AN INTEGRATED MANAGEMENT OF CHANGE SYSTEM BASED ON PROCESS SAFETY MANAGEMENT

PANG KAR KEI

Bachelor of Occupational Safety and Health (Honors)

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ABSTRAK

Industri-industri merbahaya berkembang dengan pesat berikutan peningkatan permintaan ke atas produk-produk petroleum. Peningkatan kerumitan proses pembuatan menyebabkan kesukaran memperoleh pandangan komprehensif pada perspektif keselamatan terhadap keseluruhan proses kompleks, peralatan dan kakitangan. Potensi malapetaka untuk berlaku mungkin meningkat dengan ketara apabila perubahan dilaksanakan. Perubahan yang tidak dirancang boleh mengakibatkan bahaya baru muncul yang akhirnya membawa kepada kesan yang teruk terhadap reputasi manusia, harta, alam sekitar dan perniagaan. Pengurusan perubahan adalah elemen penting yang melibatkan perancangan dan pengendalian risiko dan bahaya yang datang dengan perubahan yang dicadangkan. Walau bagaimanapun, pelaksanaan MOC saat ini tidak mempunyai loji kerana kekurangan sistem MOC sistem pengurusan dan sistem pengurusan yang merangkumi keseluruhan proses MOC ke dalam sistem bersepadu. Sejajar dengan kelemahan-kelemahan ini, sistem pengurusan MOC bersepadu bertujuan untuk membangunkan dalam kajian ini. Objektif kajian ini adalah, untuk membangunkan rangka kerja MOC, untuk membangunkan sistem pengurusan pada MOC dan untuk mengesahkan sistem pengurusan yang dibangunkan. Kaedah yang digunakan dalam kajian ini adalah serupa dengan konsep Plan-Do-Act-Check (PDCA). Peringkat "Plan" dilakukan dengan menjalankan kajian literatur dan memahami semua keperluan peraturan PSM terhadap MOC. Peringkat "Do" dilakukan dengan membangunkan rangka kerja dan sistem pengurusan. "Check" digunakan untuk mengesahkan sistem pengurusan yang dibangunkan untuk memastikan kecekapan dan kebolehpercayaan sistem ke arah operasi proses sebenar. "Act" dilakukan dengan mengoptimumkan sistem pengurusan dan rangka kerja untuk memastikan pematuhan sepenuhnya terhadap peraturan dan meningkatkan pengguna yang mesra terhadap sistem pengurusan. Hasil kajian ini terdiri daripada gambaran keseluruhan proses MOC yang dipamerkan oleh kitaran PDCA, rangka kerja proses MOC yang lengkap dengan daftar periksa yang digunakan dan sistem pengurusan MOC yang bertindak sebagai panduan dan dokumentasi perisian. Proses pengesahan yang dijalankan telah mengesahkan rangka kerja MOC memenuhi keperluan dasar peraturan MOC terpilih, manakala sistem pengurusan ini berfungsi dengan efisien dalam dokumentasi sistem dan penyimpanan informasi.

ABSTRACT

Highly hazardous industries grow rapidly due to increasing demand towards petroleum made products. Increasing complexity of manufacturing process cause difficulty to acquire a comprehensive view on safety perspective of the entire complex processes, equipment and personnel. Potential of major accident may significantly increase even more when change is implemented. Unplanned change may lead to new hazards emerged which eventually leads towards severe impact in human, property, environment and business reputation. Management of change is an important element in which involves in planning and controlling risk and hazards that comes with proposed change. However, current MOC implementation were lacking in plant due to lacking systematic MOC process and management system which comprises the whole process of MOC into an integrated system. Corresponding to these weaknesses, an integrated MOC management system is aimed to develop in this study. Objectives of this research are, to develop MOC framework, to develop a management system on MOC and to validate management system developed. Method adopted in this study is much similar as Plan-Do-Act-Check (PDCA) concept. "Plan" stage is conducted by conducting literature review and understanding all requirements of PSM regulation towards MOC. "Do" stage is carried out by developing framework and management system. "Check" is adopted to validate developed management system to ensure efficiency and reliability of system towards real process operation. "Act" is done by optimizing management system and framework to ensure fully compliance towards regulation and enhance user friendly on management system. Result of this study are comprised of an overview of MOC process which displayed by a PDCA cycle, a complete MOC process framework with checklist adopted and a MOC management system which act as guidance and documentation software. Validation process conducted has confirmed MOC framework met basic requirements of selected MOC regulation whereas management system is reliable in system documentation and information storage.

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LIST OF ABBREVIATIONS

PSM	Process Safety Management
MOC	Management of Change
RBPS	Risk Based Process Safety
PDCA	Plan Do Check Act
CIMAH	Chemical Industrial Major Accidents and Hazards Regulation 1996
COMAH	Control of Major Industrial Accident Hazard Regulation 2015
OSHA	Occupational Safety and Health Administration
PSI	Process safety information
PHA	Process hazard analysis
OP	Operating Procedure
CM	Contractor Management
PSSR	Pre-startup safety review
MI	Mechanical Integrity
HWP	Hot Work Permit
EPR	Emergency planning and response
CA	Compliance Audits
CCPS	Center for Chemical Process Safety
DOSH	Department of Occupational Safety and Health
HIRARC	Hazard Identification, Risk Analysis and Risk Control
KOSHA	Korea Occupational Safety and Health Agency
HAZOP	Hazard and Operability Study
HAZID	Hazard Identification Study

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter is highlighting on the general ideas of this study along with background of study, problem statement, research objective, research question, significance of study, scope of study, conceptual definition and operational definition.

1.2 Background of Study

Malaysia, one of the leading countries in terms of oil and gas production country in the world is extensively working on industrialization particularly in oil and gas, petrochemical and chemical industries. This advantage had attracted many foreign investors to invest in these highly hazardous industries. Petroleum is beneficial raw materials in which it can be manufactured into different kinds of products such as plastic resins, olefins and aromatics. Petronas, Shell, Polyplastics Asia Pacific and other company are some of the companies that uses petroleum as raw materials in manufacturing process, it is undeniable that fossil fuels are bringing benefits to human in product manufacturing, however it also brings great number of underlying hazards in manufacturing process. Fire and explosion cases in Seberang Prai (2004), Pasir Gudang oil Terminal (2006), Labuan (2007), and Tanjung Langsat Terminal (2008) were some of the reported major industrial accidents happened in Malaysia (Chin, Piong, Abu Bakar, Kidam, & Ali, 2016). Referring to the cases, catastrophic accident happened almost every one or two year which cause countless damage. This shows that chemical industries in Malaysia are still behind in process safety management in last decade. Major industrial accidents will not only affect personnel in the workplace but also innocent residents around the area. Financial losses, poor company reputation and compensation are enormous when a company experience accident (Kwon, 2006).

Nowadays, highly hazardous industries grow rapidly due to increasing demand towards petroleum made products. Technologies, manufacturing process in these industries is getting complex to improve productivity to meet market demand. Increasing complexity of manufacturing process cause difficulty to acquire a comprehensive view on safety perspective of the entire complex processes, equipment and personnel. Potential of disastrous events may significantly increase following the growing complexity and expanding operation process (Bert Knegtering, 2002). Process Safety Management (PSM) is a safety management approach which introduced to highly hazardous industries in ensuring safety level in the premise. Every element in PSM are interlinked and integrated to cover all aspects in manufacturing process. PSM is not only system but the result of this approach may beyond safety in terms of process safety and eventually create a sustainable operation of facility. This system can be modified into business system and practice in every layer of the organization (Centre For Chemical Process Safety, 2016).

We are living in an ever-changing world, changes occur fast in a flash at any time. What happened today might be changed tomorrow. An organization shall manage to adapt to changes quickly to ensure sustainability and competitiveness in the market (Harmon, 2007). However, changes shall be well planned to ensure the changes will not bring negative consequences to the organization. Managing changes in a complex manufacturing process is challenging as industry safety practitioner shall able to foresee and manage all possible consequences brought by the changes (Koivupalo, Sulasalmi, Rodrigo, & Väyrynen, 2015).

Management of change (MOC) element in PSM system is providing an overview and guidelines on how highly hazardous industries shall manage change without neglecting any essential aspects to ensure safety of a premise. MOC in PSM emphasized on evaluating, analyzing and preparing a company to potential consequences brought by changes in manufacturing process. However, current MOC element is proved to be one of the insignificant in terms of effectiveness in effort on improving process safety (Naicker, 2014). Current MOC approach is having flaws and weaknesses that shall be eliminated to ensure effectiveness of this system and to regain industry practitioners' confident towards MOC system.

Changes in a process plant could be temporary or permanent based. MOC procedure is supposed applied to both situation of changes. However, short-term changes always treated negligently by applying changes without complete risk assessment. The consequences of neglecting temporary changes is well displayed from Flixborough incident. There was a temporary change on the reactor to complete maintenance of corrosion. This temporary change was not well controlled and contributed to the happening of explosion (Piong et al., 2017).

In this study, an integrated MOC system is proposed to minimize these limitations. Introduction of technology factor in MOC system also included in this study to enhance the effectiveness of MOC system. A framework of MOC process is established which complied to PSM regulation yet covering every criterion stated in legal requirements. Meanwhile, a MOC management system is developed to aids in MOC procedure on standards compliance and database of MOC reports. This management system is integrated as it covers from the beginning to the end of the MOC. Apart from the basic steps in MOC process, there are several new proposals of ideas in which may help to improve current MOC process. Proposed management system will make improvement on current MOC framework specially in action items, related assessment until the storage of important reports in database. Risk rating and prediction of time required element is added into newly establish system to increase the reliability and efficiency of MOC approach. A PHA risk rating is embedded into existing risk assessment checklist and improvement on time prediction in an overall MOC process are suggested into MOC process. There is also a tracking of similar temporary MOC case in which risk assessment can be excluded by referring to previous risk assessment conducted.

Mechanical integrity, emergency response and control and contractors management seems to be the elements that most of the companies invested and working on as compared to other elements (Naicker, 2014). However, management of change (MOC) is an element which interlinked with several elements after any changes implemented in manufacturing process. This study is to contribute to produce systematic MOC framework and system to ease human work task in terms of managing situation before and after implementing change. Traditional proposed method on MOC execution are more towards time-motion based that consist of many underlying weaknesses. A comprehensive MOC framework which focusing towards planning and forecasting potential hazards are more demanded in current industries (Gerbec, 2017). Appropriate time allocation and essential supporting items are the examples of criteria that shall be improved to create a perfect MOC framework (Gerbec, 2017; Hoff, 2013).

1.3 Problem statement

Process Safety Management (PSM) is an approach which designed to manage underlying hazards and risks in highly hazardous industries. Chemical industry, oil and gas are some examples of highly hazardous industries which involved process using hazardous chemicals or energy that may cause catastrophic accident if it is not well managed.

Industrial Revolution evolved since year 1760 which manufacturing process started a new transition to the manufacturing industries all over the world. Over three centuries, industrial revolution is now moving into the fourth transition which named as Industrial 4.0 (Marr, 2016). Current revolution is representing the starting point of manufacturing industries transforming into an era dealing with technological gadgets. Automation, data exchange, robots are the basic elements representing Industry 4.0. Apart from manufacturing process, all departments in manufacturing industry too, shall be ready to face a new round of challenge in the new era of industrial revolution. Technology improvement enable complex manufacturing process easily handled by robots and artificial intelligence system which eventually lighten the burden on human. However, the conditions could be went complicated in terms on safety perspective as current safety management techniques and tools are unable to handle a brand new “smart factory”. Accident prevention and mitigation methods should be improved following the pace of technological based industry(B. Knegtering & Pasman, 2009). Complicated process could be burdensome to manage safety level solely relying on human mind without technological support. This could create rooms for safety weaknesses which could leads to catastrophic industrial accidents.

As complexity of operation process increasing, the work of managing safety level are getting difficult if relying solely using manual method. Managing change is challenging as it shall be fast and disseminate knowledge and information to address hazards. Reporting and reviewing task may be complicated as more paper work required. Moreover, applying changes on operation process are a complex procedure and relatively challenging which requires assessing need of improvements and training of personnel, potential challenges and so on (Koivupalo et al., 2015; Zwetsloot, Gort, Steijger, & Moonen, 2007). French et al., (2011) stated the same opinion as Zwetsloot which human behavior are merely impossible to perform characterization of risk and reliability test on complex environment which may restrict personnel from entering during operation. Integrated system on MOC which is well-developed and planned maybe minimize the burden on process safety related personnel in planning work on implementation of changes in operation process and thus improving production efficiency and customer satisfaction (Centre For Chemical Process Safety, 2016).

Management of change (MOC) is one of the elements under PSM which functioned to evaluate, anticipate and manage all possible consequences that may bring after implementing change in manufacturing process. Based on the findings by Naicker (2014), MOC is one of the insignificant element in PSM implementation in several case studies. It is believed that these companies focus more towards Mechanical Integrity and Emergency Response & Control elements instead of MOC. Besides, there are many more research studies are not recognizing MOC as part of important elements in safety management. This is addressed by Koivupalo et al (2015) as current MOC approach is applied after changes instead of before. The actual function of MOC is wrongly translated. This is one of the reasons which causes industry to ignore the importance of MOC. MOC element is the element which worth for employer to pay attention with. This can be seen from statistics made by previous studies in which 9.1% of process safety accidents in contributed by poor MOC (Piong et al., 2017) and 19% (Ye, Xia, & LI, 2012). Gambetti et al.(2013) addressed that approximately 80% of major accidents were traced and discovered MOC failure is the root cause. In every 1000 work tasks, there would be 5-10% of tasks required MOC while there might be 5 to 10 changes are high risk.

Hoff (2013) stated that more focus shall be put towards MOC efficiency aspects in the context of business process and to avoid unnecessary complexity in manufacturing process. Many organizations have introduced various types of safety management tools in order to reduce the consequences of changes made in manufacturing process and in organization. This is because industries view managing changes made in organization as a situation rather than a management tool (Koivupalo et al., 2015). Many organizations seem to translate the function of management of change wrongly thus neglecting the importance to invest on MOC. Moreover, weaknesses in storing of many MOC related data is causing a burden to industry practitioner to practice MOC due to non-systematic and inadequate procedure and system (Bakar et al., 2017; Piong et al., 2017).

According to Zwetsloot et al., (2007), previous proposed approach on MOC in organization are practicing time-motion based method. This method has limited operators to perform work within the timeframe given which leads to systematic bias in performing work task. For example, an operator may be given only '5 minutes to check on safety valve and pressure gauge' before firing a boiler. This may cause the operator to focus only looking on safety valve and pressure gauge during checking which may cause the operator neglected to observe any unusual condition on the other parts of the boiler during safety check. Another drawback of time-motion based MOC approach is less to predict possible consequences on changes made on the process. Previous time-motion based approach are strictly followed on the time allocated on each actions item given in the framework. This approach has overlooked some essential supporting action items which could be one of the underlying weakness of current MOC framework in detecting consequences and error. Current MOC framework are focusing too much on performing task within period given and hence performing work using checklist with underlying error and weaknesses.

Apart from time motion based, MOC is having limitation in time constrain and urgency to resume operation which contributes to failure. Simplification on risk assessment, absent of updating operating procedure and so on were causes that neglected in MOC due to urgency (Piong et al., 2017). Gambetti et al.(2013) mentioned that MOC process actually requires long lead times due to several factors. Meeting shall be conducted with affected departments and specialist to address control measure on potential risk in the change. Documents which related to process hazard analysis (PHA), process safety information (PSI) and other elements are required to review to evaluate the change. Lastly, documentation for all related work task and risk assessment is required for both temporary and permanent changes. This is obviously time consuming to perform all the steps especially for temporary MOC changes.

One of the key factors in success of MOC program is that each related element such as PHA, PSI, operating procedure (OP) and risk assessment come as component in integrated MOC program. Although various kind of integrated safety management system or MOC systems (CSChE, 2004; Sphera, 2016) have been introduced, direct integration system, each between MOC procedures, time prediction and organizational risk assessment were not extensively been studied. The present studies addressed these shortcomings of MOC system that leading to poor MOC implementation program. Therefore, new framework and management system are proposed to minimize on limitation in time prediction, prioritization of risk and make record logging and storage comes into a more convenient yet less burdensome way.

1.4 Research Objectives

Objectives in this study can be categorized into main objective and specific objectives as follows:

a. Main objective:

To develop an integrated management of change system based on Process Safety management.

b. Specific Objectives:

i. To construct framework to be carried out to implement management of change based on Process Safety Management.

ii. To develop MOC system that aids in process of managing change.

iii. To validate developed MOC system through case studies.

1.5 Research Questions

This study will be conducted to find out answers for the following question:

i. What are the steps should be taken to implement change in an organization based on Process Safety Management?

ii. What could ease the implementation of management of change process?

iii. How to ensure developed MOC system reliable and valid?

1.6 Significance of Study

Process safety management consist of 14 elements which interconnected in order to cover almost all the safety aspects in highly hazardous industries. Looking on the perspective of PSM implementation among countries, Malaysia is considered as a beginner in terms of PSM implementation in industries as comparing to other developed countries where PSM are widely applied in most of the industries. (Bakar et al., 2017). United Sates, United Kingdom, Japan are developed countries which established regulation specifically on PSM. Bakar et al (2017) addressed that encouragement shall be made by the government on application of PSM in Malaysia. Execution of PSM is anticipated to be voluntary based for all the industries in daily operation process. More studies on PSM is helping on determining a milestone target to government to take initiatives on PSM implementation in Malaysia. Local research and improvement made on PSM elements are able contribute valuable and reliable information to the public on the efficiency of PSM in establishing safety environment (Gerbec, 2017). Through studies made on PSM, benefits, methods and guidelines on implementation PSM in Malaysia will be established and promoted to the public and organizations.

Centre For Chemical Process Safety (2016) addressed that if time and duration concept is included in MOC would be an added advantage to MOC system. Previous MOC approach which applied time-motion based has become a fault in the system whereas improvised MOC system had removed this approach. Current MOC approach is having a weakness in predicting required duration to perform first phase of MOC system until decision making phase. Prediction on time required to perform every action item under MOC may provide milestones and timing target to achieve desired goals.

Implementation of ICT in MOC will produce immediate responses towards changes in which shorten time required in a MOC cycle (Hooi, Hassan, Shariff, & Aziz, 2014). Application of technological support such as web-based storage system, user friendly human-machine interface (Conger & Fulmer, 2003) are some alternatives available as Health and Safety (HS) tool in order to overcome weakness of manual method in safety. A well -developed and integrated management system would help in trace back on previous temporary cases and related risk assessment. New similar temporary MOC might be able to skip a certain risk assessment in which shorten the stress of time constrain. Koivupalo et al., (2015) addressed that there is a need of more efficient automated system in current health and safety management. There are plenty of software or applications made available in today's world that can utilized without highly skilled person to operate. Usage of software can aids in decision making if there is large number reports involved in analysis stage (Gnoni, Andriulo, Maggio, & Nardone, 2013).

1.7 Scope of Study

Important requirement in Management of Change will be studied in deep on US, UK, China, Malaysia and Singapore related regulations on PSM. Comparison between selected regulations is conducted and analyzed to produce a good MOC framework which is comprehensive in covering all aspects related to MOC element. Some of the current MOC framework is studied and analyzed to obtain the essence and weakness of existing framework. It is important to understand which weakness and limitations of current framework in order to develop an improved and error-free procedure which able to anticipate, plan and control on possible outcomes to implement change.

MOC system that can be modified and aids on MOC process is developed and tested to obtain appropriate software. The chosen software is Microsoft Access and Microsoft Excel, shall be under friendly which does not require special skills for operation and reliable in storing and reviewing records. As preceding of technological era, web-based storage of records can be made easier and safer as compared to traditional way in storing of hard copy records. Any man-made or natural disaster which may cause hard copies of records will be destroyed causing aftermath safety management getting complicated.

Reliability of developed framework and management system is verified via process safety expert feedback and case studies at two companies in petrochemical and petroleum processing sector that involve with review and data testing on MOC system. Review and comments from industries and safety expert also used for improvement and optimization of the system.

1.8 Operational Definitions

1.8.1 Process Safety Management

Process Safety Management is the application of management principles to identify, evaluate and mitigate hazards in preventing process-related injuries and accidents. PSM focused on prevention of, preparedness for, mitigation of, response to, and restoration from catastrophic release of chemicals or energy (H A Aziz & Shariff, 2017). PSM comprises of 14 elements to cover all aspect in safety management.

1.8.2 Employee Participation

Employee participation element require employers to encourage employees' participation in consultation on the development of process hazard analysis and other elements in PSM program (US OSHA, 1994).

1.8.3 Process Safety Information (PSI)

Process safety information element function to provide complete and accurate information regarding on the process which is important to ensure effectiveness of PSM program and for conducting process hazard analysis (US OSHA, 1994).

Process safety information is compilation of written information that can serve as precursor to process hazard analysis and necessary to be complied with management of change and incident investigations (WSH Council, 2012).

1.8.4 Process Hazard Analysis (PHA)

Process hazard analysis element require employer to develop thorough, systematic and organized approach in anticipation and evaluation and control on process that used hazardous chemicals (US OSHA, 1994).

Process hazard analysis is a thorough, organized and systematic approach which used to evaluates and control hazards involved in operations. PHA includes several method using what-if analysis, hazard and operability study (HAZOP), failure mode and effect analysis (FMEA), fault tree analysis or event tree analysis (WSH Council, 2012).

1.8.5 Operating Procedure (OP)

Operating Procedure element function to provide direct and clear instruction to conduct activities which involved in covered processes that are in accordance with PSI. the procedures should cover the steps for each operating phase, operating limits and safety and health considerations (US OSHA, 1994; WSH Council, 2012).

1.8.6 Training

This element provides guidance to employers and contractor employees to understand the nature and root cause of problems that arose from process operations, and to increase employee awareness on hazards on a certain process (US OSHA, 1994).

Training includes initial training for refresher, safety and health hazards, safe work practices and emergency operations. Training record should be kept containing employee identity, training date and employee understanding verification method (WSH Council, 2012).

1.8.7 Contractors Management (CM)

Contractor management element in PSM require employers establish screening process on contractors selection that involve in dealing with highly hazardous chemicals in performing job task without compromising employees' safety and health (US OSHA, 1994).

1.8.8 Pre-Startup Safety Review (PSR)

Pre-startup safety review element is established to ensure new facilities, or modified facilities are is accordance to design specifications, operating and emergency procedure are established and adequate to the premise situation (US OSHA, 1994).

1.8.9 Mechanical Integrity (MI)

Mechanical integrity element ensure equipment used in storing and processing hazardous chemicals is designed, constructed, installed and maintained accordingly to reduce the risk of chemical released and accident occurrence (US OSHA, 1994).

1.8.10 Hot Work Permit (HWP)

This element requires employers to control non-routine work in a systematic and effective way to ensure safety and health of employees in workplace. Hot work permit which stated compliance fire prevention and protection requirements shall be issued to employees who perform work nearby or at hot work process area (US OSHA, 1994).

1.8.11 Management of Change (MOC)

This element emphasizes on management on all modification to equipment, procedures, raw materials and operating process. Hazard recognition and evaluation and proposed control measures shall be conducted and evaluated before any changes is implemented (US OSHA, 1994).

