by MTRCL to maintain the system.
4 Conclusion

The implementation of CM is completed for all existing software systems in MTRCL. At the beginning, there were problems like re-organization, insufficient awareness and misconceptions of CM. The best way to overcome these entry barriers is through communication. Besides setting up configuration teams for each software system, a series of briefing sessions, training and workshops are held to communicate with all CM practitioners. At the end of the day, rather than just a CM system, it will also be an ideal and auditable asset management tool that manages the intellectual asset of MTRCL.

References