NORWEGIAN PROJECT MANAGEMENT PRINCIPLES APPLIED IN THE JURONG ROCK CAVERN PROJECT

FINN FAGERVIK[1], PETTER PLASSBAK[1] and TEO TIONG YONG[2]

[1] *Sintef-Tritech-Multiconsult (STM) Consortium, Singapore*
E-mail:ff@multiconsult.no
[2] *JTC Corporation, Singapore*

Phase 1 Jurong Rock Caverns (JRC) project is an underground facility for located at Jurong Island beneath Banyan Basin in Singapore involving the construction of rock caverns and associated tunnels to store 1.47 million m3 of hydrocarbon products.. The project also includes the construction of two access shafts, associated aboveground and underground facilities and a new jetty to support a fully operational plant.

Project Management has for decades been considered as the most valuable contribution to the success of a project. Despite this accepted statement, Project Management has up to recently been identified with the person named Project Manager and his technical competence in the specific type of project. Complexity of projects and requirement for timely delivery motivated the Norwegian Offshore Oil & Gas industry to establish management tools to support the Project Manager to succeed and the Project Execution Model became mandatory. This paper describes how the Norwegian Project Management principles have been applied to the design and construction of Phase 1 Jurong Rock Caverns.

This paper explores the introduction of the Norwegian Project Management principles in the JRC project. The areas to be elaborated are 1) brief view of the Norwegian Project Management principles, 2) brief view of those parts of the principles chosen to be implemented in the JRC project, 3) experiences related to the implementation of the principles.

Keywords: Jurong Rock Cavern, JRC, Project Management, Project Execution Model (PEM), Zero-Philosophy, Planning, Risk Management

1 Introduction

Project Management has for decades been considered as the most valuable contribution to the success of a project. Despite this accepted statement, Project Management has up to recently been identified with the person named Project Manager and his technical competence in the specific type of project.

STM is a cooperative entity established jointly by SINTEF, TRITECH and MULTICONSULT in 2006 for providing project management to the state-of-the-art underground technology in Singapore. SINTEF is the largest research organization in Scandinavia. TRITECH is a listed company in Singapore, specialising in civil, geotechnical and rock engineering. MULTICONSULT is a leading multi-disciplinary consulting and engineering company in Norway, specialising in buildings, oil and gas, transportation and infrastructure, and energy.

STM was awarded the Project Management Contract for Phase 1 Jurong Rock Caverns from JTC Corporation, Singapore in mid 2006 and accordingly the Multiconsult Project Management principles was implemented in the JRC project as a part of the STM Management system.

The Multiconsult Project Management principles are too wide to be fully covered in this paper. Consequently only the parts most essential for the success of the Design and Construction of the JRC project are described. Although the reader may not be able to get complete understanding of the principles, we trust this brief introduction may contribute to further interest for our Project Management Execution Models.

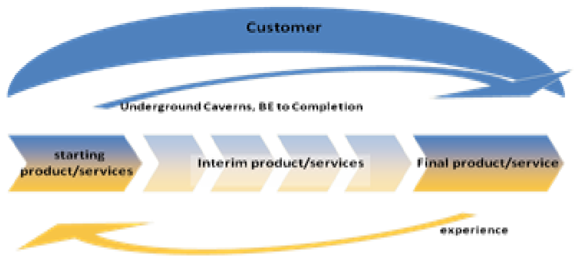
2 The Multiconsult Project Execution Model

Multiconsult Project Execution Model (MPEM) was developed during early 2000 and is based on more than 20 years of experience from Norwegian Project Execution Models originally developed for Offshore Oil & Gas projects. The complexity of the projects and requirement of timely delivery forced the Oil & Gas industry to establish management tools to support the project teams to succeed. The MPEM principles has during the last 5 years been integrated into all types of project software systems such as 3D design systems, planning progress & reporting systems, BIM systems, and are now implemented in all types of design and construction business areas.

The following section will present the brief nature of the MPEM available at the point of time when STM entered into the JRC contract in 2006. The link between the MPEM and the human factors when implementing such system will be briefly touched later when the STM Execution Model implemented in the JRC project is being elaborated.