Any changes including permanent and temporary to operation shall be thoroughly evaluated to address safety and health impact on employee (WSH Council, 2012).

1.8.12 Incident Investigation

Incident investigation element requires employer to investigate on each incident which may result catastrophic consequences from release of highly hazardous chemical in workplace. Investigation shall be made within 48 hours from the date of incident occurrence and report shall be prepared recording with incident investigation details (US OSHA, 1994).

Incident investigation shall be conducted in every incident in which potentially have resulted in, or in a catastrophic release o hazardous chemical. Investigation team shall consist at least expert in the operation process, including a permanent employee when the incident involved contractor or any persons whom experienced in incident investigation (WSH Council, 2012).

1.8.13 Emergency Planning and Response (EPR)

Emergency planning and response is an element which requires employers to address action steps to be taken by employees when the situation went beyond control or emergency. Emergency action plan shall be established to deliver related emergency procedure to employees (US OSHA, 1994).

1.8.14 Compliance Audits (CA)

This element requires employers to perform self-evaluation on effectiveness of PSM program in own premise by identifying weaknesses and addressing corrective actions (US OSHA, 1994).

1.8.15 Trade Secret

Trade secrets is element which require employer to provide all essential information for standards compliance on other elements without regard to possible trade secrets (US OSHA, 1994)

1.9 Conceptual Framework

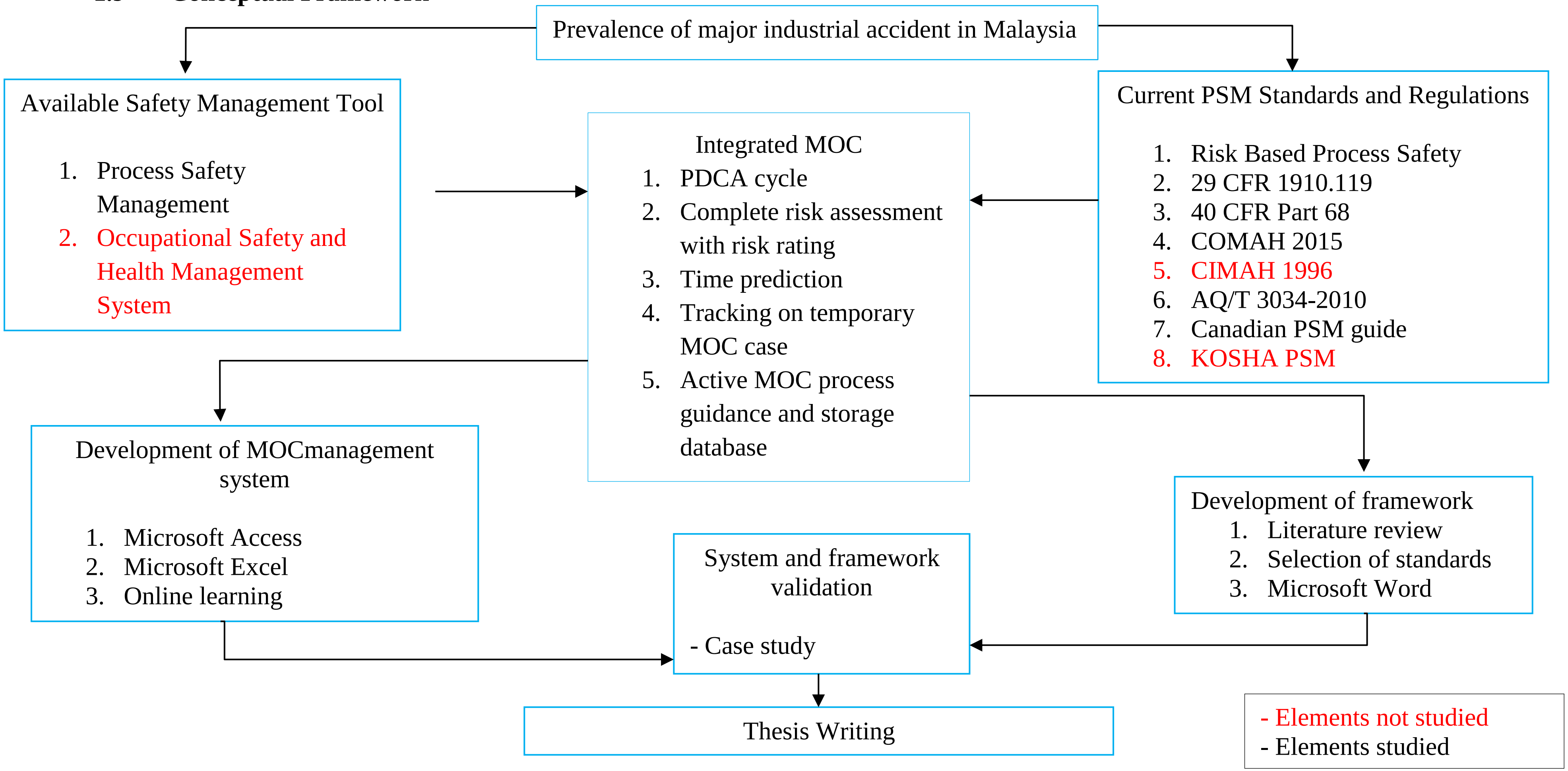

Figure 1.1: Conceptual Framework of MOC Management System

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter is about the review of previous studies and researches done on Process Safety Management (PSM), Management of change (MOC) framework and technology system which utilized as safety management tool. There are several researches found which investigated weakness of PSM in Malaysia and limitations of current MOC approach which consist of faults and error that affects effectiveness of MOC.

2.2 Process Safety Management

Process safety management (PSM) is a safety management approach which established specifically for highly hazardous industries which involved hazardous process. PSM aims to achieve a goal to prevent occurrence of major industrial accident which may cause catastrophic consequences (Luo, 2010). This approach focus on development of systems which ensuring technological, organizational and equipment factor are maintained appropriately (H A Aziz & Shariff, 2017). PSM emphasizes on anticipation of risk, risk analysis and suggest control to enhance safety level of hazardous process (Bakar et al., 2017).

2.2.1 Evolution of Process Safety Management

Process Safety Management (PSM) system has been established over 30 years which consist of 12 elements at the very first concept. These elements covering organizational, technological and equipment aspects to create a safe environment in a premise. Centre for Chemical Process Safety (CCPS), division of American Institute of Chemical Engineers (AIChE) is the first organization issued on PSM standard. Originally, PSM approach was focusing towards human factor and eventually revised in year 2007 changing its attention towards process related safety. PSM is then renamed into Risk-Based Process Safety (RBPS). Instead of covering human factor by a single element, RBPS is then involving human factor throughout 6 out of 14 elements (Bridges & Tew, 2010). Emergence of PSM system around the world are triggered by numbers of catastrophic accidents that caused severe impact towards human and environment.

2.2.1.1 United States

In early 20th century which industrialization and industrial revolution moving on to second phase, BASF plant which located in Oppau, Germany experienced an explosion in year 1921 which destroyed the premise, causing death at least 430 people and damage to approximately 700 houses around the plant (Macza, 2008). Two decades later, Bhopal incident in 1984 which cause catastrophic release of Methyl Isocyanate (MIC) has triggered OSHA to pay attention towards all premises in US that manufacture MIC (H A Aziz & Shariff, 2017).

In year 1990, OSHA begin to work on managing safety on industry that involves hazardous chemical. Federal Register (55 FR 29150) was published by OSHA to be used as a standard which named as “Process Safety Management of Highly Hazardous Chemicals” on July 17. Approximate 4000 pages of testimony and more than 175 comments are received by OSHA on the proposed rulemaking on PSM. Clean Air Act (CAA) was then enacted after four months of the proposed standard in November 1990. In February 1992, 29 CFR 1910.119 is enacted and entitled as Process Safety Management of Highly Hazardous Chemicals (H A Aziz & Shariff, 2017; US OSHA, 2000).

2.2.1.2 Europe and United Kingdom

PSM related regulations among UK and Europe countries were triggered by several tragedies that happened in Europe and Asia.

In Flixborough UK (1974), Nypro (UK) site chemical plant was extensively damaged by an explosion. It is believed that plant modifications had been made without conducting assessment on anticipating potential outcomes of such decision. 28 workers are killed, and fire had blazed over 10 days. There are number of flaws existed in the plant operation involving failure in maintenance procedures, operation procedures, management of change procedure and so on (HSE, 1975).

Seveso, Italy (1976), an industrial accident happened at a small chemical manufacturing plant, located approximately 20km north of Milan. This incident took place when one of the tanks in the plant had reached critical level resulting in the release of gas, dioxin. This toxin gas drifted over 10 square miles of nearby residential area causing 2,000 people poisoned. European Community was then influenced by public protest which demand over industrial plant safety, passing Seveso Directive (1982) to impose a strict industrial regulation towards chemical safety (Macza, 2008). Meanwhile, UK has passed Control of Major Accident Hazards (CIMAH) Regulation. Seveso Directive was updated over time in 1999, 2005 and currently known as Seveso II Directive. This is also referred as Control of Major Accident Hazards (COMAH) Regulation 2015 in UK (Vallerotonda, Pirone, De Santis, Vallerotonda, & Bragatto, 2016).

In year 1984, a worst air pollution tragedy which lethal gas named methyl isocyanate (MIC) is released to the environment from leaked storage tanks owned by Union Carbide, a multinational company in Bhopal, India. Nearly 36 tons of MIC gas released to the atmosphere forced the evacuation of at least 200,000 people. More than 3,800 people are killed and caused burning to respiratory and chest tightness to over 200,000 people. This tragedy has contaminated drinking water, soils and even pond water. Fetus and newly born babies are adversely affected by the disaster (Bowonder, 2012).

Piper Alpha, UK (1988), an event of explosion and fire had destroyed Piper Alpha offshore platform. Piper Alpha was once Britain’s largest single oil and gas producing platform in the history which supply more than 30,000 barrels in a day. However, disaster happened when there is poor communication between staff on shift change on equipment. Misuse of pipework sealing with temporary cover and without safety valve is the main contributor of the event. Gas has been released and ignited while firewalls fails to defend the platform from further explosion. This has resulted in 165 deaths and installation of platform has been completely blown out (NSC, 2013).

CIMAH 1984 is then enacted as followed by a series of catastrophic accidents. This regulation developed from Advisory Committee on Major Hazards (ACMH) and Seveso I Directive from European Commission (HSE, 2016).

2.2.1.3 Korea

Petroleum refining industry in Korea emerged from year 1964, producing 8.26 million tons of ethylene annually in year 2015. Korea is the 6th largest country in ethylene production as following to United States, Europe, China and Saudi Arabia. There were some catastrophic industrial accidents happened in Korea which contributed by major industries. In October 1989, Yeosu Chemical plant exploded, causing 16 deaths and 17 injuries. In March 1991, a chemical spill occurred causing river pollution and affected to supply of fresh water to the community. Apart from major accident in Korea, catastrophic industrial accidents in all around the world have made Korea government realized on the importance of managing safety of highly hazardous industry.

KOSHA, Korea Occupational Safety and Health Agency was established in year 1996 to manage PSM standards in Korea (KOSHA PSM). KOSHA PSM regulation is adopted from 29 CFR 1910.119 from US OSHA and AQ/T3034—2010 from China (Yuqiao, 2016). KOSHA PSM consist of 5 major area including;

i. Submission of process safety management plan report
ii. Review of process safety management plan report by safety committee before submission
iii. Evaluation on process safety management plan report by KOSHA
iv. Enforcement of Process safety management plan report

v. Monitoring of PSM implementation by Korea Labor Institute

2.2.2 Process Safety Management in Malaysia

Despite of other developed countries such as US, UK, Japan so on which PSM is widely implemented in manufacturing industries, Malaysia is considered as way behind as compared to these countries. There are a few highly hazardous industry premises in Malaysia has adopted PSM in operation, however it is lacking of sufficient evidence on the effectiveness of PSM in their premise (Bakar et al., 2017). Highly hazardous manufacturing industries in Malaysia are still practicing some common safety management tools which insufficient to cater hazardous level in their industries. In the end of last century, Hazard and Operability (HAZOP) assessment, Layers of Protection Analysis (LOPA), Fault Tree Analysis (FTA) and so on are the common approach adopted by petrochemical industry. These approaches are functioned in controlling hazardous conditions and yet accident is still happening. This shows that these approaches are imperfect enough to cover all the underlying hazards in highly hazardous industries, leaving large gap of failure to occur at any time (B. Knegtering & Pasman, 2009). Common manufacturing industries and highly hazardous industries shall adopt different safety management approach as the consequences of these industries are widely differ. Accidents originated from highly hazardous industries due to failure of management system could be fatal and leaving long term effects to the environment and human (Ness, 2015).

Process Safety Management shall be widely implemented in Malaysia particularly in industries possessing hazardous substances and process. This is because safety culture in Malaysia is not thorough and effective in all layers of community. PSM is an open-ended yet performance-based standard which can be modified according to situation of the premise. PSM practitioners are having flexibility in designing own policy and practice to comply with established standards. From the perspective of enforcement bodies, PSM implementation can be monitored through adequate inspections and training courses to promote and update latest PSM knowledge to industries (Luo, 2010).

History of major industrial accidents in Malaysia is providing a proof to the public in which an integrated system shall be implemented to increase industrial safety status to a higher extent. This can be stipulated from the case of Bright Sparkler accident (1991) in which the plant is located at Sungai Buloh, 9m away from the agriculture land. The tragedy happened when new product testing was conducted nearby dried chemicals and fire sparks flew to canteen which stored thousands of finished and semi-done products. Explosion in the plant had caused 23 deaths and 103 people suffered injuries of various degree of burns. Poor safety awareness and safety management tool are the main contributors to this disaster. This plant had breached several regulations on Occupational Safety and Health Act 1994 (OSHA), Factory and Machinery Act 1967 (FMA), Environment Quality Act 1974 (EQA) and so on. Testing of explosive product nearby chemicals, building of plant site near towards residential area, improper storage of explosive products and so on are the examples of Bright Sparkler company having a relatively low awareness and knowledge towards safety and its consequences of their unsafe acts.

Bakar et al. (2017) addressed that industries which focusing common safety practices which focusing on personal safety will leads to ignorance of hidden failures such as equipment integrity and reliability, technological failure in terms of process safety. Koivupalo et al. (2015) too, stated that organization which having goals of sustained success would focus not only towards personal safety and health but also environment factors regardless on both working environment or the nature. PSM shall be adopted in industries which having hazardous process to provide a relatively all-rounded approach in managing safety issues. Existing safety management tools could also be implemented along with PSM in order to cover limitations of PSM. However, as more studies and research has been made on PSM, current PSM system is sufficient to cover most of the safety aspects in a premise. This is proved in OSHPSM citations had suggested that all PSM elements are able to identify potential hazards that could leads to disastrous incidents through 19 case studies (Luo, 2010).

2.3 Management of Change Element in PSM

Staff rearrangement and process improvement or alterations are some common changes that may occur in any manufacturing industries. These changes might seem harmless in normal production factory but not in highly hazardous industries. A single minor change in highly hazardous industries could be fatal and cause destruction to environment and property. These elements are functioning the four big categories under PSM;

a) Technological factor
b) Equipment factor
c) Process Chemical factor
d) Human factor

Management of change (MOC) is an element which ensuring changes will not produce unexpected new hazards or increasing risk of existing hazards (CCPS, 2014). In these industries, assessments shall be conducted to anticipate the potential risk and consequences that may happen after change implemented. (EPA, 2000) stated that there are 5 aspects that shall be considered under MOC for an efficient approach:

i. Technical basis for the proposed change
ii. Impact on safety and health brought by the change
iii. Modification to operating procedure
iv. Necessary time period for the change
v. Authorization requirements for the proposed change

MOC shall be an important element which worth for attention from employers as changes could bring both positive and negative effects to the actual process. If change planning is not well managed, the consequences of change applied is 100% negative to the premise. However, it is believed that current MOC framework is containing flaws and faults which cause industries ignored to focus on MOC. Naicker (2014) addressed that MOC is one of the less significant element effectiveness based on the studies made on PSM implementation on each element. This situation may occur when industries are not aware of the importance of MOC or current MOC approach fails to meet their expectations in process safety.

Current MOC system is having flaws in failing on documenting, maintaining and provide adequate framework to manage changes. Process changes related reports and records are not kept appropriately at easily accessible place (Bakar et al., 2017). Based on accident cause analysis conducted by Kwon (2006), inadequate MOC systems has contributed 13.4% (11 cases) of accident root cause. Time period of MOC effectiveness is another limitation of current MOC approach in which the control proposed by MOC procedure will be easily ignored after a period, even in a short period. Proposed control by MOC framework may be only practiced only for a few months for adaptation but it will be neglected after the period of "adaptation"(Centre For Chemical Process Safety, 2016). This is possessing underlying risk in which new operating procedure proposed shall be practiced permanently after change has implemented until next modification is made.

Other than that, current MOC system is only applicable in the extent of planning on operation process changes. CCPS (2014) suggested that MOC system can be expand in the extent of covering capital projects which combining results of MOC with business considerations. Design phase of improved MOC system is recommended to consider on principles used in MOC which could be applied to large scale projects in an effective and efficient way. This could bring MOC system functioning not only limited to process safety but also in terms of changes in business management. Changes in business projects shall too, conduct risk evaluation and analysis before proceeding on any business changes to avoid financial loss. Therefore, it is not impossible to expand MOC framework to a larger coverage as it functions similar towards business risk analysis process.

2.4 PSM Elements Related to Management of Change (MOC)

Management of Change (MOC) is an interdependent element which several elements shall be working together to comes with sufficient evidence for decision making phase. Although PSM contains 14 elements in total, however there are some on the elements are interrelated with MOC in process change procedure as shown in Figure 2.2.

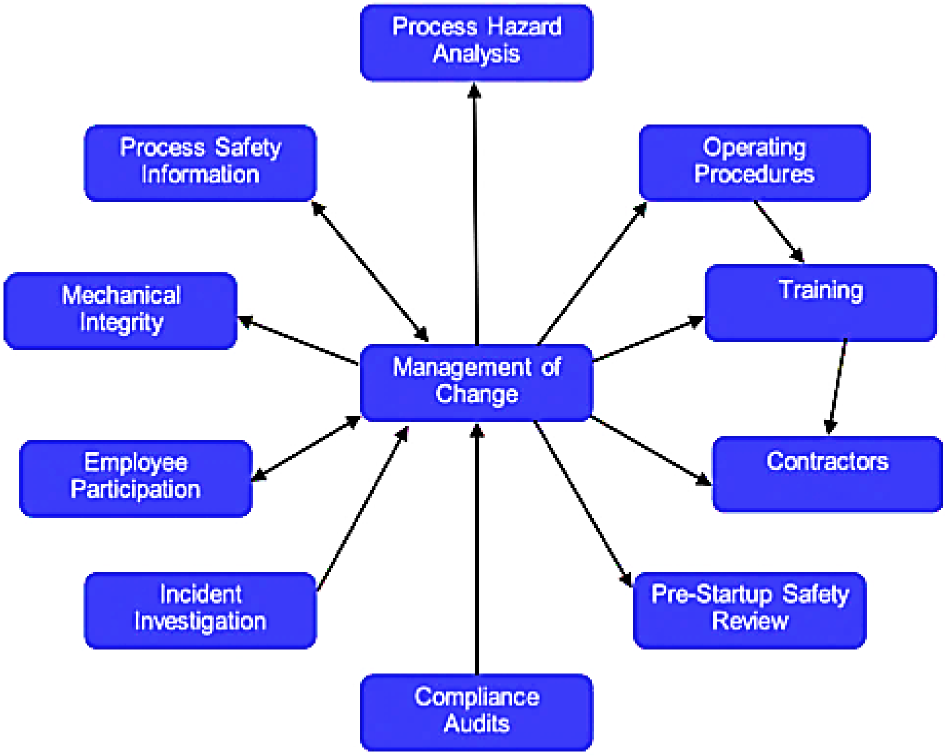

Figure 2.1: Interrelationship between PSM elements with MOC

Source: (Pacanins, 2014)

2.4.1 Technological Factor Elements

Technological factor related elements is dealing in controlling safety in terms of technology such as programming, software, operation process and so on. Technological factors are covered by process hazard analysis and operating procedure.

2.4.1.1 Process Hazard Analysis (PHA)

PHA is an approach which requires a development of thorough and systematic approach in recognizing, analyzing and controlling of hazardous process (US OSHA, 1994). There are 7 minimum requirements to be met by PSM practitioners to ensure effectiveness of PHA element:

- Prioritized actions to conduct analyses following schedule established.
- Application of appropriate method in process hazard identification and evaluation
- Establish relationship between identified hazards with potential impact and propose controls on each identified hazard
- PHA shall be performed in a team with personnel whom expert in engineering and process operation, suitable methodology and evaluation procedure.
- Establish information management systemin storing of related records, written schedule and so on
- PHA shall be updated and revalidated every 5 years
- PHAs and updates of a process shall be retained for the life of the process.

2.4.1.2 Operating Procedure (OP)

Operating procedure element is aimed to provide a clear yet efficient work procedure in each operating process which parallel with process safety information obtained. Established procedures shall address steps on each operating phase, safety considerations and systems and also operating limits on each process (US OSHA, 1994).

2.4.2 Equipment Factor Elements

Equipment is the main assets in a production industry in which machineries, automated robots, safety valves and so on are categorized under equipment. Major accident due to failure of equipment contributes the most significant number to the statistics of major industrial accident. Based on case studies conducted by Naicker, 2014, equipment failure involving system failure, inadequate maintenance and bypassed of equipment control system are the common root cause of incidents. Management of equipment is covered under mechanical integrity and pre-startup safety review elements.

2.4.2.1 Mechanical Integrity (MI)

Mechanical integrity element in PSM is to ensure all equipment used in manufacturing process are designed, assembled, installed and frequently maintained as following to established schedule. This system emphasizes on recognition and understanding on every equipment and instrumentation hence develop series of measures to ensure equipment is performing at its best efficiency. Standard operating procedure, related training on equipment handing, maintenance schedule and control steps on deficiencies found are covered under this element (US OSHA, 1994).

2.4.2.2 Pre-Startup Safety Review (PSSR)

This element is to make sure any new facilities, or new changes on existing facilities shall be reviewed to ensure construction of facilities and equipment are following design specification. Safety control system, operating and emergency procedure and maintenance schedule on every equipment is provided and adequate (EPA, 2000).

2.4.3 Process Chemical Factor Elements

Process chemical factors involve in dealing with ensuring information every hazardous chemical used in process are known and considered. Operating procedure, maintenance schedule and training of personnel are examples of some of the elements which requires sufficient information on chemicals. At minimum, safety data sheet which addressing categories of hazards possessed, labelling requirements, composition of chemicals and so on are the basic information shall be provided by chemical suppliers (DOSH, 2013).