The evolution of the MPEM as a total integrated part of the 3D design system the way Multiconsult is utilising the MPEM today, will not be further discussed in this paper. However, if further interest of the model, please find illustration at YouTube where Autodesk, one of the world leading 3D design system suppliers has used Multiconsult in their marketing of their BIM software, ref. http://www.youtube.com/watch?v=dvSgL6bZTug.

MULTICONSULTs execution model



2.1 Contract Philosophy
The Project Contract Philosophy is a basis for the success of all projects. This is the first task to be focused when utilising the MPEM. The tender requirements should specify the basic project execution principles, to allow the project manager to execute according to these principles. An early input to the contract philosophy is therefore essential.

2.2 Levels
The project management design methodology is divided in four levels in the MPEM:

- Phases and Milestones
- Key project activities
- Discipline and Control objects
- Procedures and tools

Each of the levels forms separate requirements to the entire project and to the other levels accordingly. The model links all project management activities together and they are either performed by the Project Manager, a Design Consultant, a Build Contractor, or by a Design & Build Contractor.

2.3 Phase Objectives
The phases are further divided into several stages with pre-defined and described activities to be performed. Each stage ends with a Milestone which is considered achieved when a so called Gate Review is performed and accepted.

2.4 Key Project Activities
Key Activities are defined for all activities in the project such as Project Management, Execution, Start Up, etc. As an example, some of the Key activities for Project Management are: Integration, Health Safety & Environmental (HSE), Scope of Work, Time, Cost, Quality, People, Risk, Communication, Procurement and Subcontracting. Each Key Activity is linked to the Milestones and a separate Gate Review is performed for each of them.

2.5 Discipline Control Objects
Each Key Activity is broken down into disciplines (Civil, Electrical & Power Supply, Water & Sewage, etc) and applicable control objects (Deposits, Generators, Main Trenches etc) respectively. The quality status for each of the control objects, (S1, S2, S3, S4, S4,) is continuously defined for each of the milestones (MS-1, MS-2, MS-3.1, MS 3.2, MS 3.3, MS 4).

Control Object check lists are established for each of the control objects and represent the quality status and applicable dependencies for each control object.

2.6 Discipline Flow Charts
Flow Charts are defining the work processes for each of the disciplines and the discipline main deliveries to the next stage. The flow chart also defines the input necessary to perform each part of the Scope of Work, the parties that provided the input and the parties to whom the part deliveries shall be delivered to, from the disciplines.

All these “deliveries”, activities, and “part deliveries” are scheduled to be coordinated and successfully completed within time and quality. For complex projects this is mandatory in order to achieve a successful project.

2.7 Discipline Co-ordination in 3D Design System
The MPEM is the basis for being able to manage a systematic 3D design process as well as the 3D design system is the basis for an optimised implementing of the MPEM. This means that all information and drawings are established and gathered from the 3D model. This is different from the earlier design practice up to early 2000 where the 2D design was used to establish the 3D model.

As an example to show the eminence of the Project Execution Model some general highlights related to a LNG terminal project completed 4 years ago are listed below:

- 150 persons were designing simultaneously in the 3D Model
- Design period was 3 year
- 4 companies and 8 disciplines located at 5 different sites (4 in Norway 1 in India) were involved

- 50000 Control Objects was documented
- 30 different types of construction drawings were issued including 12000 Fabrication Isometrics and 13000 Pipe support drawings
- Automatic collision check for all type of items
- Progress measurement related to status for each of the 50000 objects
- Quantity calculations
- Data communication with 11 other data system and software input to Equipment Suppliers numerical operated machines.

2.8 Progress Monitoring

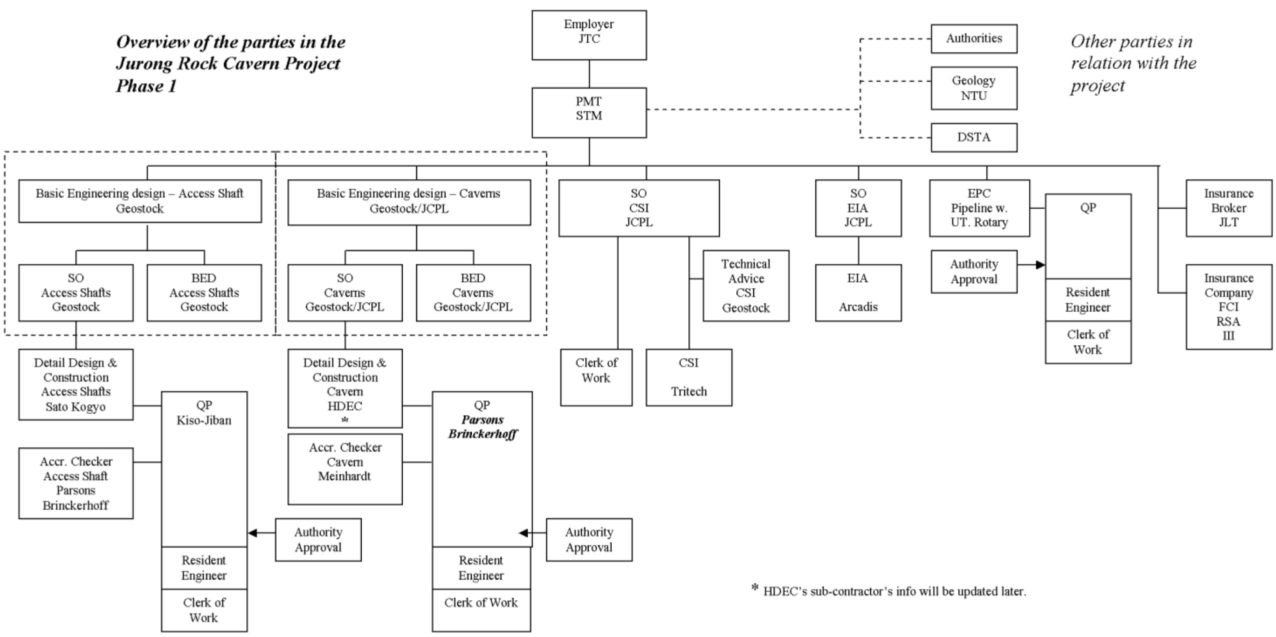
The MPEM structure as briefly described above, establishes a basis for real time electronic progress monitoring. Progress monitoring through the Design Phases adopts computer based system and gives real time management information necessary to implement the right mitigation measures to achieve the MPEM milestones and this avoids the expensive and time consuming delays in the construction phase. The MPEM also links the site follow up system with the 3D modelling which gives:

- Tracking construction items which are completed, ongoing or not yet started
- Visualising the construction status real time in the 3D design system for follow-up and reporting purposes
- Tracking planned and actual quantities

3 STM PEM implemented in the JRC project

The STM Management System in the JRC project is based on the above described Multiconsult Project Execution Model (MPEM). From this part of the paper the Project Management Execution system shall be recognized and named as the STM Project Execution Model (STMPEM).

3.1 Contract hierarchy and Contracts to be Managed by STM



3.2 Implementation challenges

STMPEM captures the basis for Project Manager's planning, review, co-ordination and surveillance of the Design and Construction of Phase 1 Jurong Rock Caverns. The STMPEM has also been included in the requirements for the Basic Design and Construction Management Contract as well as for the Design & Build of Cavern and associated facilities Contract. In this respect, Planning, 3D design modeling, Electronic communication and archiving, HSE, and Risk Management were especially highlighted.

The establishment of the STM Project Management Team (PMT) included taking over of already ongoing project activities. When choosing level of implementation of the STMPEM, STM needed to evaluate the status of activities such as:

- Status of ongoing activities
- What was already agreed with respect to contract requirements and routines
- Time period prior to commencement of activities
- Training of the team, establishing proper procedures and time allowed for culture awareness
- Clients and Contractors acceptance of mandatory STMPEM routines
- Implementing one culture into another culture cannot be achieved successfully without accepting that this takes time
- Contractors capability to respond to what would be required in the tender documents

– Contractors level of PEM competence and potential mitigating measures when necessary

When STM recognized that the MPEM as adopted in previous projects could not be fully implemented in the project due to above mentioned challenges, a new challenge was brought to the table. STM realized that in addition to a challenging implementation process for STMPEM, a thorough redesign to fit into existing local project execution practice was also needed.