2.4.3.1 Process Safety Information (PSI)

PSI element is playing a role in ensuring accurate and adequate information on chemicals and manufacturing process itself are provided. This is essential in developing an effective safety management system and to provide sufficient information for PHA assessment. Process chemical, process technology and related equipment shall be addressed in written PSI report. US OSHA (1994) stated that there are minimum requirements which shall be provided in PSI report;

i. Toxicity information
ii. Permissible Exposure Limit (PEL)
iii. Physical data
iv. Reactivity data
v. Corrosivity data
vi. Thermal and chemical stability data
vii. Potential hazardous effects of inadvertent mixing of different materials

2.4.4 Human Factor Elements

Human is the main assets in a manufacturing factory in which workforce requiring human intelligence and manual handling. In spite the fact that many technology creations such as artificial intelligence robots and automated machines have been created to lessen the burden of manual handling workforce, however these technologies will not be functioning well without supervision of human.

2.4.4.1 Training

Training is the important elements in human factor in which this process is essential in transformation of newly employed workers in mastering necessary techniques, skills and knowledge related to work task. Non- trained workers are considered as a hazard which they might operate equipment and instrumentation wrongly.

Therefore, this element is to ensure newcomers understand the nature of work task, basic hazard identification skills and safety requirements on related work task. US OSHA (1994) suggested that an effective training program shall include initial, refresher training and documentation on training progress and improvement.

2.4.4.2 Emergency Planning and Response (EPR)

EPR element addressed the requirement on immediate actions that shall be taken by employees when process went out of control. Emergency response is differing in different situation such as unwanted release of chemicals, breakdown of equipment or explosion incidents. Emergency planning shall include these basic criteria as stated under OSHA PSM regulation, CFR 1910.119 (US OSHA, 1994).

i. Escape routes and procedure
ii. Post-evacuation employee accounting procedure
iii. Emergency reporting means
iv. Duties and procedures of selected employees who:
    - Remain to operate critical equipment
    - Perform rescue and medical duties
    - Contact person or location for detail action plan information
    - Employee alarm systems

2.4.4.3 Employee Participation (EP)

Operating a process with solely monitoring by supervisor is impossible in mitigating all potential hazards in process operation. Supervision by workers whom performing work task on a certain process would be the most accurate method in detecting faults and errors as workers is working with the same equipment 12/7 shift. Employees would be the persons whom know the equipment well. Therefore, employee participation is encouraging employees to actively participate in hazards reporting in process to mitigate potential of catastrophic incident. This enhance on two-way communication between employers and employees to improve process efficiency and safety level (US OSHA, 1994). Employees participation is particularly important after changes take place to detect any abnormal situation or performance of equipment.

2.4.4.4 Contractors (CTR)

Element on contractors require highly hazardous industries company to be cautious in selection of contractor to perform work in premise. Screening of contractors shall be performed before selection of contractors whom able to perform work task without compromising employees' safety and health. Contractors, in this context is including subcontractors which does not hired by employer as permanent workers but only temporary work project in the premise. Contractors is considered as outsider whom requires safety briefing on safety precaution and emergency action plan during first entry to the premise. This is because highly hazardous industries are not allowed to compromise to any unexpected hazards which may cause to occurrence of disastrous accident (US OSHA, 1994).

2.5 Importance of Management of Change

Management of change, MOC should be an essential element which employer shall pay attention to the benefits of implementing this approach. Application of changes without well planning may cause severe consequences to many aspects. Consequences may not come directly after changes but will be any day in the future when all situations come together forming an opportunity for accident to happen. This situation is in accordance with Reason's Swiss Cheese Model as shown in Figure 2.2.

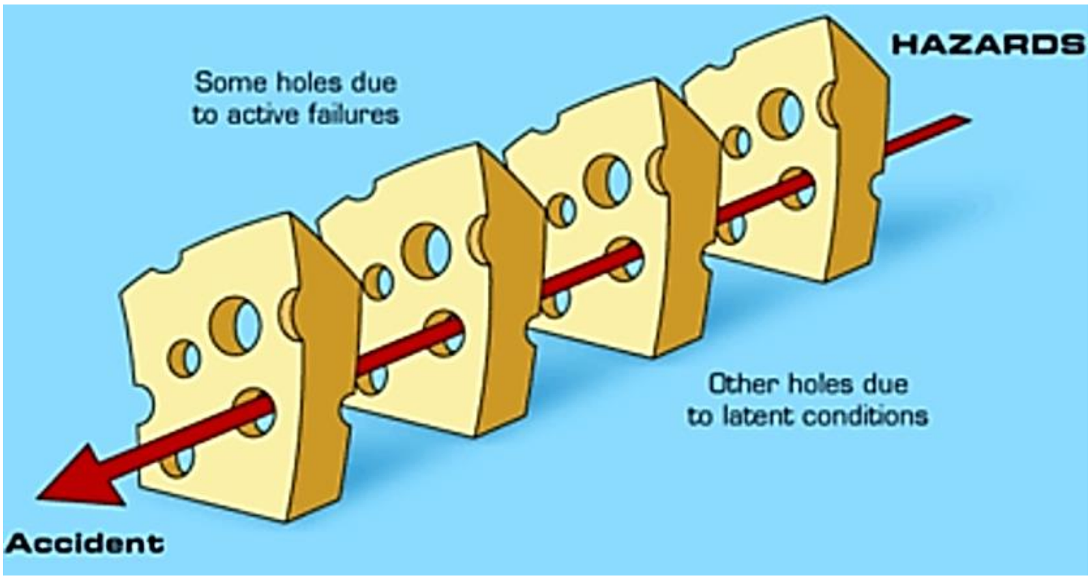

Figure 2.2: Reason's Swiss Cheese Model
Source: (Reason, 2000)

There are a few major industrial accidents happened due to absence or poor MOC procedure. Bakar et al. (2017) conducted a case studies on 770 major accident cases obtained from available occupational accident databases. Each PSM element is ranked according to the effectiveness and frequency of failure in accident prevention purpose. MOC has contributed about 9% of among all the accident occurrence. One of the major accidents which stipulated the importance of MOC in highly hazardous industries. In year 1990, a wastewater tank had exploded at ARCO chemical plant which located in Channelview, Texas. This incident occurred due to significantly reduction on nitrogen purge during maintenance meanwhile temporary oxygen analyser unable to detect accumulation of flammable gas in the tank. Absence of appropriate MOC system was the largest contributor to the incident where no risk assessment made to analyse the potential hazards and consequences. Employees are not educated with consequences of their maintenance procedure. Furthermore, pre-start up review is not conducted after maintenance work is done.

In business world, successful enterprise shall have the ability in managing and exploiting changes effectively, turning unpredictable situation into business opportunity. Therefore, enterprise will require effective MOC system to survive in ever-changing world. MOC is having an advantage in not only applicable to process safety but also in terms of business perspective. MOC system covering planning and proposing tactical control actions on potential risk (Koivupalo et al., 2015; Kontogiannis, Leva, & Balfe, 2017). Zwetsloot et al. (2013) too, addressed that integrated yet effective MOC framework is necessary in managing complex system and organization. MOC is relatively challenging to ensure a company to stay resilience from hazards and underlying risks. For example, a premise planned to increase productivity rate in order to meet the market demand is required to increase flexibility in operating procedure and process installation. MOC system is important in planning the suitable changes that shall be made on equipment and technology (Bert Knegtering, 2002).

Other than that, any new improvement or technology requires evidence in building confidence on users and consumers. Management often consider the benefits behind changes proposed before any investment decision is made (Utne, Brurok, & Rødseth, 2012). MOC system is providing scientific evidence by reviewing, analysing on accident reports, safety standards on a proposed change or modification may aid in employer's decision making. It is showing evidence through statistics and previous lesson that is strong in terms of reliability and validity (Wang, Wu, Shi, & Huang, 2017).

Centre For Chemical Process Safety (2016) addressed that the degree of potential hazards is varying among facility and operation process. Improvement of PSM element effectiveness will be more significant in higher hazard facility. This is because highly hazardous facility is unable to compromise any single minor mistakes on process or equipment modification. For example, highly hazardous industry will require stronger MOC system in managing changes as this industry is dealing with reactive chemicals which easily react with oxygen gas. Managing of risk in highly hazardous industry involves selection of effective preventive barriers is important in mitigating risk. Analysing hazard level of residual risk, cost and benefits shall be considered under MOC element to establish suitable safety interventions by considering financial and process safety aspects (Wang et al., 2017).

2.6 Comparison of PSM standards on MOC

2.6.1 PSM Regulation in US Occupational Safety and Health Administration

US Occupational Safety and Health Administration (OSHA) had established PSM standards in February 1992 with the title of Process Safety Management of Highly Hazardous Chemicals. However, PSM standards in US is only made after experiencing a series of chemical disastrous events. These events had brought catastrophic consequences to all parties which eventually leads to promulgate of PSM standards that aims to increase safety level in chemical industries (Long, 2009). 14 elements has been incorporated into the standards to manage all aspects in an industry on technological, personnel and equipment factor (H A Aziz & Shariff, 2017). Requirements on MOC by 29 CFR 1910.119 is stipulated under Table 2.1.

Table 2.1: 29 CFR 1910.119 on Management of Change

29 CFR 1910.119(1)	**Explanation**
1910.119(1)(1)	Establish written procedure to process chemicals, technology, equipment and procedure.
1910.119(1)(2)	Requirements on established procedure.
1910.119(1)(3)	Training and delivery of information to related employees
1910.119(1)(4)	Update process safety information (if necessary)
1910.119(1)(5)	Update operating procedure (if necessary)

Source: US OSHA ,1994

2.6.2 PSM Regulation in Europe/ UK

Control of Industrial Accident Hazard Regulation 1984 (CIMAH) was first enacted in year 1999, acting as a guidance to industries to comply with Seveso Directive I. CIMAH 1984 was then adopted by Malaysia to prevent occurrence of industrial accident. CIMAH 1984 was then improvised into CIMAH 1999 and changed to Control of Major Industrial Accident Regulation (COMAH) 2015. COMAH 2015 is enacted to prevent and mitigate the occurrence of major accidents which may cause permanent damage or harm to people and environment (HSE, 2015b). MOC requirement in COMAH 2015 is shown in Table 2.2.

Table 2.2: COMAH 2015 on Management of Change

COMAH 2015	Explanation
Reg 7 Schedule 2(2)(d)	- Establish written procedure to process chemicals, technology, equipment and procedure. - Procedure shall address: • Definition of the change • Related responsibility and authorities to initiate change • Documentation of planning and implementation progress • Impact analysis on change proposed • Documentation on related information including update on operating procedure and training • Definition on post-change review procedures, corrective measures and subsequent monitoring

Source: HSE, 2015a

2.6.3 PSM Regulation in US Center for Chemical Process Safety

Centre for Chemical Process Safety (CCPS) was created in year 1985 by American Institute of Chemical Engineer (AIChE), functioning to develop and publish latest technical information in major industrial accident prevention specifically on chemical related industry. Risk Based Process Safety is then created to provide framework of process safety management to the public. RBPS recognizes that all hazard occurrence is unequal. RBPS approach is built upon four foundation pillars; commit to process safety, understand hazards and risk, manage risk and learn from experience. RBPS requirement on MOC is shown under Table 2.3.

Table 2.3: RBPS on Management of Change

RBPS	Explanation
Maintain a dependable practice	- Establish consistent implementation on MOC - Involve competent personnel - Keep MOC practice effective
Identify potential change situation	- Define MOC system scope - Manage all possible source of change
Evaluate possible impacts	- Obtain and provide essential information to manage changes - Apply thorough procedure in review process
Decision making	- Change authorization - Ensure authorizers addressed important issues
Complete follow-up activities	- Records update - Changes information delivery to related personnel - Establishment on risk control measures - Records storage

Source: CCPS, 2014

2.6.4 PSM Regulation in US Environmental Protection Agency (EPA)

United States Environment Protection Agency (EPA), established in year 1970 which function to ensure environmental protection is made through research, enforcement and standard-setting (EPA, 2018). EPA is then promulgated the plan called Risk Management Program (RMP) regulation to contribute in chemical accident prevention. RMP (40 CFR 68) aims on mitigating risk of chemical accident at local level, providing guidance in emergency preparedness and response plan and to disseminate knowledge on chemical hazards to the public (H A Aziz & Shariff, 2017). 40 CFR 68 requirement on MOC is shown under Table 2.4.

Table 2.4: 40 CFR 68 on Management of Change

40 CFR 68		Explanation
§ 68.75 (a)	-	Establishment of written procedure related to changes made that affect covered process
§ 68.75 (b)	-	Criteria shall be addressed in written procedure
§ 68.75 (c)	-	Information delivery and training to affected employees by change implemented
§ 68.75 (d)	-	Update process safety information (if necessary)
§ 68.75 (e)	-	Update operating procedure (if necessary)

Source: EPA, 2000

2.6.5 PSM Regulation in China

China has been one of the leading countries in manufacturing industry meanwhile it also is also leading in occurrence of disastrous accident. From year 1979- 2010, several chemical industrial accidents happened and cause severe effect to the surrounding. 103 lives had been killed and around 900 people injured. Therefore, regulations and guideline for process safety management in petrochemical corporations (AQ/T 3034-2010) has been established to enhance safety level among petrochemical industry in China. AQ/T 3034-2010 requirement on MOC is shown under Table 2.5.

Table 2.5: AQ/T 3034-2010 on Management of Change

AQ/T 3034-2010 (4.9)		Explanation
4.9.1	-	Establishment of written procedure related to changes to protect human, environment, property and company reputation.
4.9.2 (a-e)	-	Criteria shall be addressed in written procedure
4.9.3	-	Update of process safety information.
4.9.4	-	Delivery of information and training provided to affected employees and contractors on changes made.
4.9.5	-	Further information on MOC may refer Guidelines on petrochemical process safety management (AQ/T3012-2008) (11).

Source: State Administration of Work Safety, 2010

2.6.6 PSM Regulation in Canada

Process safety management in Canada is applied based on voluntary initiatives program. Canada does not establish own legislation to enhance PSM implementation among highly hazardous industry but mostly adopted from Centre for Chemical Process Safety (CCPS). This Process Safety Management Guide was prepared by Process Safety Management Division of the Canadian Society for Chemical Engineering (CSChE) which intended to provide introductory guidelines for Canadian PSM practitioner on PSM implementation (CSChE, 2012). CSChE PSM Guide requirement on MOC is shown under Table 2.6.

Table 2.6: CSChE PSM Guide on Management of Change

CSChE PSM Guide	Explanation
5.0 Management of change	- Criteria shall be addressed in written procedure.
5.1 Change of process technology	- Proposed operation shall subject to review and approval by qualified personnel. - Qualified personnel shall be available when authority needed at short notice.
5.2 Change of facility	- Hazard assessment on equipment on proposed changes. - Procedure established shall be available for minor and major changes, simple yet approved by qualified personnel.

Source: CSChE, 2012

Table 2.6: CSChE PSM Guide on Management of Change (Continue)

CSChE PSM Guide	Explanation
5.3 Organizational changes that may have impact on process safety	- Transition period and new organization shall be addressed. - Departure of staff or any changes in organization units shall not interfere accountability and safe control of operation in the premise.
5.4 Variance procedures	- Simple procedure for exceptions shall be established and approved by qualified personnel.
5.5 Permanent changes	- Should subject to usual MOC framework and handled in conjunction with other plant program - Conduct appropriate risk management
5.6 Temporary changes	- Should subject to condition as permanent changes - Time limit shall be clearly defined

Source: CSChE, 2012

2.7 General Concept on MOC Framework

A framework shall able to provide an overview to end user on a system process on early planning of budget, time required and so on. A system framework shall able to include all necessary details and information for the process (Majid, Shariff, & Rusli, 2015). A complete MOC framework shall inculcate technical dimensions and impacts brought by the change. This can be determined by various type of risk assessment to aid in decision making. Organizational dimensions shall also be addressed in the result of the framework including workers distribution and training on related change. Other than that, consecutive steps on a specific action item shall be anticipated when result obtained is not as predicted (Gerbec, 2017). Example of framework is shown in Figure 2.3.

Based on Gerbec (2017), MOC process begins with change proposal and identification on type of change. There are checklists attached along with criteria in each change category, including organizational policy, management system, PSM element and technical details. Impacts and summary shall be conducted after all risk assessments. MOC change proposal and approval process will be ended with documentation of related information. However, change implemented shall be monitored to prevent unexpected risk arise.

Center for Chemical Process Safety (2008) published an example of MOC system procedure work flow chart showing a general concept with recommended essential action items. Request change form shall be the initiation step of MOC procedure. Once change is approved, proposed change shall be evaluated whether meets the definition of change as established. Multidisciplinary review on potential hazards and associated risk shall be conducted. If multidisciplinary review is unnecessary, a simple review shall be conducted to addressed potential hazards accompanied with the proposed change. Pre-implementation tasks shall be completed before proposed change is implemented, meanwhile controls shall be applied along with change implementation to control associate risks. Post-implementation task shall be carried out to review the effectiveness of control measures established.

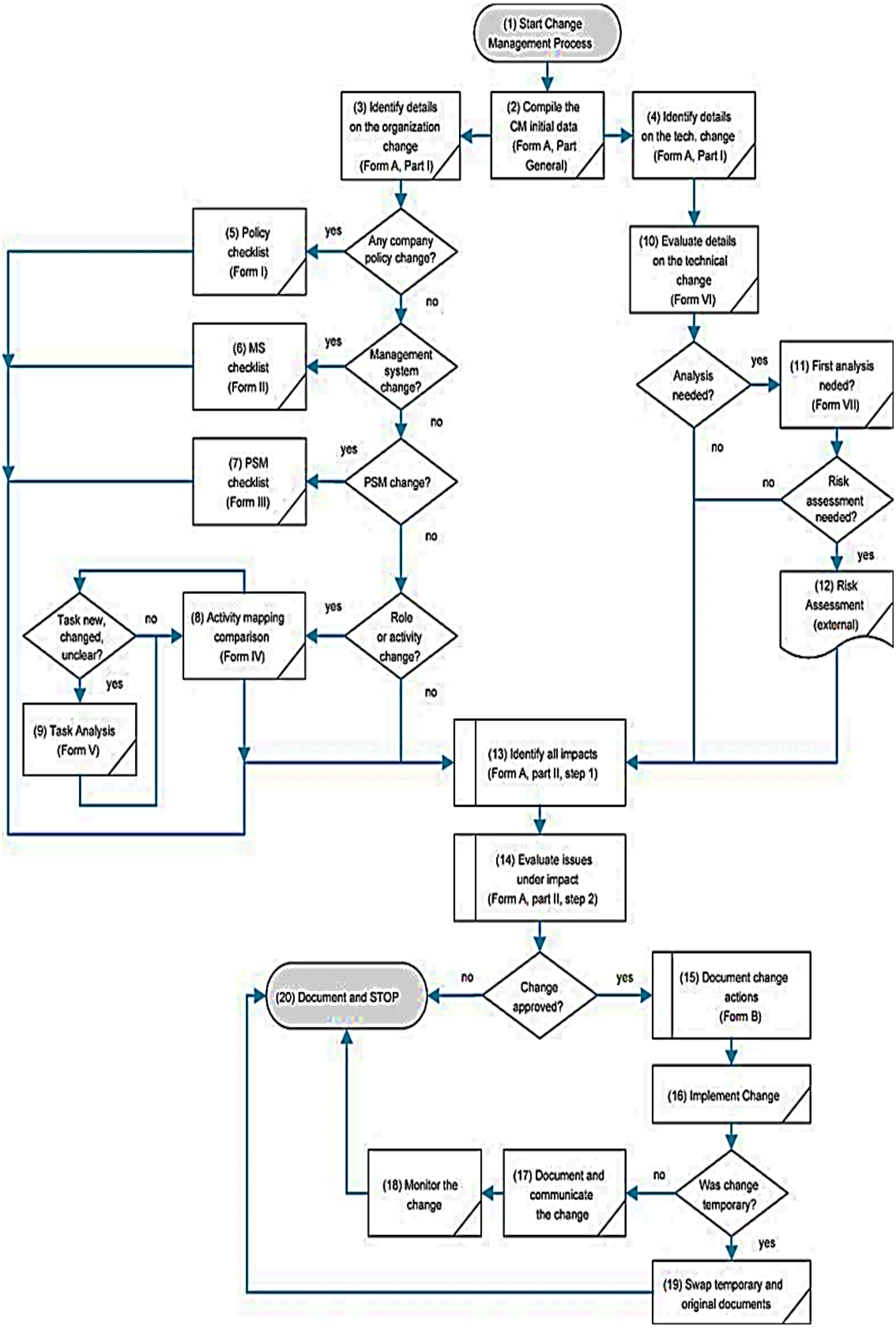

Figure 2.3: Example of MOC framework

Source: Gerbec, 2017

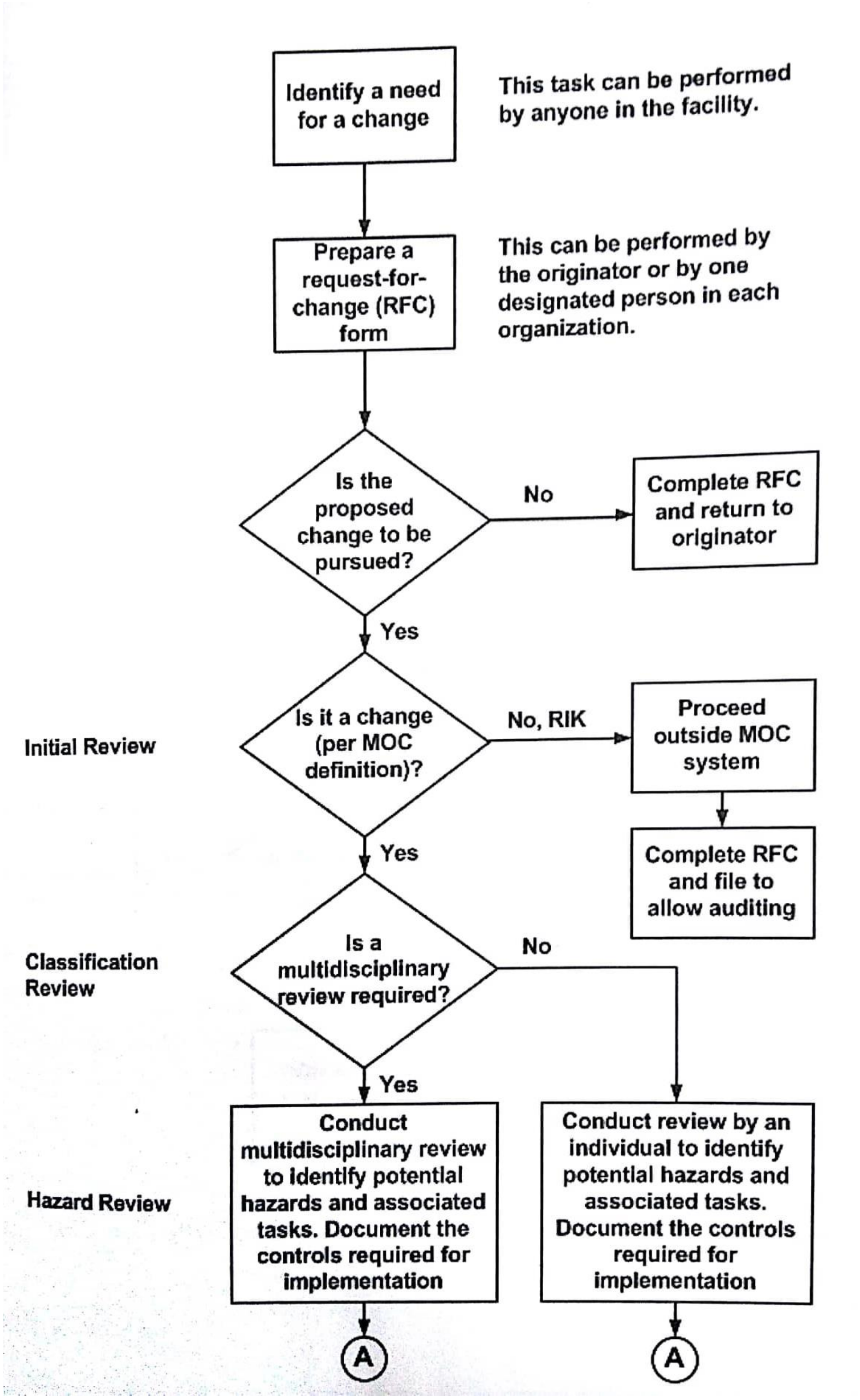

Figure 2.4: Example of MOC System Procedure Work Flow Chart

Source: Center for Chemical Process Safety, 2008

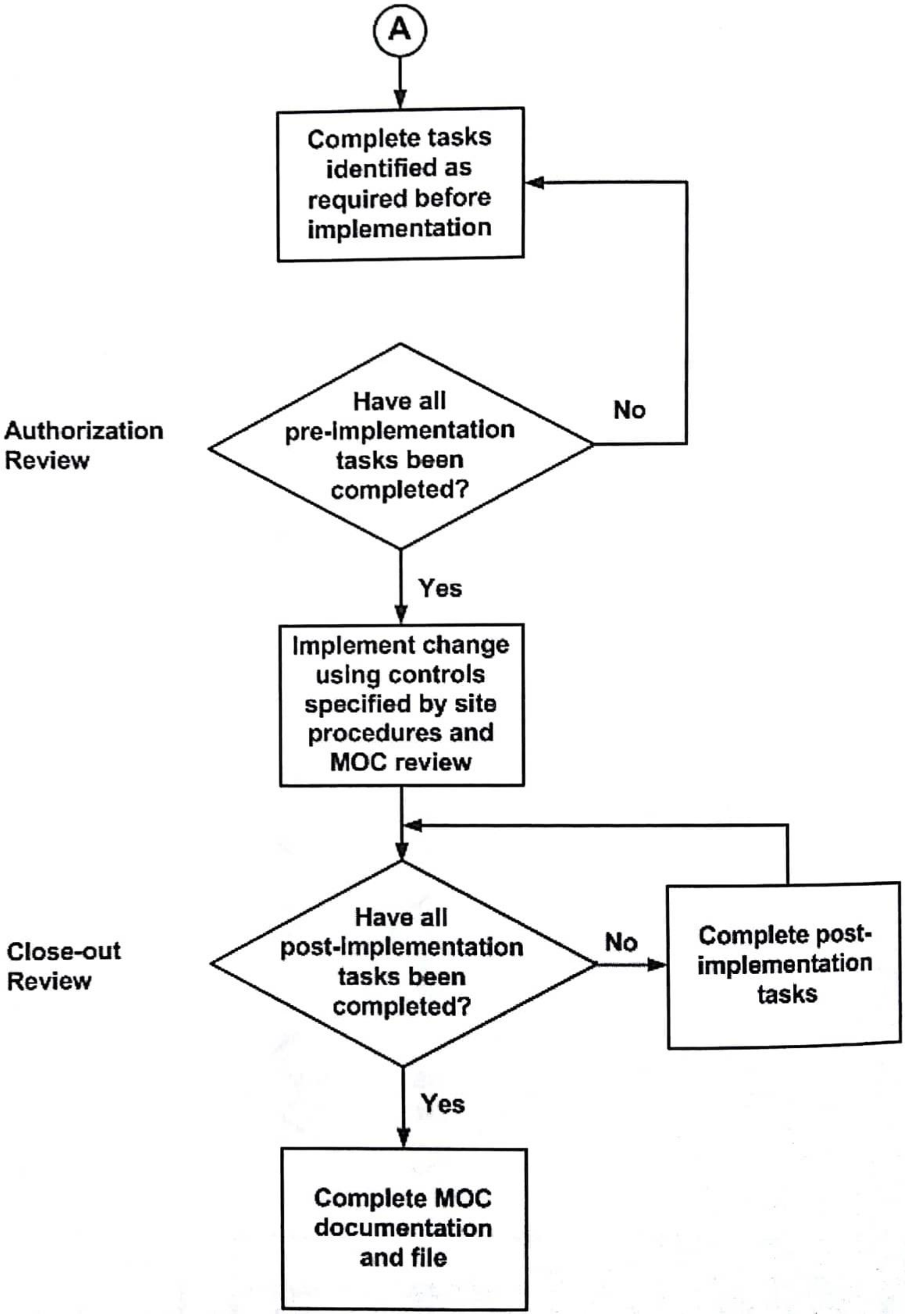

Figure 2.5: Example of MOC System Procedure Work Flow Chart (Continued)
Source: Center for Chemical Process Safety, 2008

2.8 Introduction of Technology in MOC

Kletz (2001) stated that human has higher tendency in making errors when they are required to perform task beyond mental and physical disability. Mr Trevor Kletz claimed that human will not escape from making mistakes unless that living being is not a human. Although human errors are claimed as not the root cause of industrial accidents, however this could be one of the contributing factors (Kletz, 2001b). In management of change, there are many procedures and actions items that requires attention by assessor. Compliance of standard, criteria in assessment checklist, result analysis and so on shall be conducted to perform a whole MOC system. This could be a large burden to human to perform it without any aiding tools acting as reminder for each action items under MOC framework. As workload is getting complex and heavy, an integrated management system shall be introduced to safety management to aids in process safety (Centre For Chemical Process Safety, 2016). Arruda (2006) too, had agreed on the same opinion in which databases and previous intervention shall be involved in MOC framework.

There are various kinds of software and application made available in the market which designed to cover extreme parts that human is unable to perform. For example, technology can be manipulated to ease the work of documenting, sharing of information or reviewing previous record. Software tool would be useful in storing of large or previous reports for future review purpose (Gnoni et al., 2013). These all can be all done by moving fingertips instead of traditional approach on using hard copies.

Technology can be used in providing a clearer overview on MOC system on each step, what standard they should comply and what kind of gaps are existing in their system. This methodology has been proved by a case study conducted in which a local refinery. Prototype model which developed based on emergency planning and response (EPR) is applied in the premise and has proven that it managed to aid in managing of PSM standard compliance (Majid, Shariff, & Loqman, 2016). Examples on Microsoft Access management system are shown in Figure 2.4 and Figure 2.5. These examples are showing the common interfaces in Microsoft Access. Apart from that, there is another eletronic MOC (eMOC) designed specifically for Eastman Chemical Company in which held several functions including record keeping, approvals, notification, tracking, reporting and audit trails. One of the advantage of this eMOC is constrcucted to function in intranet of company which it would be accessible to all employee of the company (Garland, 2004). Example of eMOC is shown under Figure 2.9.

Figure 2.6: Example of Microsoft Access Management System

Source: Majid et al, 2014

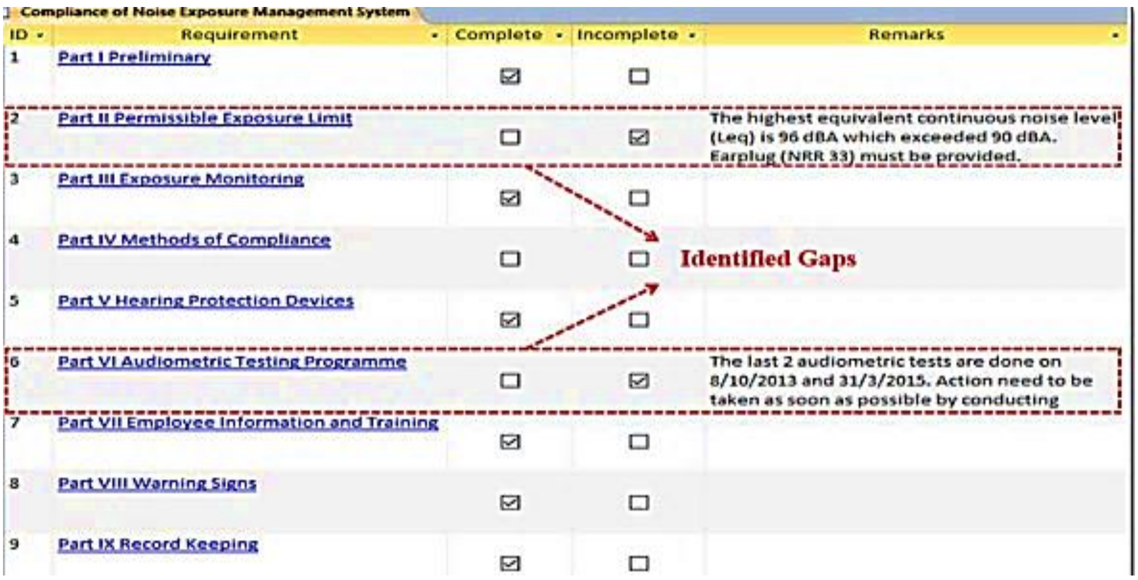

Figure 2.7: Example of Microsoft Access Management System Main Interface

Source: Leong & Aziz, 2017

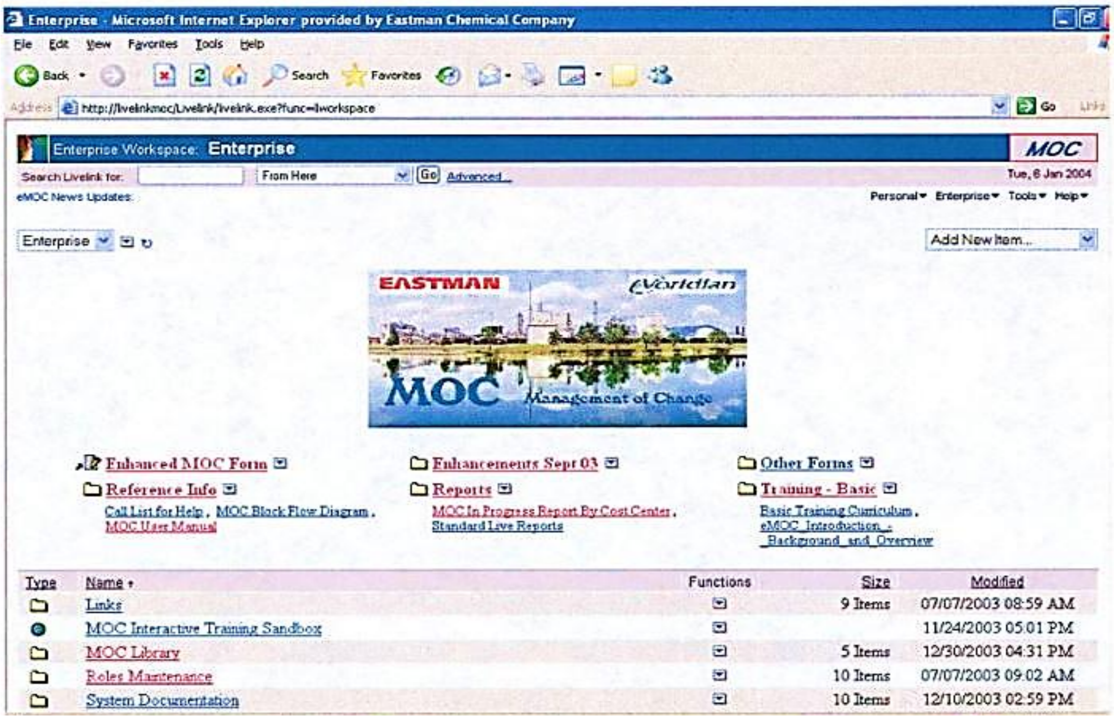

Figure 2.8: Example of eMoc Home Page

Source: Garland, 2004

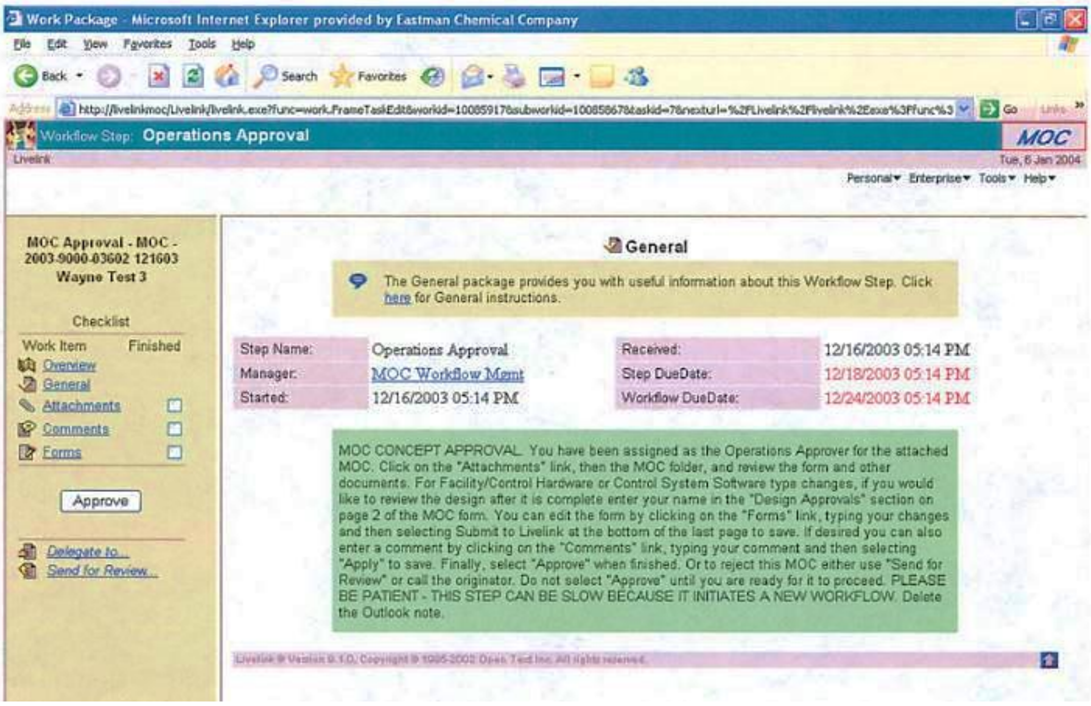

Figure 2.9: Example of eMoc Workflow Step

Source: Garland, 2004

2.9 Conclusion

Literature review above has stipulated there is weakness flaws in current MOC approach and improvement is needed to manage change in highly hazardous industries. MOC is important in process operation which potential risk and consequences will be analyzed before any changes is made. Comparison of regulations and standards around the world is conducted in order to provide freedom in selection of standards to be adopted which match situation in Malaysia chemical industry.

Importance of MOC and technology in process safety have also been highlighted above showing the relationship between technology and MOC system. Application of technology may enhance effectiveness of MOC system in standards compliance and documentation of related records.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter is discussing on the research method and procedure adopted to achieve objectives of study. Methodology is commonly referred as the techniques that applied to conduct research including data collection and analysis instruments. Modern tool usage is addressed under this chapter which shows how outcomes of each objective was achieved using these tools. This chapter consists of study technique, study instruments and validation technique for this study. Figure 3.1 shows the overall process flow of the study. Appendix A shows the Gantt Chart for timeline planning for this thesis. Literature review has begun when research title was selected. It is done by searching related information via internet, books and other sources. Comparison on established PSM regulations on MOC is then conducted to select the best regulation which provides detail guidelines and requirement on every criteria and action items. A brainstorm on integrating element was conducted to propose improvement on current MOC process. Selection of integrating element was done by referring to problem statement identified and searching on related solution to minimize selected issue. Next, development of framework, MOC management system and validation of management system is conducted once all the preparation work and information are complete. A checking step was implemented to determine whether developed MOC framework and management system fulfilled selected PSM requirement and selected risk assessment complete to cover all area of operation process.

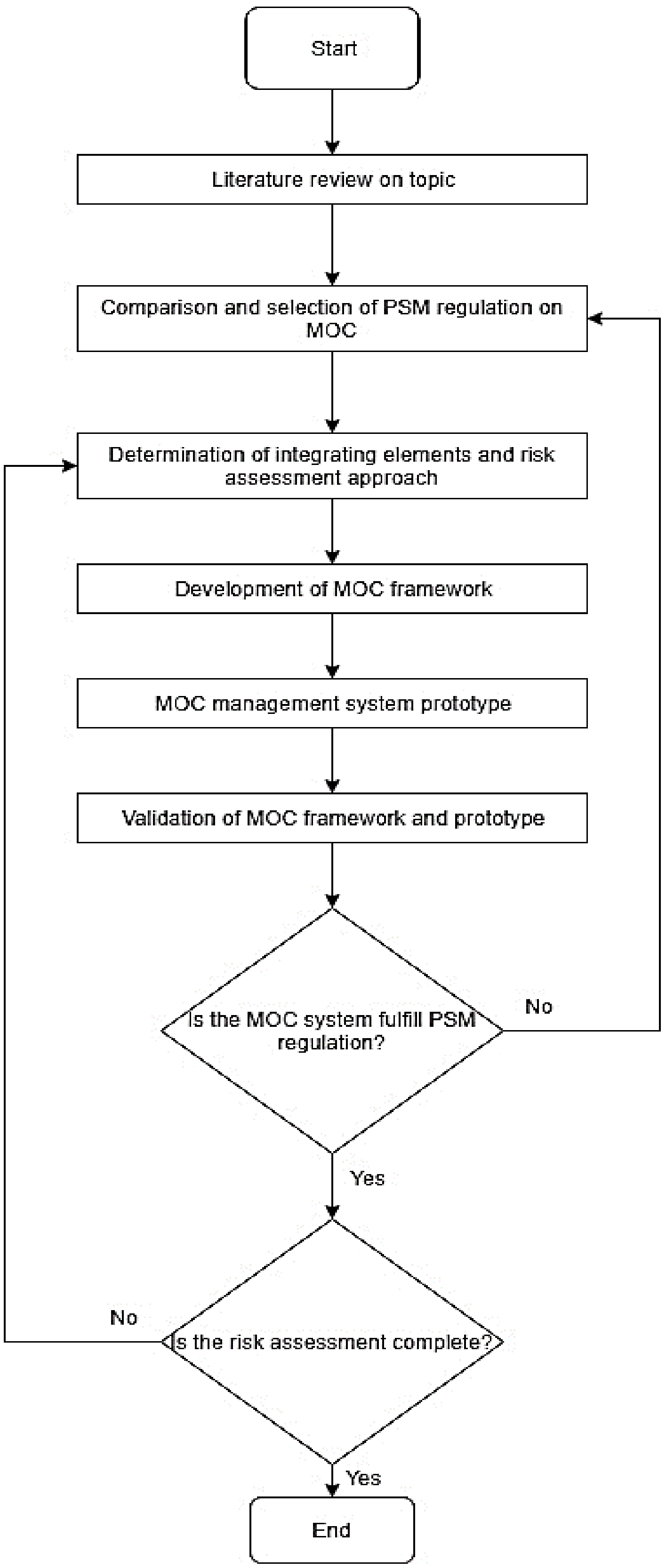

Figure 3.1: Overall Methodology Process Flow

3.2 PSM Standard Analysis on Management of Change Element

PSM standards were compared and analyzed on MOC elements in each standards and regulations. 29 CFR 1910.119, 40 CFR 68, RBPS, AQ/T 3034-2010 and PSM guide were studied in deep on MOC requirements and criteria in each standard. Requirements and criteria in every selected standard are stipulated under Chapter 2. Further analysis is done on the literature review obtained. Literature review were conducted by deciding keywords and begin searching on previous research studies and journal articles. Example of keyword used in this study including management of change, process safety management, management system and so on. Relevant sources of databases such as Science direct, Springer, research gate and many more were applied to search on relevant journal articles and related information was cited in this study.

3.3 Development of Framework

A Plan Do Check Act (PDCA) model was applied to provide a general review of MOC system to educate related personnel on MOC system. A year 1991 PDCA cycle was applied in this study as this model is suitable for science of improvement study. PDCA cycle comprises of 4 steps which is plan, do, check and act. This model highlights important objective in every stage of the cycle. For example, planning stage highlights the important criteria before implementing changes such as important risk assessment, prediction on potential impacts and so on. Related risk assessment and data collection shall be carried out for further analysis on the feasibility of the potential change. Do is the stage where change is initiated. Any unexpected observation or situation shall be recorded. Checking stage is the monitoring of the MOC framework conducted earlier in order to ensure no overlooking of important action items which may affects the reliability of risk assessment outcomes. Lastly, act stage is to review the MOC process to identify underlying faults or weaknesses and to make improvement for future. PDCA cycle model was established to provide an overview on MOC system on before and after changes applied in manufacturing process.

PDCA cycle shows in Figure 3.2 comprises human, technological, management and goals to be achieved throughout the process. According to Gerbec (2017), planning of MOC starts with collection of information on the potential change. Evaluation on technical and organizational aspects shall be considered to prepare an effective plan implementation. Planning of change management method shall address impacts in production process, necessity of changes on every process and full risk assessment on the specific process if change is required. When change is required, change proposal shall be produced and the progress of operation process shall be monitored to manage any unexpected consequences. Actual change process is required to be monitored regularly to ensure the change will not cause any hazards to the premise. Change implementation process and plan shall be reviewed and improved for more systematic MOC procedure.