The challenge was how this could be managed without losing the benefits of the STMPEM structured project execution as well as how to ensure meeting the forthcoming project milestones.

3.3 STMPEM

Based on above described challenges, the STMPEM structure was redesigned and it became different from the planned structure. The implemented STMPEM included the following elements:

- 30 day Start-Up Plan
- Web based Quality Plan
- HSE & Risk Management
- CTR based Project Control system
- Work Breakdown Structured planning system
- Review, Surveillance & Monitoring procedures
- 3D design system integration
- Communication and Meetings
- Web Hotel based document control system and archive

4 Experiences related to implementing the STM Project Management principles

4.1 30 day Start-Up Plan

The Start-Up Plan is a generic plan ensuring that all activities necessary for a successful project start up is achieved. The activities are both related to the PM Scope of Service and to ensure that the entire project is well established. The "name" of the plan indicates that this is the schedule for the first 30 days and that further activities during this period are sufficiently defined and scheduled. The main activities defined are:

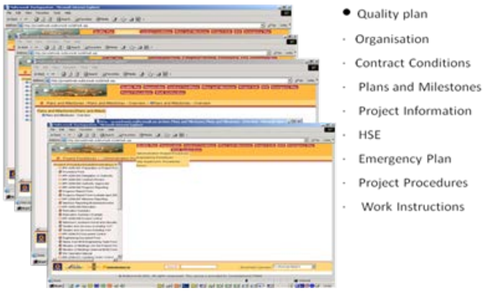
- Vision and Goal
- JTC's expectations
- Basis for execution
- Contract review
- Master plan and milestones
- Services to be provided and delivered
- Organisation
- Training and support
- Project Control System
- HSE and Risk Management System
- QA system
- Surveillance and verification routines
- Administrative routines, system and support

Without this structured generic 30 days plan, STM would not have been able to define, communicate and perform all necessary activities to ensure the project milestones are successfully met in the first months of the project.

The activities related to Basic Design of Shafts, were already established when STM was awarded the Contract and the possibility to implement the STMPEM became very challenging as the Contract requirements were already established. However the attitude of the STMPEM was applied and some of the routines were accepted and implemented by the Consultant and Contractor.

4.2 Web Hotel

In 2006 STM's Web based Quality System was not as common as it is today. STM had developed a system which at that point of time was a "State of the Art" system. The effectiveness of this system shown through the proven structure enabling internal communication between more than 10 locations of the STM Management Team as well as giving dedicated access of the system to communicate among the Client, Consultants and Contractors.



The Web-Hotel consisted of both The Project Filing System and The STM Project Management System. The Web Hotel was also developed to be the communication platform for the submission and approval of the Basic Design Review. The Design Review, which involved personnel at several locations around the world, could not have been performed within the planned timeframe without the implementation of the Web Hotel system.

The Work Breakdown Structured Planning System (WBS) (described later in the paper) implemented in the Planning and Progress monitoring requirement, together with the Web Hotel system, was able to keep control of the various versions of reviewed documents, their comments and finally the accepted documents up to completion of each design area. The principle defined by the STM Web Hotel was also included as a requirement in both the Basic Design and Construction Management Consultancy Contract and the Design & Build Contract and it was successfully implemented by the Basic Design and Construction Management Consultant.

4.3 HSE & Risk Management

JTC has required in the Tender specification for the consultancy and construction contracts to have a high focus on HSE. Based on this strong HSE, attitude STM together with JTC established and implemented the requirement of zero injury and impact. During the last 15 years, Multiconsult had been involved in implementing the HSE "Zero Vision", not only into the Offshore Oil and Gas industry but also into onshore Oil & Gas industry, Public transportation industry etc, which result in all part of construction industry having to adopt this mindset.

As STM were responsible for establishing the requirements for the Basic Design Contract including the general requirements for the Design & Build Contract for the Project, the "Zero Philosophy" and the Risk Management requirements was implemented early together with JTC's involvement.

The Zero Philosophy is considered one of the most important contributors to ensure that the JRC project so far has achieved an acceptable accident frequency rate even though this requirement only was introduced to the Cavern construction Contract. The difference in the accident frequency rate for the construction of shafts and the construction of caverns could not statistically be attributed only to the implementation of the Zero Philosophy, but it is still a valid indicator regarding the importance of this philosophy being implemented in the cavern construction contracts. The mindset or attitude has shown a positive development from the start of the project and the JRC site today is continuously aiming at improving the HSE attitude of zero injury and impact.

4.4 HSE – Zero Philosophy

"The Jurong Rock Cavern Project has an HSE mindset of zero injury and impact".

There are no philosophies that will produce results unless it is being discussed and supported by Management and implemented accordingly. Implementing the HSE philosophy will need one to change the mindset of those involved in the project. The method for implementing the JRC HSE Zero Philosophy is illustrated by the following examples:

HSE Vision

The Jurong Rock Cavern project shall be developed, operated and decommissioned while preserving the environment, personnel health and assets. The development shall be completed without injuries.

- We shall demonstrate a strong commitment and responsibility for the health and safety of People

HSE Commitments

It is recognized that the Jurong Cavern Rock Project development must resolve a number of technical challenges with potential for HSE impact. In order to minimize potential negative impacts, the Project is committed to:

- Open and active communication about critical work plans and results, based on a "No surprise" philosophy

HSE Goals

- Be in the forefront regarding measures to ensure safety and environmental care

HSE Strategy

- Visible management commitment to HSE

HSE Program

Every consultant and contractor in the Jurong Rock Cavern Project is required to establish a HSE program that describes management system, goals and activity plans for their work area related to the relevant project phases including design, construction, or operation.

A systematic Accident Prevention scheme has been implemented with a system for reporting and recording of all unwanted incidents, The submitted reports will be analysed to provide a trending of the safety infringements. Subsequently HSE activities will be prioritised based on the key infringements.

HSE Site Manual

The HSE Site Manual describes the attitude and behaviour expected on the JRC site, as well as activities mandatory to be performed by the Contractor during the various project phases. The activities including, HSE awareness and training, Compulsory induction course, Right to stop hazardous work, Safety Inspections, Management HSE Inspections, address HSE violations (Disciplinary reaction), Constructability Studies, Safe Job Analysis, HAZID studies, are examples considered as main contributors for achieving an accident frequency rate of 0,69 since the start up of the Cavern Contract June 2009.

Figures from JRC Project Report March 2012

Total number of man hours since start of Shaft Construction January 2007	- 7,310,686 mh
Frequency rate (Total no. of reportable accidents / total mh)* 1 million	- 1.23
Number of man hours since start of Cavern Contract June 2009	- 5,793,754 mh

Frequency rate Cavern Contract - 0.69

4.5 Risk Management

A systematic and continuous establishment and follow up of risks and uncertainties have been performed through the project from the planning and design phases to the construction phase. The STM organization has developed and operated a Risk Management System (RMS). The system has ensured that major risks and uncertainties are uncovered and brought to management's attention in due time for corrective action. Project downsides and upsides have been focused. The risks have been reported and followed up by STM in close cooperation with all parties of the JRC project including the Client, the consultants and the contractors. In this respect and to be consistent through the entire project, similar Risk Management systems have been established and followed up by the consultants and the Contractors for their part of the work.

STM has coordinated all risk management activities. However, the responsibility for identification and reporting of potential risks and uncertainties rests within the whole project organization. The STM Risk Assessment Process consists of four basic steps:

- Define undesirable events and risk elements groups
- Brainstorming in Groups to define and rank risk elements based on consequences and probabilities
- Establish risk register and define risk mitigation actions
- Execute, register, evaluate and continuous follow up of mitigating actions

The following Risk Issues have been included:

- Design solutions with new or unproven technology or proven technology utilised in a new manner or complex technical solutions
- Schedule critical activities including construction activities
- Complex interfaces
- Areas where results could affect HSE performance negatively
- Areas where there is an opportunity to benefit from value engineering, improve the Life Cycle Cost and other important outputs from the work interface with other Project Contractors and stakeholders
- Areas that could negatively affect Employers reputation.

The information input to the RMS is based on established information sources such as:

- Activity schedules and plans
- Design and Safety Reviews
- Activity Oriented Quality Plan
- Budgets
- Verifications/Audits
- Past experiences or previous similar nature of construction activities

The risk management activities are closely coordinated to ensure that information is generated from the same sources and from the same status of time.