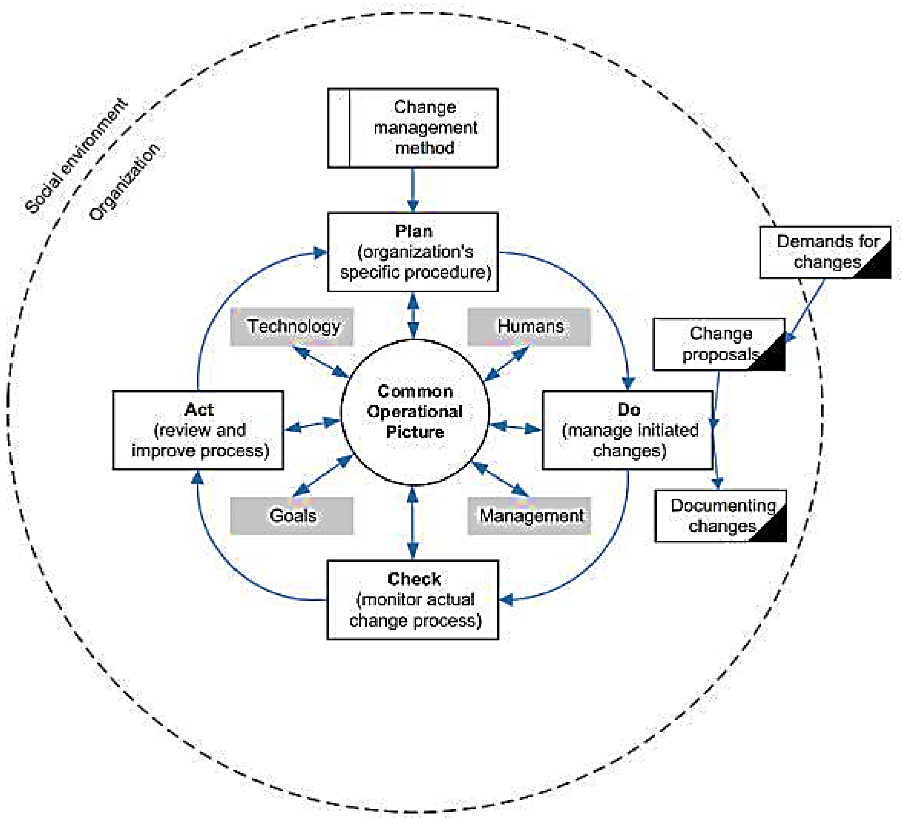

Figure 3.2: PDCA cycle model

Source: Gerbec, 2017

Framework of MOC was developed based on standard selected in earlier step for compliance of standard. This framework summarized all vital action items, standard requirement and strategies in managing changes in process operation. Overview of the framework is constructed by using Microsoft Word in flowchart format in which provide a clear picture on each step to be taken in MOC system. Feedback loop is applied at the end of the framework which emphasis on completion of every action items in the framework. Any incomplete of action items requires personnel to conduct incomplete action item before proceeding to decision making phase. This framework functioned under planning stage in PDCA model which functions to collect related data and information on the potential impacts that will be brought by the change.

This MOC framework is considered as integrated as inculcate all requirements on US 29 CFR 1910.119 regulation from the begin until the end of MOC process. PDCA cycle provides an overview on the process which each stage is covered in this study. Planning stage, which requires various kinds of risk assessment checklist are provided with a standard framework on every step to be taken. Checklist in Appendix B and C are functioning to covers technical and organizational change risk assessment for end user of this framework. The remaining stages in PDCA cycle were covered by MOC management system which functioning to store all related reports, acting as monitoring aiding instrument on regulations compliance and database to store reports for long term period.

Appendix B is showing the general checklist for end user to perform early identification of involved parties and equipment on the change. Checklist in Appendix B is adopted from Canadian Society of Chemical Engineering Guidelines on MOC (CSChE, 2004) whereas Appendix C is adopted from a research study on MOC by Gerbec (2017). Requirements or criteria which is involved will be directed to a specific section in Appendix C to perform further risk assessment. Figure 3.3 shows the sequence of appendices that completes each action item in MOC management system

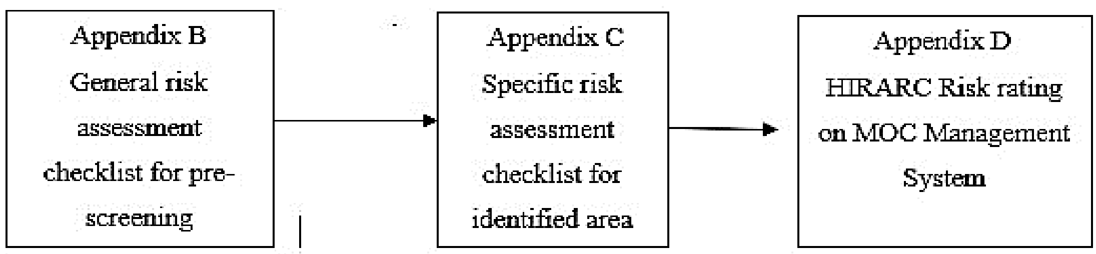

Figure 3.3: Sequence of Appendices Function in MOC Management System

3.4 Development of MOC Management System

A user- friendly and systematic software was chosen as database management system on MOC. This management system acting as a guidance to personnel on standard compliance and record documentation. Microsoft Access software was selected to develop the MOC system as this software does not required special skills in operating the system. Microsoft Access operation is much similar than Microsoft Excel but Access is relatively appropriate in developing management system. Interfaces were constructed, listing on every standard that should be complied and relative action items to comply on the standard. Prediction on time required input on each action items was designed to overcome current MOC framework which applying time-motion based concept. This concept is addressed to be limitations of MOC system effectiveness which influenced employees' hazard recognition skills (Zwetsloot et al., 2007). Instead, prediction of time allocation would be a suitable alternative as current MOC approach is lacking on prediction of time required to perform a whole planning of a change on process safety. This is to aid on initial planning of MOC to complete evaluation and analysis stage to reach decision making phase. Risk rating on each assessment performed input was embedded to aid in decision making and analysis phase in evaluating potential consequences of the change in both of business or process safety perspective.

Microsoft Excel was utilized for documentation and checklist software which details of every risk assessment checklist will be stored in the software and interlinked with Microsoft Access. Application of Microsoft Excel and Microsoft Word in the management system is to overcome the limitation of Microsoft Access in documentation of all reports and risk assessment related in a MOC planning. This two software is applied to overcome weaknesses of both software.

MOC management system was created by starting from blank Microsoft Access database. Tables were created to store all necessary information in fields. Several forms were created to provide data entry pages for user. Assessment completion log are included and divided accordingly using different table. Google drive, a cloud-based storage was used as external file storage for MOC related reports. Microsoft Excel is used to display risk assessment checklist which can be used in the format of softcopy and hardcopy.

3.5 Development of MOC Management System

Based on the underlying lying weaknesses as identified in Chapter 1, it is found that risk rating could be embedded to categorize the significance of change that will cause to the organization and process operation. Risk rating were allocated at the end of every identified hazard and impact. This may aid in planning of resource and financial investment on control measure on high rating risk. Other than that, risk rating on risk assessment may help in decision making on the implementation of change in the organization.

In this study, a PHA risk rating is embedded in risk assessment checklist (Galante, Bordalo, & Nobrega, 2014). The risk rating is shown in Appendix B. This risk rating is selected over as this risk rating addressed not only occupational safety but also financial loss and any potential environment and property impacts.

3.6 Location of Study

Two case studies were conducted at two process industries which located at Gebeng, Pahang, Malaysia. Evaluation and feedback from industries practitioners are important in making improvement on developed management system which fits the real operation process. Industries practitioners are acting as end-user which their preferences shall be prioritized to create a user-friendly and effective system.

3.7 System Validation

Validation of developed MOC system were conducted through case study approach. Validation process were conducted at two highly hazardous industries. Operation method of developed management system was presented and explained to selected safety and health personnel to fully utilize management system created in order to ensure the reliability of the management system in aiding MOC system application. Other than that, review of documentation and interview session with industries practitioners are conducted to optimize developed MOC system.

Case study validation is one of the strong result validation method as it is tested with actual situation in operation process. This allow researcher to obtain proofs on practicality of developed system apart from theoretical explanation. Case study approach too, having an advantage which allow researcher to study complex process of industry in depth (Bert Knegtering, 2002). Industry practitioner may easily identify benefits and weaknesses of developed system by comparing to previous approach applied.

There were safety practitioners with various background participated in validation process whom provide suggestions and feedback in different perspective towards the management system. Table 3.1 shows the background of each evaluator in validation process. Feedback forms were distributed to every evaluator which consist of scaling of every criteria listed comprising of systematic level, accuracy and so on. There is also a subjective column in the feedback form which enable evaluator to list down their personal comment.

Table 3.1: Background of Participated Evaluator in Validation Process

Process Plant	Background	Job position
A	Process operation	Process Safety Engineer
A	Occupational Safety and Health	Safety Manager
B	Process Operation	Plant Director
B	Occupational Safety and Health	Safety Officer
B	Quality and Environment	Quality and Environmental Officer

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter discuss in detail on objectives and result in this research study. There is a Management of Change framework developed to provide guidelines for end user to perform action items in MOC. Framework shown in this chapter is establish based on OSHA US regulation, 29 CFR 1910.110(l). There is a MOC management system introduced in this chapter displaying how the system is working to ease documentation work and tracking of previous MOC cases. In addition, this chapter also discuss results of system validation which conducted in two process industries in Gebeng, Pahang. Related documentation obtained via case study and validation process are inserted into management system to shows the functionality of the system database.

4.2 PDCA Cycle

PDCA cycle is applied to provide overview for the whole process of MOC from the beginning till the end. PDCA comprises of four main stages, plan, do, check and act. General ideas on each stage in PDCA cycle is shown in Figure 4.1.

In the first stage, plan shall conduct related documentation work and identification on area affected by the proposed change. Proposal on the change, general risk assessment and administrative arrangement throughout MOC process shall be done within this stage. Legislative requirement shall be reviewed and ensure all the criteria is met when MOC process is completed. Planning on procedure in conducting MOC is vital to ensure all the essential action items is conducted and utilized in decision making on the implementation of new change.

Do, the implementation or “action” step in which all the planned procedure and decision making are done in this stage. Specific risk assessment on affected area shall be conducted to identify significant risk that may arise following of the change. Results of risk assessment are important in aiding decision making. Change can be implemented when those significant risk is controllable by the premise. In addition, MOC management system as established in this study shall be updated in every MOC case. This system should also be updated even though the change is rejected in order to be used as reference in the future.

Review and monitoring of change shall be conducted under check stage to keep track on the condition after change is implemented. Operation process which altered or implemented changes shall be monitored for a period to prevent any occurrence of unexpected hazard or risk. Review of MOC procedure and action items are necessary to improve any flaws or weaknesses in current procedure.

Act, a stage in which implement corrective action or improvement on the existing MOC procedure. This is not limited only in MOC but this can also be improved on implemented change. Extra control measures on potential risk of the implemented change can be added to increase safety level of the related process.

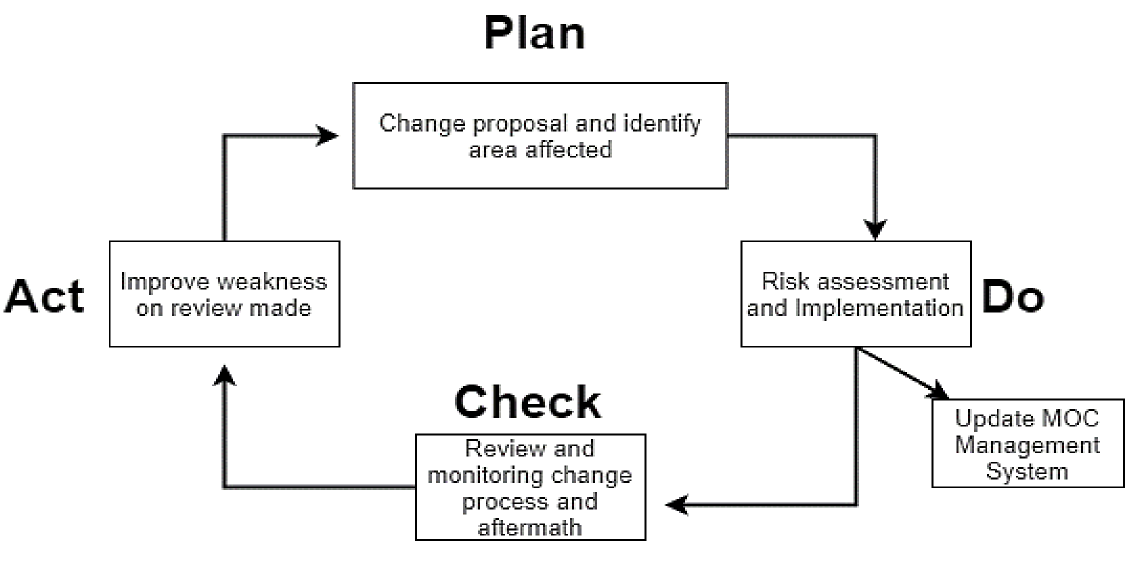

Figure 4.1: MOC PDCA Cycle

4.3 Management of Change (MOC) Framework

Framework has been extensively used in all industries especially in manufacturing industry which involves complex production process. Framework is vital in displaying fundamental structure of a process, providing guidance to end user to perform every essential action item. In this study, MOC framework is constructed into four section comprising starting step, part A, B and C as shown in Figure 4.2, 4.7, 4.12 and 4.15 respectively.

Figure 4.2 shows the first section of the framework which begins with general risk assessment checklist adopted from online to identify affected area or department by the change (CSChE, 2004). Form A, as shown in Figure 4.3 shall be used to perform the general risk assessment. Upon preliminary result of general risk assessment is obtained, end user shall decide whether specific risk assessment such as hazard and operability study (HAZOP), what-if analysis and any other related analysis. If hazard identified in general risk assessment is medium or low significant, risk assessment checklist could be applied for specific risk assessment on every related area. End user shall proceed to perform specific risk assessment checklist, Form B as shown in Figure 4.4. Every affected area identified are directed to following checklist in Form B. Form B also acted as change proposal which provides format for safety and health personnel to propose change initially as a notification before a completed MOC cycle is conducted.

Area affected in this risk assessment is separated into two categories, organizational and technology or technical changes. Action items for organizational change will be directed to part A of the framework. Technical or technological change risk assessment shall proceed to Form VI, as shown in Figure 4.5. Safety assessment is optional to be conducted when there is no significant change in equipment or chemical. Form VII shall be implemented when fire safety assessment is required. Example of Form VII is shown in Figure 4. Part B shall be carried out when all the necessary action items are performed.

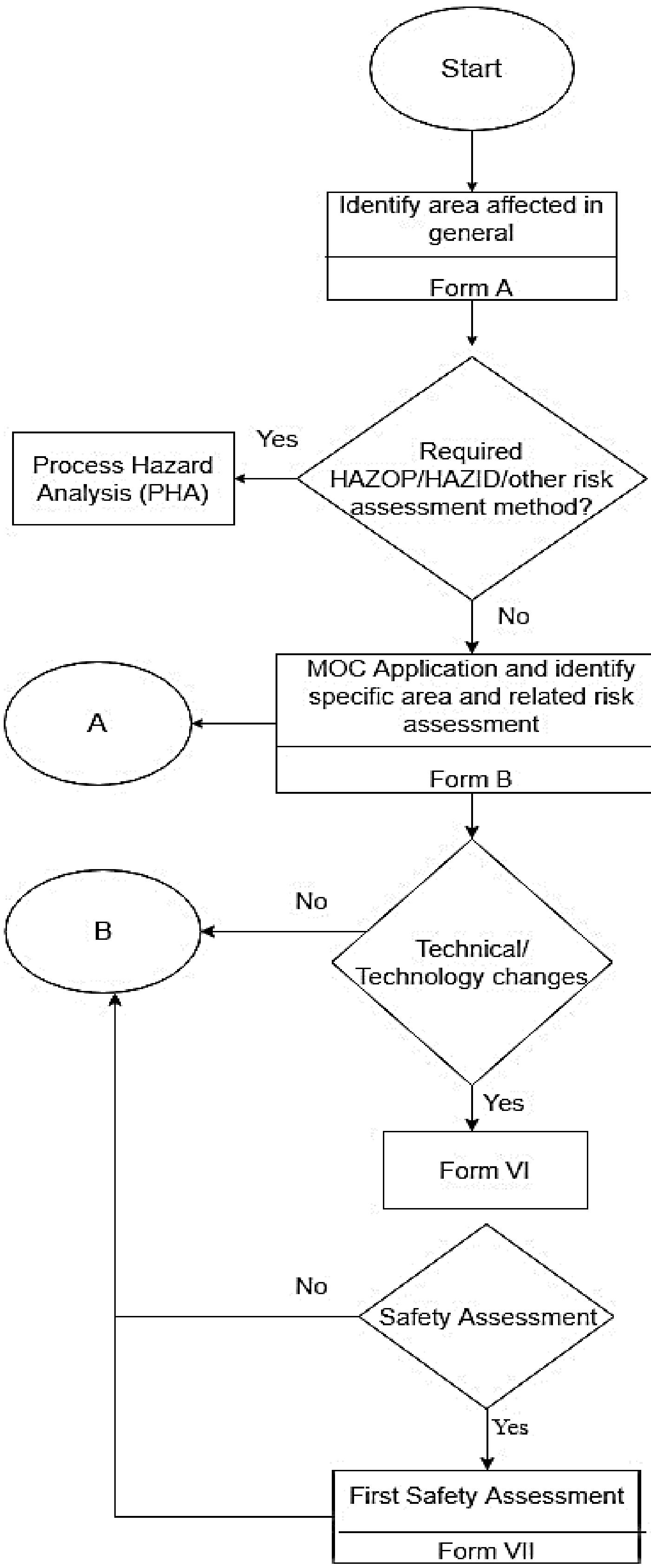

Figure 4.2: MOC Framework

Form A

General Risk Assessment Checklist

Could the change affect S&H in the following areas	Effect	Priority (H/M/L)
Operation of the process		
• Startup or shutdown	Delay shutdown process for 2s	M
• Identification of unsafe condition (including ability of operator to complete required tasks in given time frame)		
• Emergency operations		
• Ability of operator to monitor critical controls & alarms		
• Ability to deal with the mumber of alarms associated with an upset or emergency		
• Recovery from an incident		
• Knowledge/ expertise of workers		
• Development & maintenance of operating procedures		
• Level of staffing for special procedures		

Figure 4.3: Example of General Risk Assessment Checklist

FORM B

CHANGE PROPOSAL APPLICATION

PART - GENERAL INFORMATION

Change No.: Year: Date of the proposal submitted:

Proposer of the change:

Proposal title:

Please explain dimensions of a change

Plans - subject:

Rationale for the change:

What is directly intended to be affected:

- ☐ Plant revenues

Figure 4.4: Example of Change Proposal Application Form

FORM VI – EVALUATION OF THE TECHNICAL & TECHNOLOGY CHANGE

Change No.: Year:

This is a technical and technology related first safety assessment of the proposed change. Please identify what kind of an impact could the change have

Date of evaluation:
Reference documents:
Team members:

ID, (sub)Component & audit question		Impacted (require MOC)	What is impacted?	Kind of impact?	Possible consequences?[a]	Possible mitigations?[a]	Probability	Severity	Is mitigated impacts adequate?[a]
A	**PROCESSES**								
A.1	Deviations from normal procedures	yes/no							yes/no
A.2	Emergency response/actions								
A.3	Short term testing/test								

Figure 4.5: Example of Technical & Technology Change Evaluation

FORM VII – FIRST SAFETY ASSESSMENT OF THE PROPOSED TECHNICAL / TECHNOLOGY CHANGE

Change No.: Year:

The proposer of the change and the appointed decision maker persons shall evaluate together the scope of the change, and provide answers to the following questions. The goal is that all potential impacts on safety, safety measures (safety barriers), or risk related to the use of hazardous materials or energies are identified and documented.
Results of this first analysis shall be clearly understandable to any other reader.

Date of evaluation:
Reference documents:
Team members:

ID, (sub)Component & audit question		Impacted (require MOC)	What is impacted?	Kind of impact?	Possible consequences?[a]	Possible mitigations?[a]	Probability	Severity	Is mitigated impacts adequate?[a]
A	**CHEMICAL SUBSTANCES**								
A.1	Does the proposal introduces a novelty to the company, plant, personnel in terms of new substances (chemicals, solvents, their different composition, etc.)?	yes/no							yes/no

Figure 4.6: Example of First Safety Assessment

Figure 4.7 shows the actions items required in organizational change in MOC framework. Form I, shall be applied when organizational policy in the organization is affected followed by Form II, evaluation for organizational management system. Example of Form I and II are showed in Figure 4.8 and 4.9. PSM evaluation is compulsory in this context as MOC is interrelated with at least 9 elements in PSM including Process Hazard Analysis, Process Safety Information, Mechanical Integrity, Employee Participation, Incident Investigation, Compliance Audit, Pre-Startup Safety Review, Contractor, Training and Operating Procedure. (Aziz et al., 2016). Form V and IV is optional depending on the nature of the change in which required to carry out when the change affected routine task of worker. Example of Form V and IV is showed in Figure 4.10 and 4.11. New activity analysis shall be conducted to identify any underlying hazard in the change of the work task. This is similar as job safety analysis in which commonly practiced in safety and health management. Activities mapping step is provided to enable end user to make comparison between proposed new task and old task. This step will help in identifying weakness of old work task and to discover whether proposed new task is able to overcome existing weakness and flaws. When organizational change risk assessment is completed, end user shall proceed to part B of the framework.

Moreover, an extension of risk assessment checklist by Gerbec (2017) is made by implementing risk rating column. This is to aids end user in prioritizing hazards and risk which requires adequate mitigation measures. A PHA risk rating is embedded into risk assessment checklist as this risk rating covered both process safety and occupational safety context. Example of risk rating embedded is shown in Appendix B. In addition, industry may use their internal standard of risk matrix where applicable.

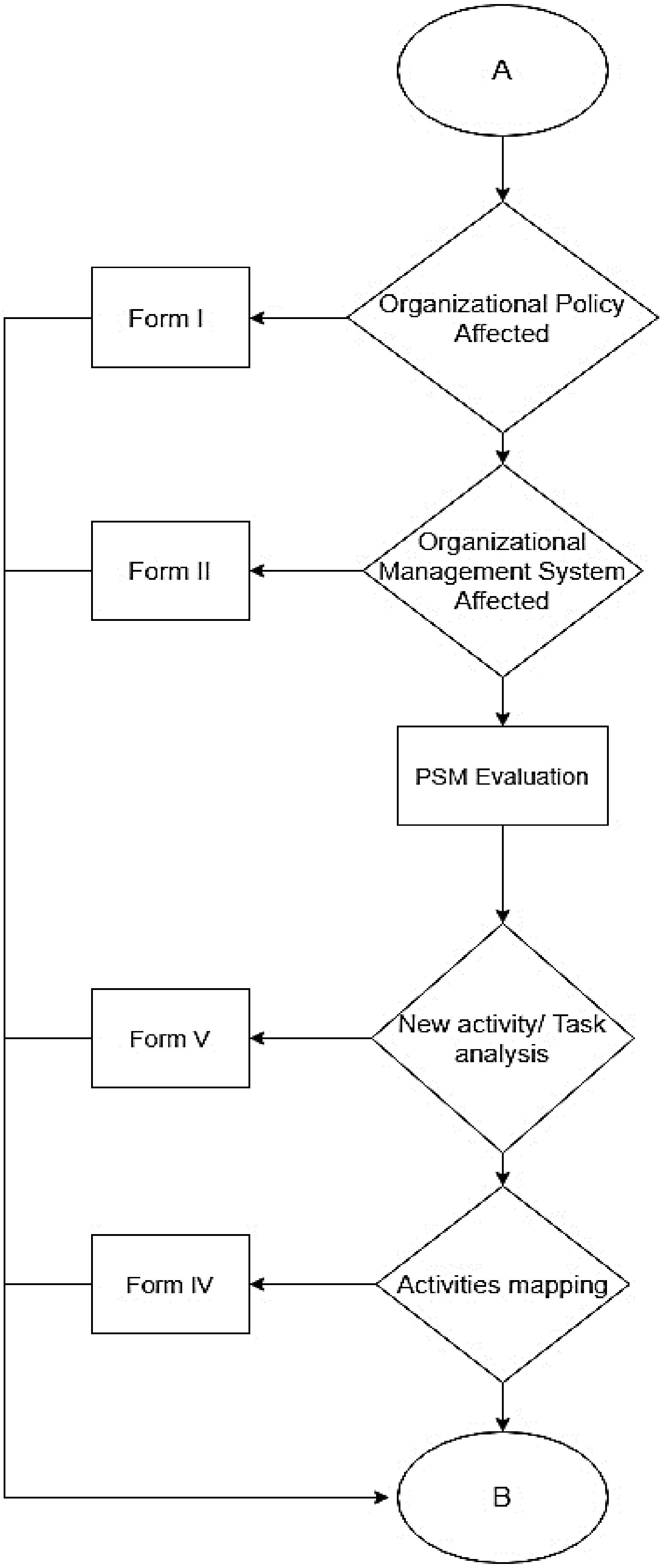

Figure 4.7: MOC Framework (continued)

FORM I – EVALUATION OF THE ORGANIZATION'S POLICY CHANGE

Change No.: Year:

This is organization's policy change evaluation form. Please use this form for all policy aspects, or specific aspects considered for a change or addition (new aspects).