4.6 CTR based Project Control system

The STM CTR (Cost Time Recourse) system has been implemented to ensure that all STM Contractual obligations are defined, planned, executed and documented. The CTR system is linked to the Job Functional descriptions and accordingly to each of the STM Team personnel and the procedures for executing the specific part of the Scope of Work. Similar CTR systems requirement is transferred to the consultancy and construction contracts implementation in the WBS structured planning system.

4.7 Work Breakdown structured planning system (WBS)

The Work Breakdown structure was established by STM through preparation of the tender documents for both the consultancy and construction contracts. The requirement is mandatory for the consultants and the Contractor to ensure accurate and traceable documentation of the project from Basic Design through Detail Design and from Construction to final documentation of the Commissioning. The responsibility for each of the WBS levels is;

- STM on behalf of JTC
  - Level 1: Overall Project Plan
  - Level 2: Project Master Schedule
  - Level 3: Contract Summary Schedule
- Consultant / Contractor
  - Level 4: Contract Master Schedule
  - Level 5: Contract Detail Schedule (Network)
  - Level 6: The Consultant's / Contractor's Detailed Work Element Schedule (Registers)

The WBS structure is briefly described in the following examples of the planning objectives and planning requirements:

Planning Objectives

- The Level 3 schedules shall be prepared and maintained based on input from project user groups such as project management, engineering, procurement, construction, commissioning, operations and subcontractors as appropriate.
- Detail schedules shall identify critical issues and potential constraints upon execution.
- Detail schedules will include sufficient details to provide an accurate current status of the work, approved changes and the consequences of actual versus planned productivity.

- Identify opportunities to reduce expenditures and shorten the schedule to optimize the overall project execution.

Planning Requirements

- Use a Work Breakdown Structure (WBS) to group project activities into manageable and controllable Sub-areas
- Engineering Schedules shall be organized by appropriate Cost Time Resource (CTR) packages and engineering deliverables to measure progress and performance.
- Construction schedules shall be organized by appropriate Work Packages to facilitate integration with the progress and performance reporting.
- Performance Factor for each discipline/area group will be included in the monthly report. The performance factor is calculated as actual work hours divided by earned work hours so that numeric representation of less than one is favorable.

4.8 3D Design System Integration

3D Design system integration is a basis for an optimal use of the STMPEM. This requirement was put into the Basic Design Contract and also into the Design &Build Contract. However the actual situation has shown that the Design & Build Contractor due to several reasons, has yet to utilise a 3D design system as the basis for the design. The advantages with respect to planning, quality control, progress monitoring and communication of technical topics as planned for by the STMPEM were consequently reduced. Traditional Design and Construction monitoring and traditional progress reporting has replaced the STMPEM principles.

4.9 Training and support

An extensive training and transfer of Project Execution experiences from Norway including regular daily support took place during the first year of the project to ensure a successful implementation of the STMPEM. As the STMPEM requires a huge mental change in attitude from traditionally being “controlling” project activities to “Managing” project activities, STM recognised that implementation would take more time than estimated. Preparation for the different project phases was therefore chosen to be the arena for training and support, as this gave “on the job practical training”.

5 Conclusion

Implementation of the Norwegian Project Management principles in the Design and Construction of Phase 1 Jurong Rock Cavern Project, have been much more challenging than expected when STM entered into the Project Manager contract in 2006. However, the good cooperation between JTC and STM has overcome the challenges in a very productive way and the added value to the JRC project is considered high for those parts of the STMPEM which has been fully implemented including HSE, Risk Management and Electronic Archiving.

For STM internal performance the STMPEM has also been challenging. At a certain point of time the STM PM Team consisted of personnel from six different countries with different cultures and backgrounds. Based on extensive transfer of Norwegian experiences and daily supports during the first year, and very positive project team members’ attitude, the implementation of the STMPEM in the PM Team is considered successful.

For those parts of the Norwegian Project Management principles which were decided not to be implemented in the project, the sheer awareness that those parts have not been implemented have established successful mitigation activities performed through daily surveillance by the STM Project Manager Team.

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