Date of evaluation:
Reference documents:
Team members:

ID, (sub)Component & audit question		Impacted (require MOC)	What is impacted?	Kind of impact?	Possible consequences?[a]	Possible mitigations?[a]	Probability	Severity	Risk rating	Is mitigated impacts adequate?[a]
A	**Company level policies**									
A.1	Will top management still provide the perspective, establish a system, set the expectations, and provide the resources for successful operations?	yes	Existing expectations to produce 1 tons in an hour		Proposed change may do not meet actual expectations		D	3	Medium	yes

Figure 4.8: Example of Organizational Policy Change Assessment

FORM II – EVALUATION OF THE ORGANIZATION'S MANAGEMENT SYSTEM CHANGE

Change No.: Year:

This is organization's policy change evaluation form. Please use this form for all policy aspects, or specific aspects considered for a change or addition (new aspects).

Date of evaluation:
Reference documents:
Team members:

ID, (sub)Component & audit question		Impacted (require MOC)	What is impacted?	Kind of impact?	Possible consequences?[a]	Possible mitigations?[a]	Probability	Severity	Risk rating	Is mitigated impacts adequate ?[a]
A	**Scope and planning of the management system**									
A.1	Will the human resources, infrastructure for operations, environment for operations be impacted?	Yes	Number of operators in Solid dpt	May require second to operate new packing machine	Possible lack of personnel in second work shift	Request additional manpower to fill second shift	B	3	Serious	yes

Figure 4.9: Example of Organizational Management System Change Assessment

FORM V – ACTIVITES ANALYSIS

Change No.: Year:

This is activities (task) analysis record sheet. The purpose is to breakdown the safety important activities, personnel roles and resources needed in order to feed the Form IV comparisons among "old" and "new" role activities evaluations.

Date of evaluation:
Reference documents:
Team members:

ID	Task/sub-task or Activity/sub-activity	Type	Actors & Roles	Duration	Importance	Notes
1						
2						
3						
4						
5						
6						
7						
8						

Figure 4.10: Example of Activity Analysis Assessment

FORM IV - THE ACTIVITIES MAPPING AND EVALUATION

Change No.: Year:

Old and new roles activity mapping form. In a case more roles are about to change, use one form per each. If initial activities analysis is needed, please use also Form V.

Old role name:
New role name:
Date of mapping:
Reference documents:
Team members:
Initial activities analysis compared: yes ☐ no

	OLD ROLE ACTIVITIES										NEW ROLE ACTIVITIES								COMPARISON [b]		
				Involves [a]								Any new role issues?									
No	Appointed activities	Can it be eliminated?	Req. hours per week	Response to deviations	Assuring plant integrity	Assuring plant availability	Managing HSE procedures	Manages essential knowledge and expertise	Subject of change?	Significant risk?	Appointed activities	Req. hours per week	Significant HSE hazards?	High workload, fatigue?	Competence issues?	Communication issues?	Team work issues?	Motivation issues?	Old role control measures that were applied?	Additional measures needed, or any comments?	Will controls be adequate?
1																					
2																					

Figure 4.11: Example of Activities Mapping and Evaluation

Part B of the framework is displayed in Figure 4.12 which focus on implementation of change, documentation and follow-up. Summary of issue and mitigation hazard, Form VIII, as illustrated in Figure 4.13 shall be completed to address significant hazards identified throughout all the risk assessment. This form would ease for decision making on change approval without looking on all risk assessment forms. When change is not approved, all related risk assessment forms and documentation shall be stored into MOC management system for future reference. When change is approved, updates on other PSM elements shall be notified upon necessary. Notification of other PSM elements will be explained in Part C. Both temporary and permanent change shall be documented in Form C. Example of document change action form (Form C) is displayed in Figure 4.14. Change shall be recorded before and after implementation to ensure change is managed well and monitored especially on temporary case. MOC management system shall be updated after change is implemented.

Part C of the framework is shown in Figure 4.15 which highlight notification on related PSM elements. OP, PSI and MI element shall be notified and update when the change affected these elements. For instance, OP element shall be updated when there is new work task or process introduced process operation. PSI element shall be updated when new chemical is used in the process while MI element shall be updated when equipment is installed or changed in maintenance schedule.

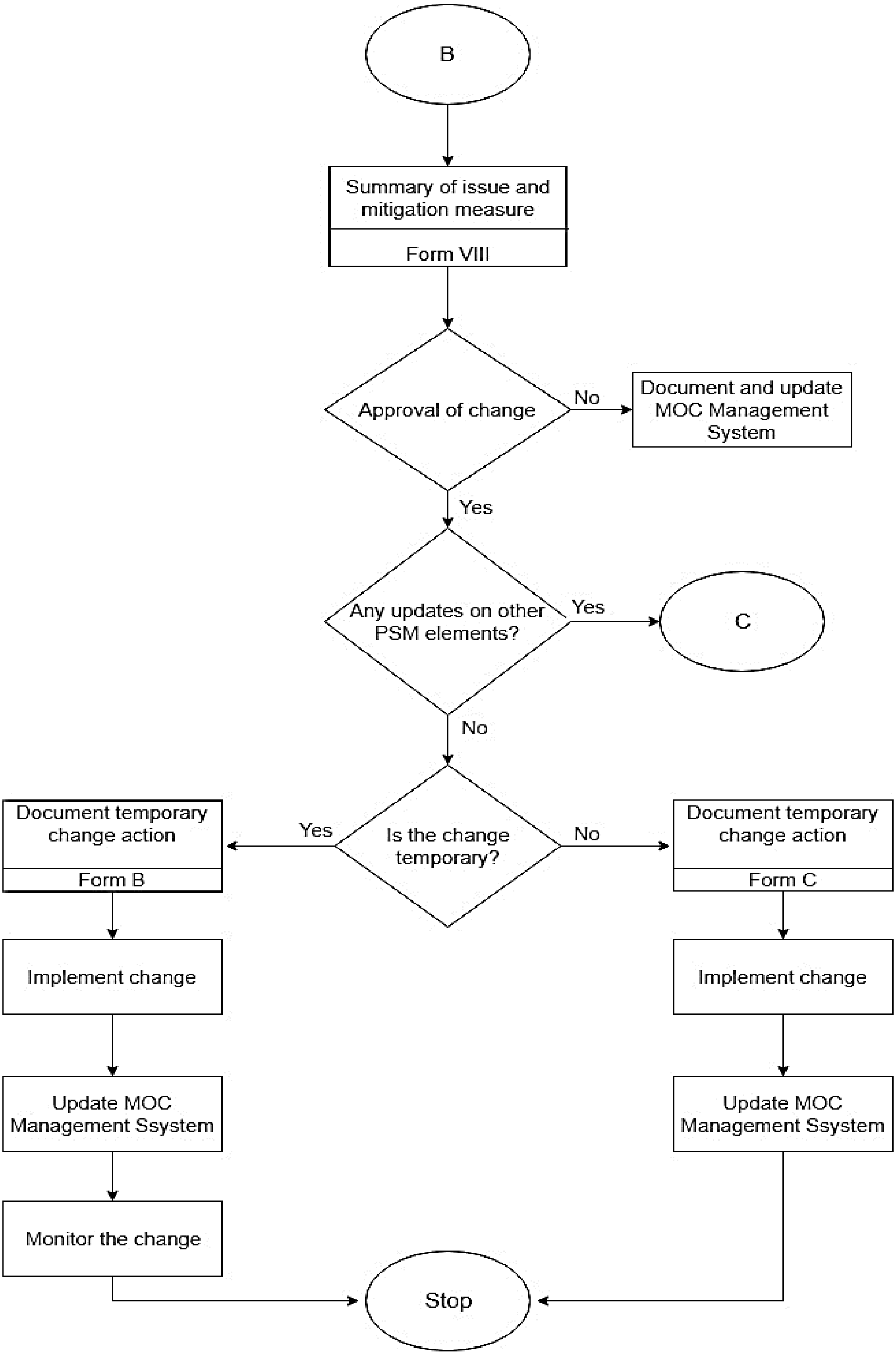

Figure 4.12: MOC Framework (continued)

Form IX- Summary of issue and mitigation measure

Please summarize, one by one, the interactions among the issues identified and management categories (list also IDs). Next, specify potential impacts, consequences, potential mitigations in means of measures, appointed for action and dealine. Finally, appointed person shall approve or reject each issue identified for implementation.
At the bottom of the form, the overall proposal for change is to be decided for approval or rejection.

No	Issue - what is impacted?	Impacted Categories (IDs)	Kind of impact?	Possible consequences?	Mitigations		Approved?
					Measure	Deadline	
1	Number of operators in Solid dpt	II.B.1,B.2	May require second to operate new packing machine	Possible lack of personnel in second work shift	Request extra manpower from human resources dpt		
2							
3							
4							

Figure 4.13: Example of Summary of issue and Mitigation Measure Form

FORM C- DOCUMENT CHANGE ACTIONS

Change No.: Year:

This is the approved change actions detailed planning and follow-up plan.

Date of actions planning:
Reference documents:
Team members:

From Form IX; logically order measures to actions for completion!						To be filled-in after change was implemented					
						Action completed		Action validation		Action closing	
No	Measure to Action	Action responsible	Deadline	Related documents	(Issue No.)	Date	Signature	Appointed	Signature	Was temporary	Closed
1											
2											
3											

Figure 4.14: Example of Document Change Actions Form

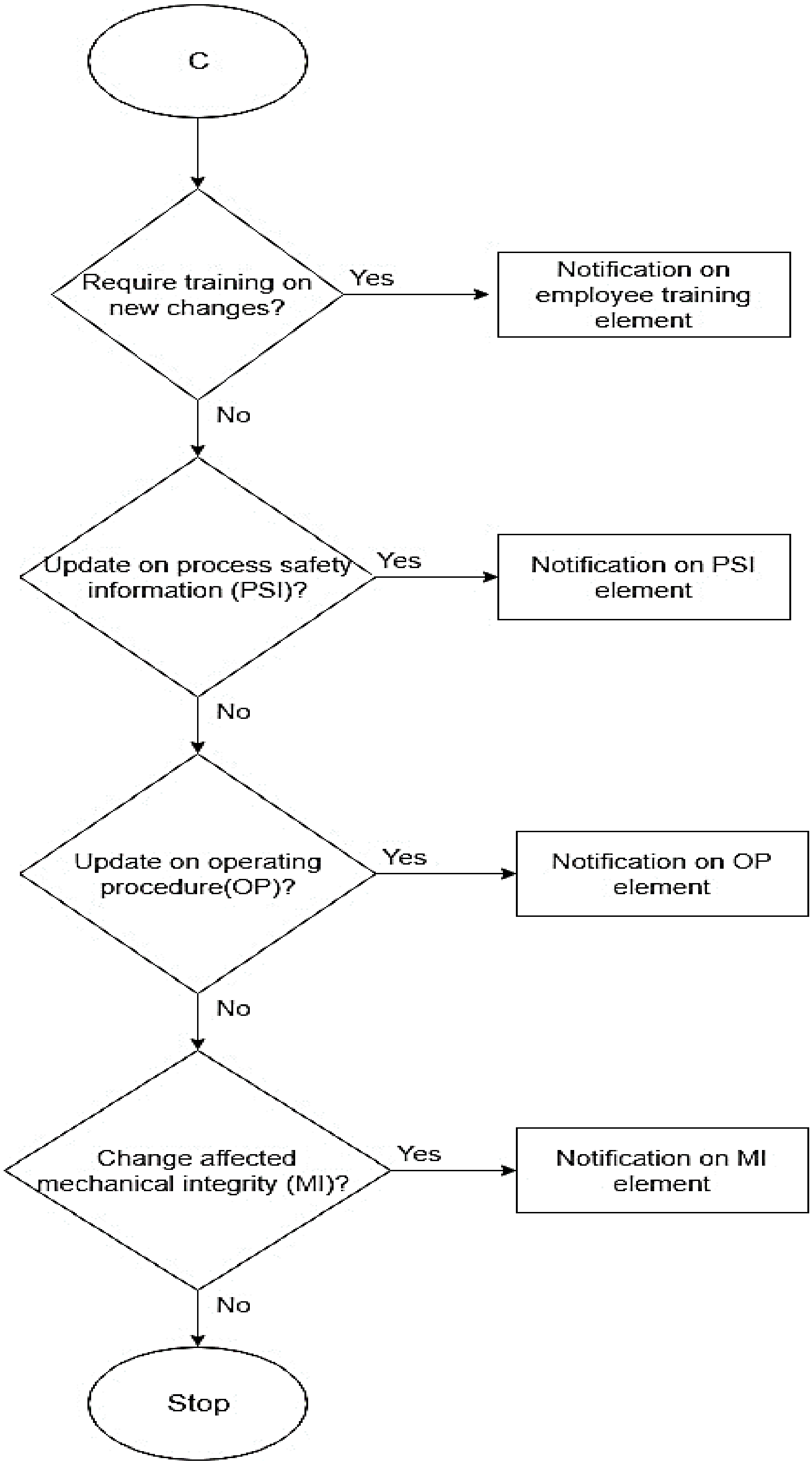

Figure 4.15: MOC Framework (continued)

4.4 Management of Change (MOC) Management System

A MOC management system is developed which functions to guide end user on MOC process meanwhile act as storage database on MOC related documents. This system stores lists of risk assessments checklist as shown in MOC framework. It is acting as an active guidance in which merged MOC framework as discussed earlier into the system which able to provide guidance to end user without referring to the flow chart.

This management system is designed with several features to ensure that the system is user friendly without causing confusion and complication. This system begins with a security page as illustrated in Figure 4.16, which required user to login username and password. It is designed to enable only enable MOC team members and related management personnel to access the system. Workers 'ID is applied as login username of the system to avoid any confusion to workers among this system and company internal database.

Based on Figure 4.17, it is main interface appear after user login which function to guide user throughout the MOC process. There is list of risk assessment form hyperlinks stored in the interface to enable user access to specific form. In the part of this interface, there would be forms which are compulsory for user to fill in for information and record logging. For example, Form C is vital in "Check" stage under PDCA cycle as it is important in review process. Change shall be reviewed to ensure all planning and control measures are adequate to all the potential risk.

Documentation is another step in MOC process in which important in future review and retaining evidence on regulatory compliance. A documentation navigation form is created to guide user to input all necessary information into the system. It comprises of 8 forms which stores general data on new MOC case, information on every specific risk assessment also summary and follow up action. Example of the navigation form is displayed in Figure 4.18.

There are several features proposed in which in reach to the problem and issues addressed. Referring to Figure 4.18, a feature which address type of change whether is permanent or temporary would help end user to easily track on previous temporary change cases and related risk assessment conducted. Temporary cases may often be the loop of an organization in accident occurrence as risk assessment are often simplified or merely absent due to implementation period. It can be seen from few major accident cases such as Flixborough accident (Piong et al., 2017). In order to ease for tracking, a query is made available in the system, listing all the temporary cases and related basic information. Apart from that, there is another additional feature in which enable user to track open task of MOC which yet to meet to due date established. There is a status input which enable MOC team to select whether the task is "Completed", "Pending" or "Incomplete". An open task query is designed to track on MOC cases which holding on status of "Pending" or "Incomplete".

In addition, there is fields created named with time begin and time completed in risk assessment documentation forms. This feature is made available in order to overcome time- motion based study which identified as weakness in previous MOC approach (Zwetsloot et al., 2007). This feature is aims to help in recording period required to perform every risk assessment which this can be used as reference to predict overall time required from change proposal to approval. This is believed to be significant in solving the current issue of time constraint in MOC (Gambetti et al., 2013).

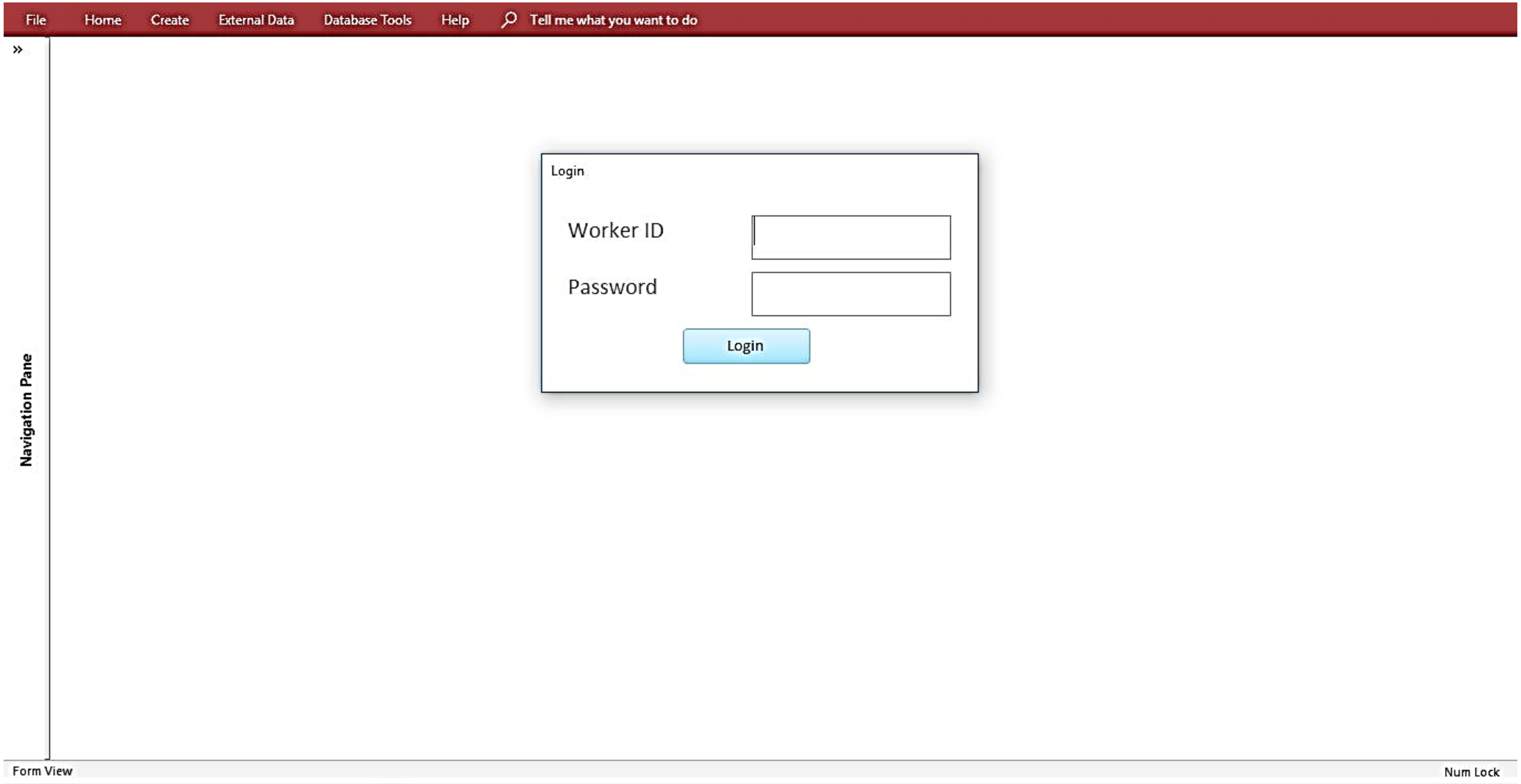

Figure 4.16: User Login interface of MOC Management System

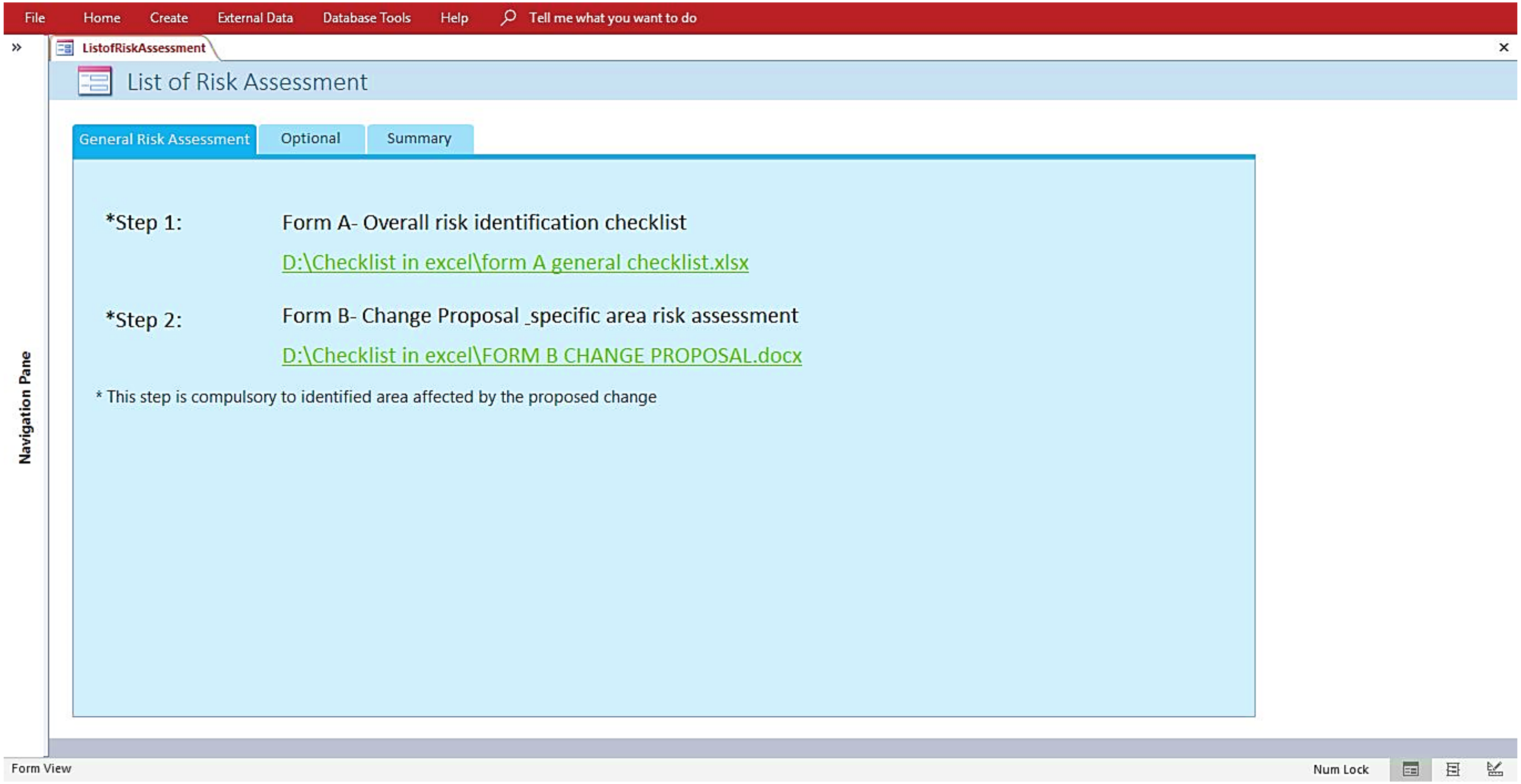

Figure 4.17: Main interface of MOC Management System

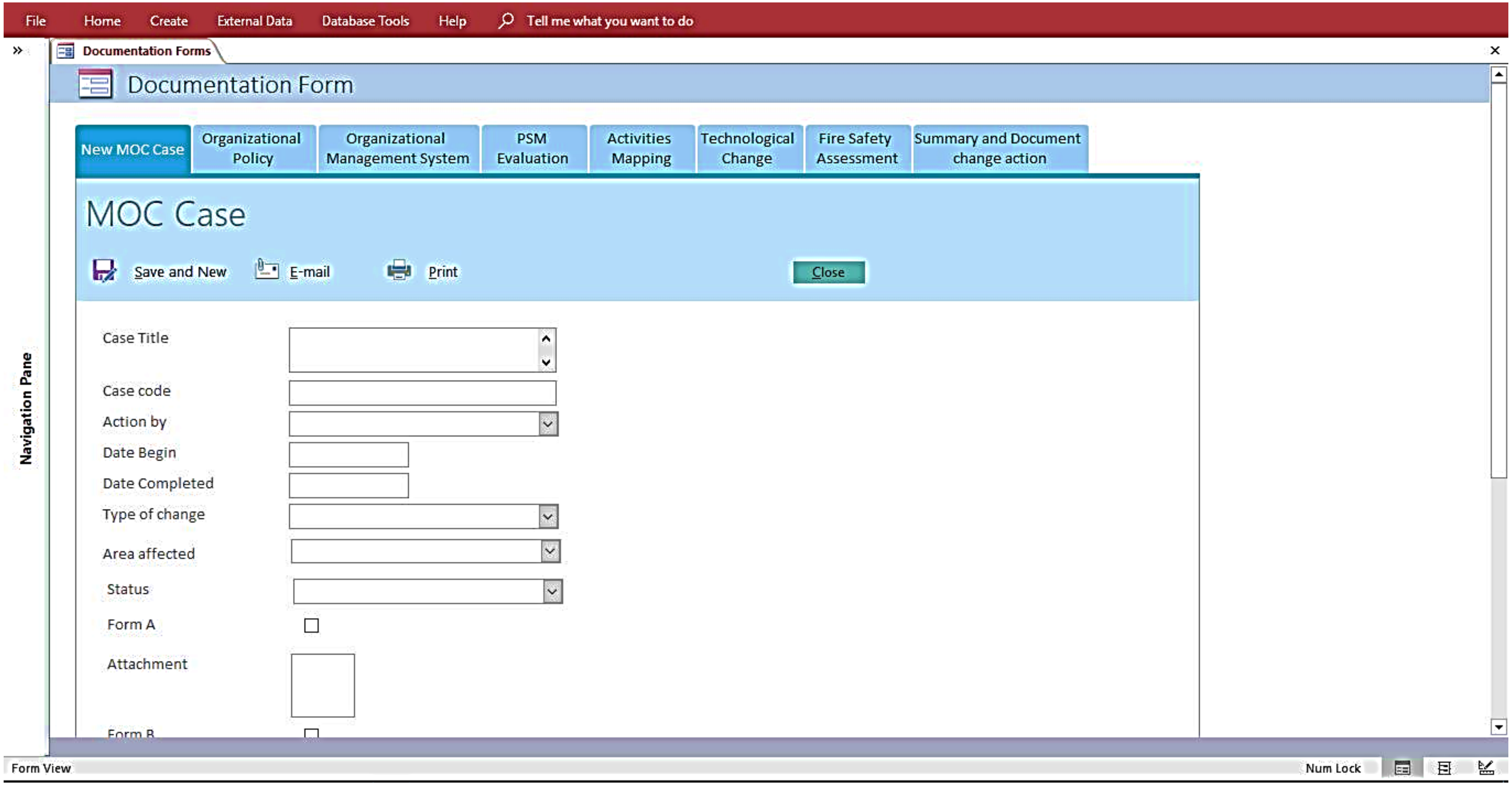

Figure 4.18: Documentation interface of MOC Management System

4.5 Management of Change (MOC) System Validation

MOC management system is validated by obtaining real process plant data which collected from process industries. Feedback and comments from safety practitioner in process industries by interview and presentation session during visit to the process plants. Two case studies had been conducted in two different process to ensure reliability and realistic level of this management system. According to the feedbacks from both industry safety practitioners, it has proven that this management system had met to basic requirement on MOC. Moreover, it is merely absence of MOC management system introduced to the current market.

4.5.1 Case Study 1

A permanent MOC case data was obtained by process industry which related to migration of solid block friatec pump. As illustrated in Figure 4.19, the status of the MOC case is marked “Incomplete” as the case is ongoing task which will due in year 2020. Status of a MOC case is considered as complete when the change has reach predicted completion date. This case study data obtained was affected only technological area of the process, therefore, there were absent of documentation related on organizational change. There is a MOC application form provided by the plant which similar to Form B. Therefore, form B column is ticked with yes following with evidence of the form uploaded as attachment. Apart from storage in the management system, all evidence files were uploaded to cloud storage to serve as backup file when management system is corrupted. All risk assessment forms related to this case is inserted into technological change assessment interface as shown in Figure 4.20.

Based on Figure 4.21, an approval form is provided to be inserted into system, therefore, “Summary/Approval form” column is ticked as “Yes” and evidence is uploaded as attachment to be stored in the system. However, date completed in this interface is not inserted in this interface. Unlike the date completed column as shown in Figure 4.19, date completed column shows in this interface is designed to record the completion date of MOC process until approval stage.

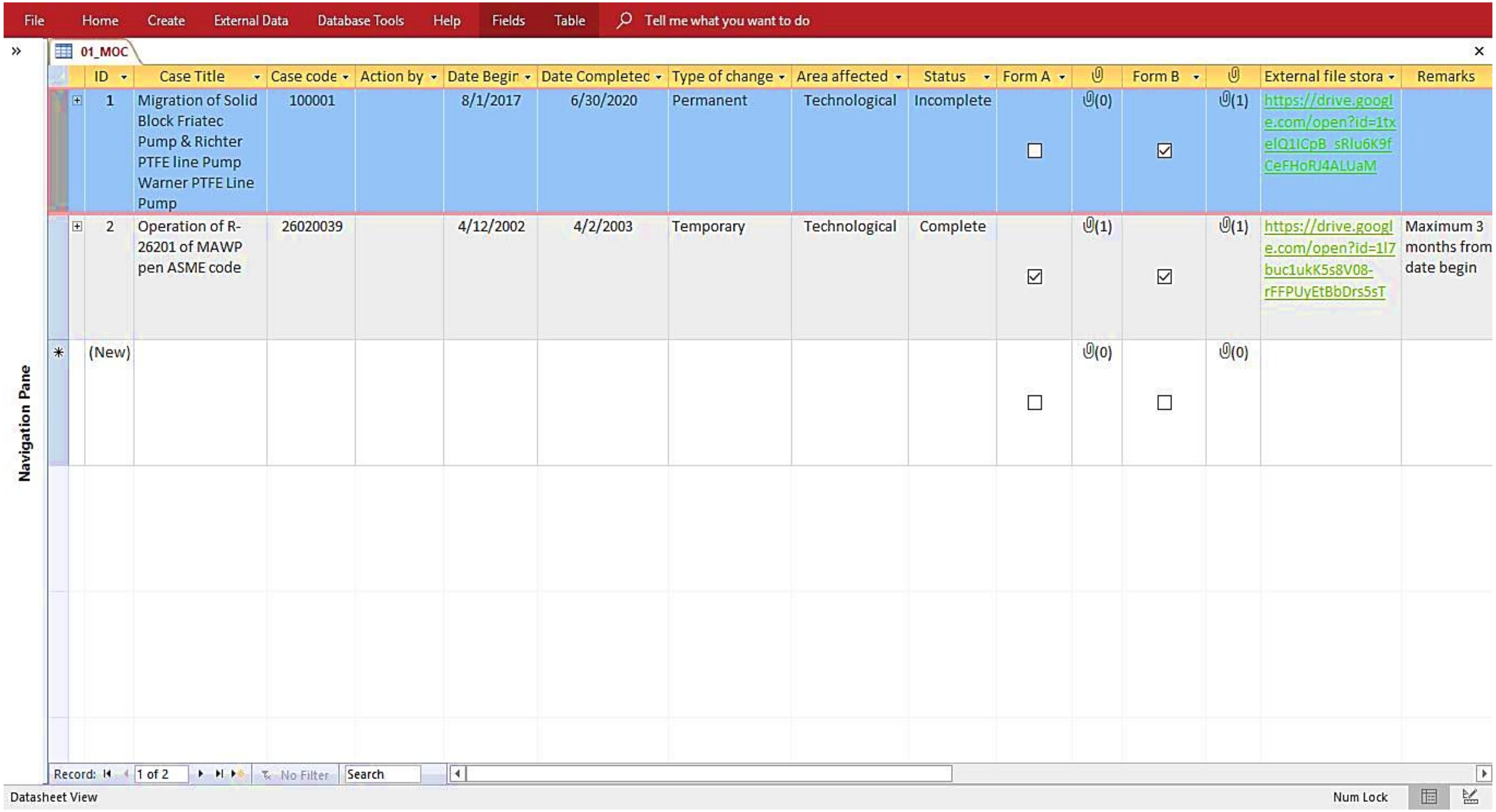

Figure 4.19: MOC Case interface

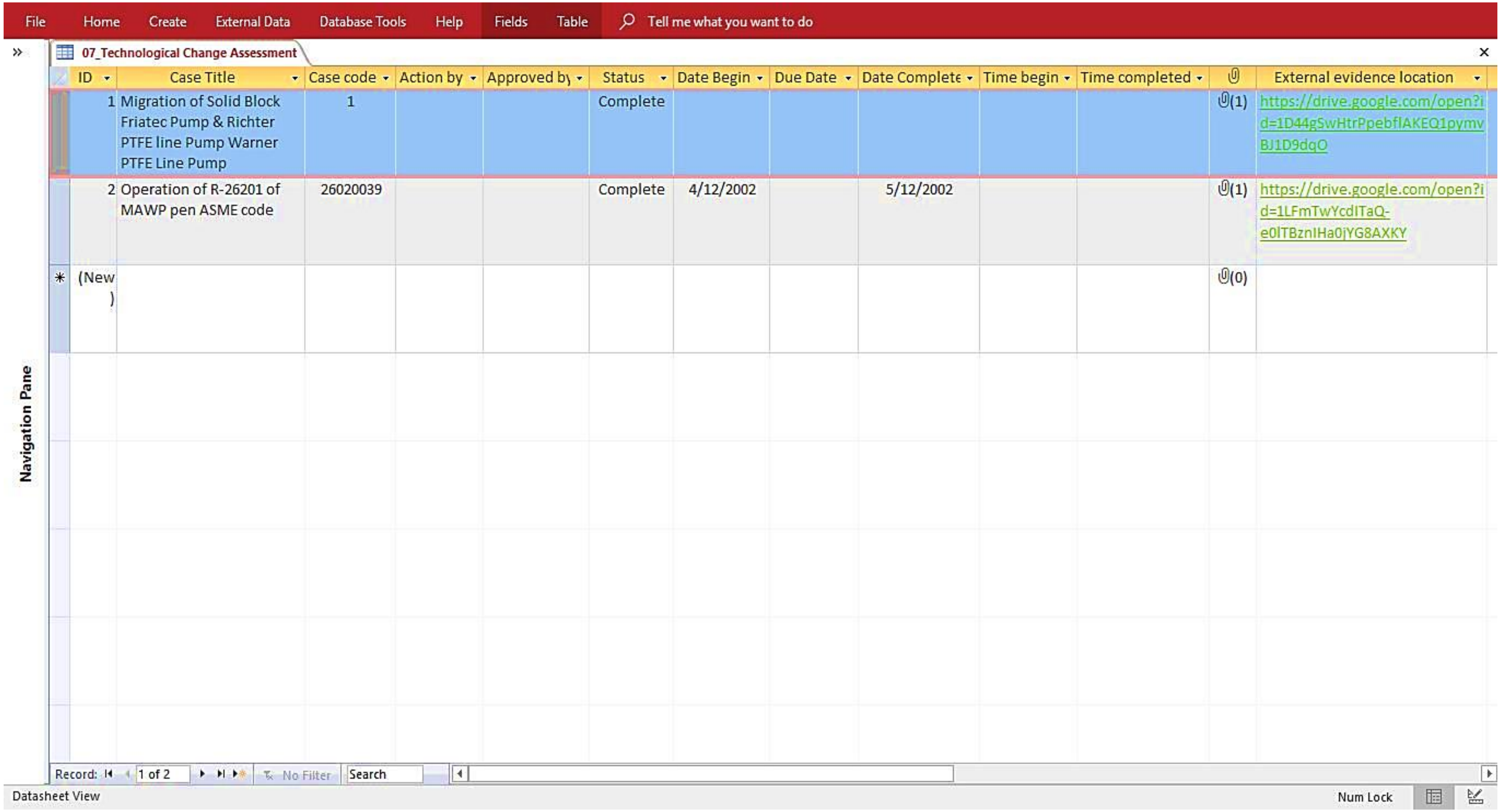

Figure 4.20: Technological Change Assessment interface

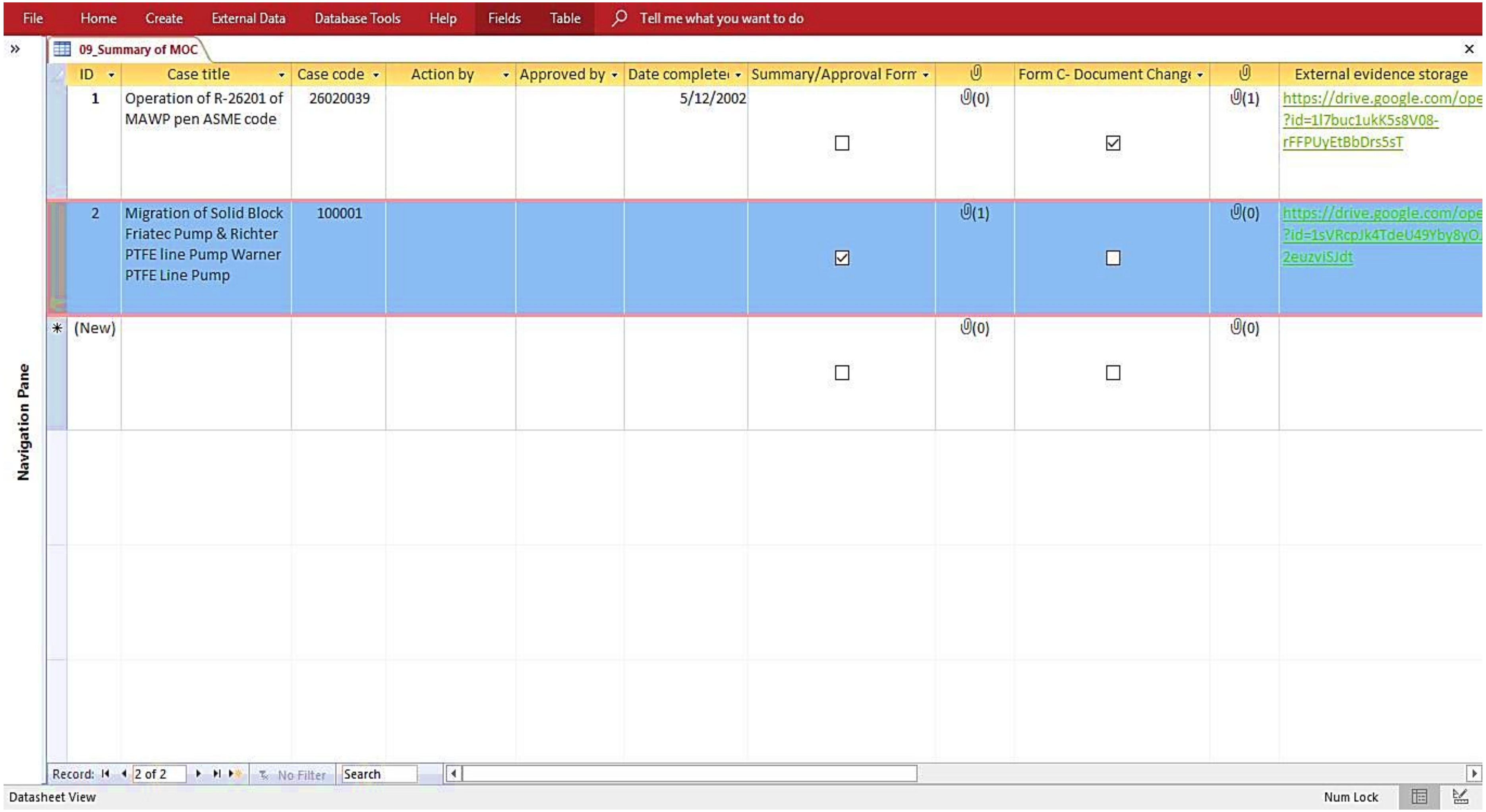

Figure 4.21: Summary of MOC Case interface

4.5.2 Case Study 1

A temporary equipment change case is provided by process plant which involved in changing thickness of equipment. This change is marked as “Completed” as the change is due in year 2003. In “Remarks” column, it is stated that the change is implemented with maximum period of not more than 3 months. In this case, both general checklist which similar to Form A and change application form is provided and inserted into system as attachment. Cloud based storage hyperlink is attached which function as external file storage as shown in Figure 4.22.

Technological change assessment form related to this case is inserted into system. There is date of completion recorded in this case which ease for future reference in terms of period required. As shown in Figure 4.22, there is only one day required to perform technological change risk assessment in this case including documentation update, however it might not show the actual period required to perform only risk assessment without calculating documentation time required. Based on Figure 4.23, there is only review of change action document provided in this case. This is because temporary change is monitored throughout three months change implementation.

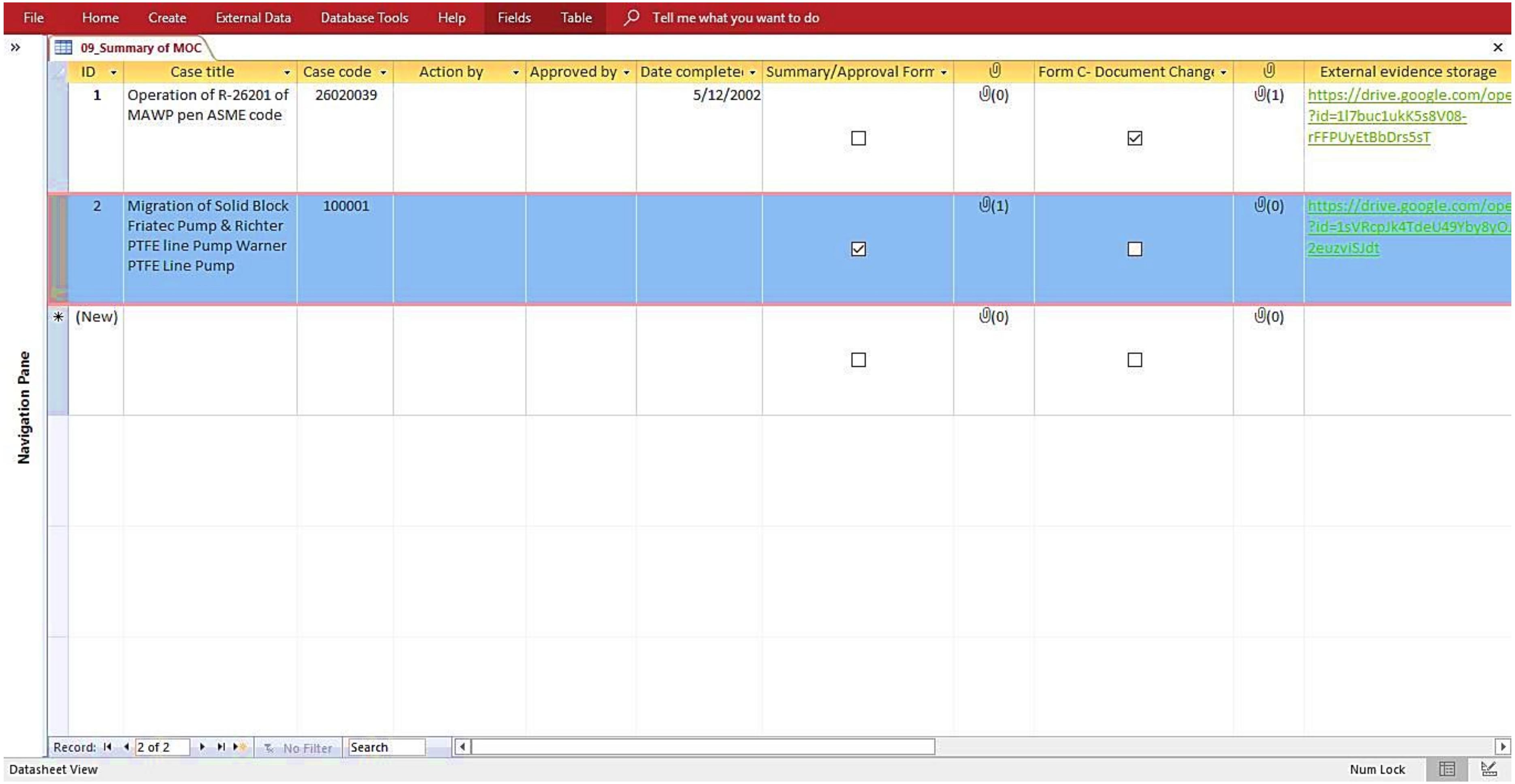

Figure 4.22: MOC Case interface on case 2

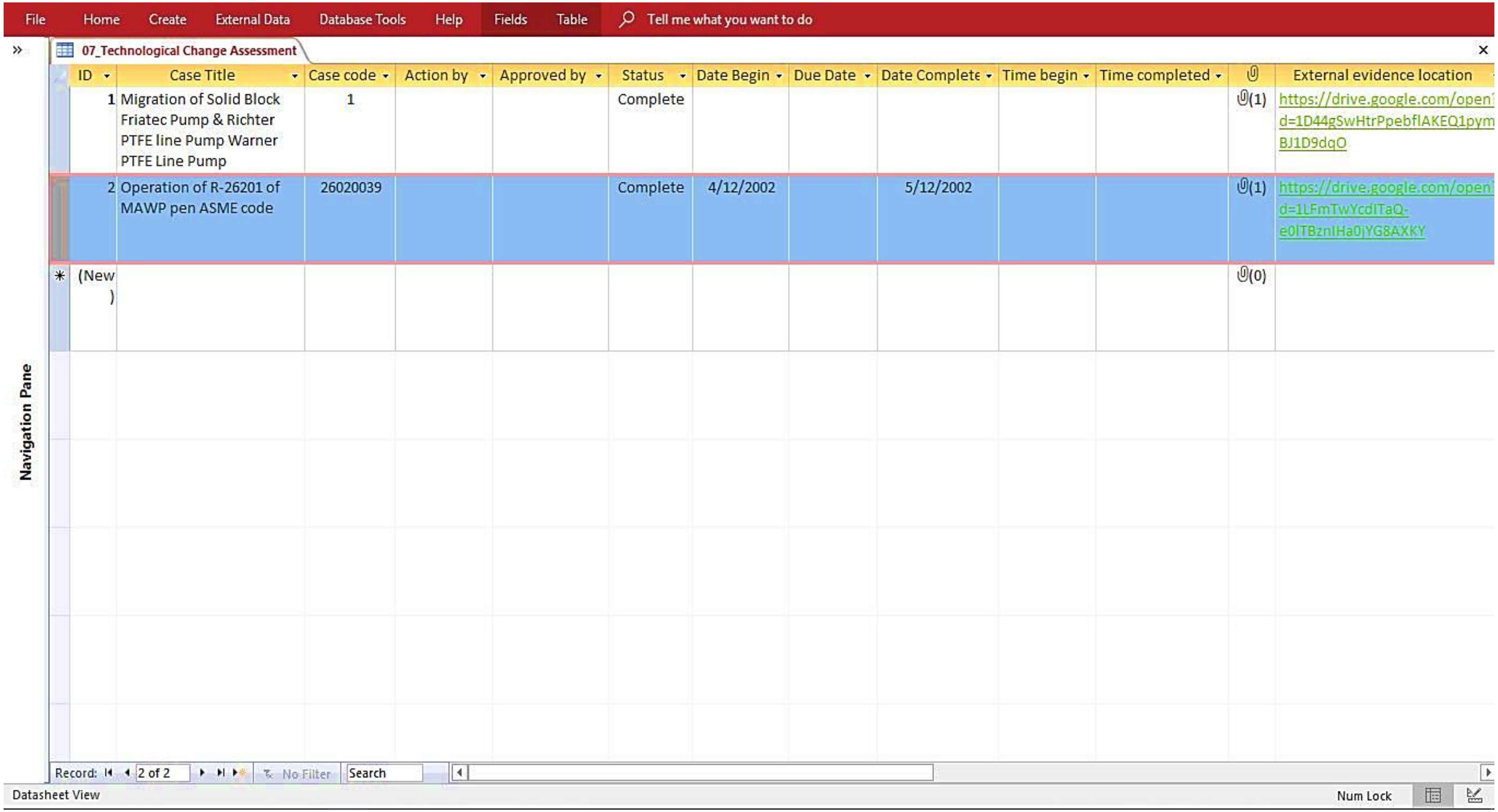

Figure 4.23: Technological Change Assessment interface on case 2

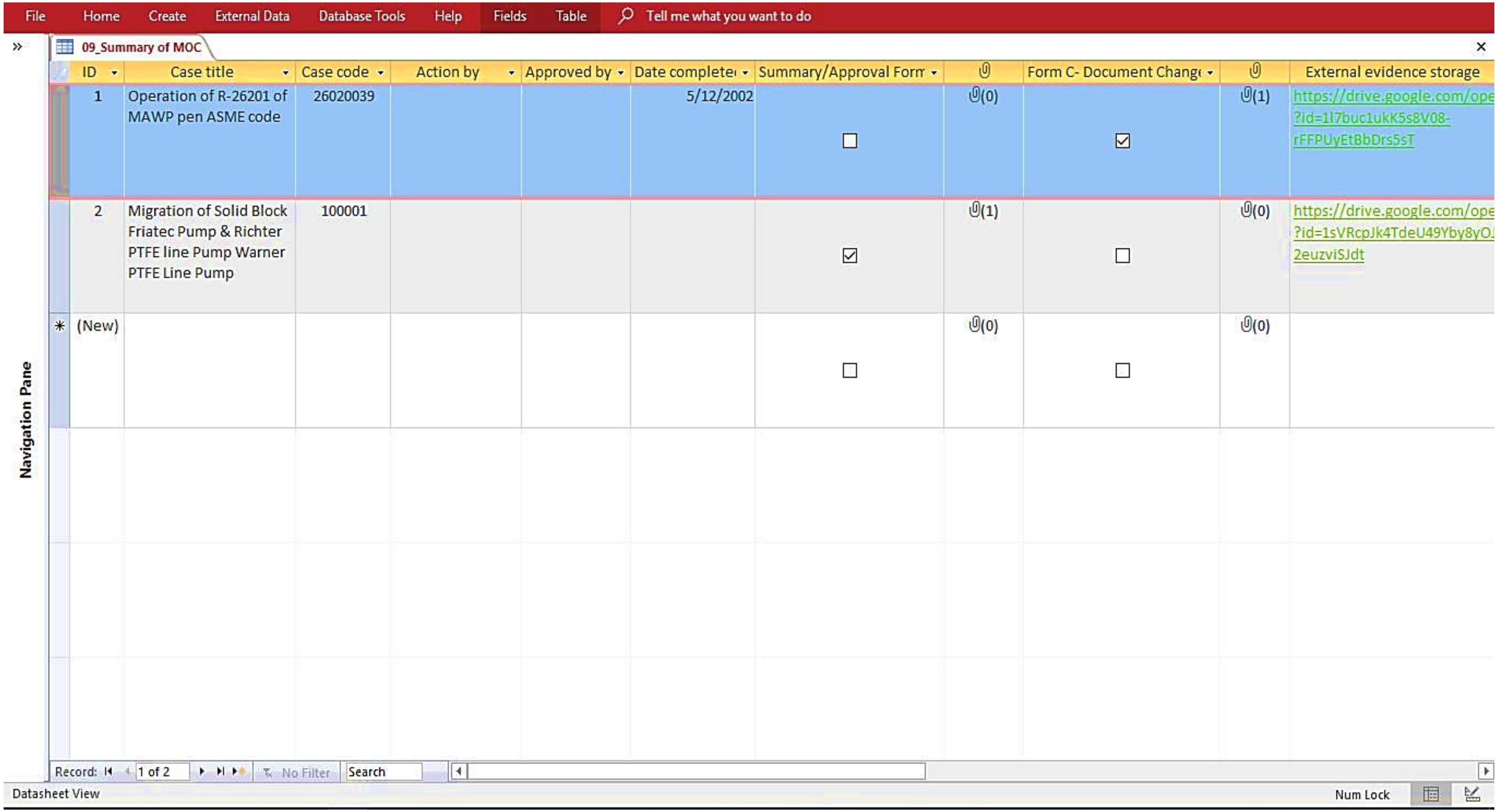

Figure 4.24: Summary of MOC Case interface on case 2

4.6 Conclusion

Based on two case study conducted, this system is acknowledged by safety practitioners in process industries that it could make significant contribution in MOC management and tracking of temporary cases. This system may act as active guidelines and system database in the same time which covers the whole MOC process.

Both companies are having similar approaches in terms of MOC management. However, it is found that management in permanent and temporary change is inconsistent in which less attention and risk assessment is conducted in temporary change. Therefore, it is believed that this system could contribute in managing temporary change more effectively. Improved MOC framework is compared with existing MOC flow chart from both companies. It is found that improved MOC framework is having similar work flow in MOC and came with some special action items such as attachment of checklist in every action item along with risk rating. There are some unfilled information in adopted checklist are identified as gaps which covered some lacking in current MOC practices in process industries.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS OF FUTURE WORKS

5.1 Introduction

This chapter covers on conclusion and recommendations based on this research study. Conclusion in this chapter will summarize the whole research study including objectives and findings. Meanwhile, recommendation is suggested for improvements in future research and study with similar area.

5.2 Conclusion

The objectives of this research were to establish a MOC framework and management system based on PSM regulation, 29 CFR 1910.119. A PDCA cycle is established to provide an overview of MOC process and a MOC framework which highlights all the important action items and related risk assessment forms recommended for each action items. An MOC management system is established in which stores all related risk assessment forms, change proposal, also act as storage database for related documents.

Case studies have been conducted to validate management system developed to determine the reliability and applicability in real life operation process. It is proved that this management system able to ease the burden of documentation and yet proposing new approach in MOC management. Tracking of open MOC task and temporary case is additional features in the system. Time begin and completed field in the system is established to enhance time prediction in performing every risk assessment and period required for a whole MOC process.

5.3 Recommendation

Key factors in MOC management are complete risk assessment, mitigation measures and adequate follow-up actions. A longer research period is required to recommended to perform a continuous research on MOC to discover more significant features and action items to establish a lesser weakness and flawless MOC process. It is recommended that return of investment (ROI) and detail steps on follow up action to be added into MOC framework to expand the coverage of MOC in real lie practices. Adopted checklist could be improved by covering more detail in MOC issue. Management system software can be designed more perfectly with extra features to tackle more current issues in MOC.

In future research, it is recommended that this software to be made into centralized software which enable users to surf the system anywhere away from computer in office. Pilot testing can be implemented in further research to determine the reliability of risk assessment checklist and management system in real process plant.

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APPENDIX A
GANTT CHART

Research Activities	2018											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Title Selection	■	■										
Discussion with supervisor		■										
Introduction		■	■									
Literature Review			■									
Methodology			■									
Submit first draft proposal			■									
Submit second draft proposal				■	■							
Submission of proposal					■							
FYP 1 Viva Presentation					■							
Develop framework						■						
Develop MOC system							■	■				
Case Studies/ Validation									■			
Thesis Writing									■	■		
Thesis draft submission										■		
Thesis presentation											■	
Thesis submission												■

APPENDIX B
GENERAL RISK ASSESSMENT CHECKLIST

Managing Organizational Change – Risk Assessment Checklist

COULD THE CHANGE AFFECT S&H IN THE FOLLOWING AREAS:	Effect	Priority H/M/L	Safeguard	Action
Operation of the Process				
• Startup or shutdown				
• Normal operation				
• Identification of unsafe situations				
• Emergency shutdown (including ability of operator to complete required tasks in given time frame)				
• Emergency operations				
• Ability of operator to monitor critical controls & alarms				
• Ability to deal with the number of alarms associated with an upset or emergency				
• Recovery from an incident				
• Knowledge/expertise of workers				
• Development & Maintenance of operating procedures				
• Level of staffing for special procedures				
• Communications between shifts				
• Decision making and lines of authority				
• Ability of operator to intervene or respond in an emergency as a safeguard (as identified in PHA or Layers of Protection Analysis)				
• Accuracy of operating procedures				
Safe Work Practices				
• Safe Work Permits (e.g. hot work, cold work, etc.)				
• Isolation, Lockout, Tagout				
• Confined space entry				
• Blinding or isolation procedures				
• Flare or line entry procedures				
• Periodic audits of safe work practices				
• Firewatch procedures				
• Line opening				
• Other safe work procedures				
Maintaining Plant in a Safe Condition				
• Knowledge / skill of trades				
• Technical expertise of engineering support				
• Test and Inspection programs (with zero overdue)				
• Preventive Maintenance or Reliability program				
• Quality assurance of trades work				

APPENDIX C
SPECIFIC RISK ASSESSMENT CHECKLIST

FORM A

CHANGE PROPOSAL APPLICATION

PART - GENERAL INFORMATION

Change No.: Year: Date of the proposal submitted:

Proposer of the change:

Proposal title:

Please explain dimensions of a change

Plans - subject:

Rationale for the change:

What is directly intended to be affected:

- ☐ Plant revenues
- ☐ Plant costs
- ☐ Product(s) quality

PART II – INTERACTION MATRIX AND MITIGATIONS

Step 1: After the evaluations using forms I to VII have been performed, consider possible interactions among management categories and levels in the matrix:

		Inputs – please enter Form I to VII Categories IDs in related cells for issues identified				
		I	II	III	IV	VI & VII
	Impacted:	Organization's policy	Organization's management system	Organization's PSMS	Activities and safety critical roles	Technic or technology & safety analysis
1	Organization's policy					
2	Organization's management system					
3	Organization's PSMS					
4	Activities and safety critical roles					
5	Technic or technology & safety analysis					

Comments to the matrix and individual cells:

Step 2: Please summarize, one by one, the interactions among the issues identified and management categories (list also IDs). Next, specify potential impacts, consequences, potential mitigations in means of measures, appointed for action and dealine. Finally, appointed person shall approve or reject each issue identified for implementation.

At the bottom of the form, the overall proposal for change is to be decided for approval or rejection.

No.	Issue - what is impacted?	Impacted Categories (IDs)	Kind of impact?	Possible consequences?	Mitigations			Approved?
					Measure	Action by?	Deadline	
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								

Other comments, as well as explanations to potential approval:

Decision: ☐ The proposed change is approved ☐ The proposed change is rejected	Appointed responsible person:
	Date: Signature:

FORM B – DOCUMENT CHANGE ACTIONS

Change No.: Year:

This is the approved change actions detailed planning and follow-up plan.

Date of actions planning:
Reference documents:
Team members:

Use from Form A, Part II, step 2; logically order measures to actions for completion!						To be filled-in after change was implemented					
						Action completed		Action validation		Action closing	
No.	**Measure to Action**	**Action responsible**	**Deadline**	**Related documents**	**(Issue No.)**	**Date**	**Signature**	**Appointed**	**Signature**	**Was temporary?**	**Closed?**
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											

Comments:

Change implementation actions are closed by the appointed person:
Confirmed by appointed person:
Date:
Signature:

FORM I – EVALUATION OF THE ORGANIZATION'S POLICY CHANGE

Change No.: Year:

This is organization's policy change evaluation form. Please use this form for all policy aspects, or specific aspects considered for a change or addition (new aspects).

Date of evaluation:
Reference documents:
Team members:

ID, (sub)Component & audit question		Impacted (requires MOC)?	What is impacted?	Kind of impact?	Possible consequences? [a]	Possible mitigations? [a]	Action by? [a]	Is mitigated impact adequate? [a]
A	**Company level policies**							
A.1	Will top management still provide the perspective, establish a system, set the expectations, and provide the resources for successful operations?	(yes/no)	(free text)					(yes/no)
A.2	Will assurance of operations integrity that requires management leadership and commitment, be visible in the organization, and will involve accountability at all levels?							
A.3	Will set of policies cover all the aspects relevant for the company?							
A.4	Will the company's legal obligations by the law be impacted?							
A.5	Will policy affect the organization or roles of the top management members?							
A.6	Will the management accountability for the policies and their implementation be impacted?							
A.7	Will formal management schemes (e.g., ISO, OHSAS, EMAS, etc.) be impacted by the change? Which?							
A.8	Is the change to introduce a new management aspect/policy?							
A.9	How/to whom is the change to be communicated and being available?							
A.10	Other policy impacts?							

Note: [a] – identified additional mitigation measures, actions and potentially non-adequate impacts are to be compiled at upper level form.

FORM II – EVALUATION OF THE ORGANIZATION'S MANAGEMENT SYSTEM CHANGE

Change No.: Year:

Please use this form for evaluation of the changes at level of the general management system.

Date of evaluation:
Reference documents:
Team members:

ID, (sub)Component & audit question		Impacted (requires MOC)?	What is impacted?	Kind of impact?	Possible consequences? [a]	Possible mitigations? [a]	Action by? [a]	Is mitigated impact adequate? [a]
A	**Scope and planning of the management system**							
A.1	Will the scope (internal, external issues, products and services) of the company - management system be impacted?	(yes/no)						(yes/no)
A.2	Will leadership and commitment of the management be impacted?							
A.3	Will organizational roles, responsibilities and authorities be impacted?							
A.4	Will the management objectives set at relevant functions, levels and processes be impacted?							
A.5	Will management processes (inputs, outputs, pertaining actions, objectives, responsibilities, resources, etc.) be impacted?							
A.6	Will the measurement of the objectives be impacted?							
A.7	Will the criteria for reaching the objectives be impacted?							
A.8	Will communication of the objectives be impacted?							
A.9	Will the planning or resources or deadlines set for objectives be impacted?							
A.10	Will the planning, integrity or resources for the management system changes be impacted?							

FORM III – EVALUATION OF THE PROCESS SAFETY MANAGEMENT CHANGE

Change No.: Year:

This is change evaluation form for organization's process safety management system.

Date of evaluation:
Reference documents:
Team members:

ID, (sub)Component & audit question/statement		Impacted (requires MOC)?	What is impacted?	Kind of impact?	Possible consequences? [a]	Possible mitigations? [a]	Action by? [a]	Is mitigated impact adequate? [a]
A	**Mandate and commitment**							
A.1	Will the capability of top management to define and endorse the process safety policy (policy) be impacted?	(yes/no)						(yes/no)
A.2	Will the alignment of the company's values, goals, objectives and strategies with the policy be impacted?							
A.3	Will the alignment or coverage of other management aspects with the policy be impacted?							
A.4	Will the accountability or roles of the top management related to policy be impacted?							
A.5	Is the policy to be changed?							
A.6	Is the way that the policy is communicated or being available to be impacted?							
B	**Design of framework for managing risk**							
B.1	Will the change impact the way the legal obligations are identified?							
B.2	Will the change impact the way standards, guidelines, models, best practices, etc., are be identified and implemented?							
B.3	Will the form, extent and (sub)partners of contractual relationships be impacted?							
B.4	Will the procedures for allocating resources for effective policy implementation and operation be impacted?							
C	**Accountability**							
C.1	Will the roles and responsibilities of the personnel appointed for allocating safety roles be impacted?							
C.2	Will the roles and responsibilities of the personnel accounted for competence assurance programmes be impacted?							
C.3	Will the roles and responsibilities of the personnel accounted for process risk assessments be impacted?							
C.4	Will the roles and responsibilities of the personnel accounted							

FORM IV - THE ACTIVITIES MAPPING AND EVALUATION

Change No.: Year:

Old and new roles activity mapping form. In a case more roles are about to change, use one form per each. If initial activities analysis is needed, please use also Form V.

Old role name:
New role name:
Date of mapping:
Reference documents:
Team members:
Initial activities analysis performed: ☐ yes ☐ no

	OLD ROLE ACTIVITIES										NEW ROLE ACTIVITIES									COMPARISON [b]		
				Involves [a]								Any new role issues?										
No.	Appointed activities	Can it be eliminated?	Req. hours per week	Response to deviations	Assuring plant integrity	Assuring plant availability	Managing HSE procedures	Manages essential knowledge and expertise	Subject of change?	Significant risk?	Appointed activities	Req. hours per week	Significant HSE hazards?	High workload, fatigue?	Competence issues?	Communication issues?	Team work issues?	Motivation issues?	Old role control measures that were applied?	Additional measures needed, or any comments?	Will controls be adequate?
1																					
2																					
3																					
4																					
5																					
6																					
7																					
8																					
9																					
10																					

Notes: [a] – select either Low/Mid/High, if applicable.
[b] – identified additional measures and potentially non-adequate controls for new role are to be compiled at upper level form.

FORM V – ACTIVITES ANALYSIS

Change No.: Year:

This is activities (task) analysis record sheet. The purpose is to breakdown the safety important activities, personnel roles and resources needed in order to feed the Form IV comparisons among "old" and "new" role activities evaluations.

Date of evaluation:
Reference documents:
Team members:

ID	Task/sub-task or Activity/sub-activity	Type	Actors & Roles	Duration	Importance	Notes
1						
2						
3						
4						
5						
6						
7						
8						
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11						
12						
13						
14						
15						
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21						
22						
23						
24						

FORM VI – EVALUATION OF THE TECHNICAL & TECHNOLOGY CHANGES

Change No.: Year:

This is a technical and technology related first safety assessment of the proposed change. Please identify what kind of an impact could the change have.

Date of evaluation:
Reference documents:
Team members:

ID, (sub)Component, potential impact(s) on	Impacted (requires MOC)?	What is impacted?	Kind of impact?	Possible consequences? *	Possible mitigations? *	Action by? *	Is mitigated impact adequate? *
A. PROCESSES							
A.1 Deviations from normal procedures	(yes/no)						(yes/no)
A.2 Emergency response/actions							
A.3 Short term testing/test							
A.4 Temporary procedural changes							
A.5 Changes to raw materials, intermediates or products							
A.6 New raw materials, intermediates or products							
B. PROCESS CONDITIONS							
B.1 Temperature							
B.2 Pressure							
B.3 Vacuum level							
B.4 Flow rate							
B.5 Level							
B.6 Composition							
B.7 Chemical reactivity or reaction kinetics							
B.8 Substance's hazardous properties							
B.9 Corrosion potential							
C. INSPECTION & MAINTENANCE							
C.1 Equipment inspection-							
C.2 Procedures & instructions for inspections							
C.3 Changes to the equipment set-up							
C.4 Periodic equipment maintenance							
C.5 Alarm, safety and security systems testing							
C.6 Equipment maintenance (preventive/corrective)-							
C.7 Procedures & instructions for maintenance							
C.8 Equipment preventive or corrective repairs							
C.9 Work permits or work in Ex-rated zones							

APPENDIX D
PHA RISK RATING IN MOC RISK ASSESSMENT

Table 1. Probability Levels

Cat.	Description	Aspects
A	Frequent	Likely to occur often in the life of an item.
B	Probable	Will occur several times in the life of an item.
C	Occasional	Likely to occur sometime in the life of an item
D	Remote	Unlikely, but possible to occur in the life of an item.
E	Improbable	So unlikely, it can be assumed occurrence may not be experienced in the life of an item.
F	Eliminated	Incapable of occurrence. This level is used when potential hazards are identified and later eliminated.

Cat.	Description	Mishap Result Criteria
1	Catastrophic	Could result in one or more of the following: death, permanent total disability, irreversible significant environmental impact, or monetary loss equal to or exceeding $10M.
2	Critical	Could result in one or more of the following: permanent partial disability, injuries or occupational illness that may result in hospitalization of at least three personnel, reversible significant environmental impact, or monetary loss equal to or exceeding $1M but less than $10M.
3	Marginal	Could result in one or more of the following: injury or occupational illness resulting in one or more lost work day(s), reversible moderate environmental impact, or monetary loss equal to or exceeding $100K but less than $1M.
4	Negligible	Could result in one or more of the following: injury or occupational illness not resulting in a lost work day, minimal environmental impact, or monetary loss less than $100K.

Table 3. Risk Assessment Matrix

SEVERITY / PROBABILITY	Catastrophic (1)	Critical (2)	Marginal (3)	Negligible (4)
Frequent (A)	High	High	Serious	Medium
Probable (B)	High	High	Serious	Medium
Occasional (C)	High	Serious	Medium	Low
Remote (D)	Serious	Medium	Medium	Low
Improbable (E)	Medium	Medium	Medium	Low
Eliminated (F)	Eliminated			