MANAGEMENT OF CHANGE FRAMEWORK WITH INTEGRATED RISK ANALYSIS FOR TEMPORARY AND EMERGENCY CASES

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PANG KAR KEI

Thesis submitted in fulfillment of the requirements
for the award of the degree of
Master of Science

Faculty of Industrial Sciences and Technology

UNIVERSITI MALAYSIA PAHANG

MAY 2021

ACKNOWLEDGEMENTS

First, I would like to express my sincere appreciation to my master thesis supervisor, Dr. Hanida Abdul Aziz, for her valuable responsive guidance, continuous encouragement, wise advice, opinions and consistent support. I am immensely grateful for her assistance from the beginning to the final level of the research with her tolerance and patience all the time to overcome my problems and provide inspirations and practical suggestions in this project.

In addition, I am immensely grateful to other postgraduates, who have similar research topic with me and are willing to share ideas, resources and suggestion throughout my project.

Besides, I would like to show great appreciation to Faculty of Industrial Science and Technology in supporting me in terms of financial and other necessary assistance for my project completion. Last but not least, special thanks to my lovely parents for their endless caring and full support at all time.

ABSTRAK

Industri pemprosesan berkembang pesat berikutan peningkatan permintaan atas produk-produk petroleum. Potensi malapetaka untuk berlaku mungkin meningkat dengan ketara terutamanya perubahan sementara dan perubahan kecemasan dilaksanakan. Walau bagaimanapun, pelaksanaan dan perhatian pengurusan perubahan (MOC) kini terutamanya terhadap perubahan sementara dan kecemasan adalah kurang dalam industri proses disebabkan interpretasi yang berbeza dan tidak konsisten berdasarkan piawaian yang ditetapkan, kekangan waktu dan ketersediaan data. Konsep penyelidikan ini adalah bertujuan untuk membangunkan panduan yang lengkap dengan bantuan perisian dokumentasi untuk pengurusan kes perubahan sementara dan kes kecemasan. Objektif kajian bertujuan untuk membangunkan rangka kerja MOC untuk kes sementara dan kecemasan, membangunkan sistem pengurusan pada MOC dan untuk mengesahkan rangka kerja dan sistem pengurusan yang dibangunkan. Kajian ini dimulai dengan analisis terhadap standard dan kriteria pengurusan keselamatan proses (PSM) yang terpilih. Semua kriteria dalam peraturan OSHA PSM telah dimasukkan dalam item tindakan kritikal dalam kerangka. Senarai penyemakan penilaian risiko yang diterima pakai telah dicadangkan dengan penambahan rujukan penilaian risiko untuk meningkatkan penilaian terhadap keutamaan risiko. Kajian ini telah diperluas ke pengembangan perangkat lunak teknologi yang mengintegrasikan semua penyimpanan data, pelacakan dan penutupan kes MOC ke dalam satu perisian. Rangka kerja yang dikembangkan telah ditbina menjadi model yang dikenali sebagai Pengurusan Sistem Pengurusan Perubahan (MOCMS) untuk meningkatkan pengesanan kes MOC sementara yang terbuka dan tamat dan memudahkan proses untuk mendapatkan maklumat. 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 perisian. Kerangka dan perisian dokumentasi yang dibina juga diuji keberlanjutan dengan mengulangi kes perubahan sementara yang sedia ada di kilang. Secara keseluruhannya, kerangka kerja yang dibina telah memenuhi prosedur dan amalan yang dipraktikkan di kilang proses dimana semua borang dan senarai semak yang diliputi dalam kerangka kerja yang dibangunkan. Selain itu, kerangka kerjayang dikembangkan telah mencadangkan item tindakan yang lebih komprehensif dan terperinci, seperti penilaian risiko untuk perubahan organisasi dan senarai semak penilaian risiko terperinci secara teknikal dan perubahan teknologi. Penilain dilakukan terhadap kes perubahan sementara di kilang proses hanya memberi tumpuan terhadap kerja pembinaan dan bukan terhadap faktor keselamatan keseluruhan proses merepakan salah satu penemuan penting dalam proses kajian rintis. Prisian dokumentasi yang dibangunkan juga dilengkapi dengan ciri-ciri pengesanan masa yang diambil untuk setiap item tindakan telah berjaya mengesan masa yang diperlukan untuk setiap kes perubahan. Ciri-ciri ini telah didapati bahawa masa yang masa yang diperlukan untuk menyelesaikan penilaian risiko di kerangka yang dibangunkan adalah lebih pendek daripada proses penilaian risiko kes MOC yang asal. Oleh itu, kajian rintis telah mengesahkan bahawa kerangka kerja MOC telah memenuhi unsur-unsur penting dalam MOC peraturan MOC terpilih dengan penambahbaikan terhadap isu-isu yang dikenalpasti sedangkan sistem pengurusan dapat dipercaya untuk memperbaiki dokumentasi sistem dan penyimpanan maklumat.

ABSTRACT

Process industries overgrow due to increasing demand for petroleum made products.The potential of major accident may significantly increase even more when temporary and emergency change is implemented. In fact, temporary and emergency changes were identified as one of the main contributors to the failure of Management of Change (MOC) in industries, leading to catastrophic outcomes in process industries. However, current MOC implementation and attention, especially towards temporary and emergency, lack in process industries due to inconsistency and different interpretation based on the established standards, time constraint and availability of data.. Corresponding to these weaknesses, an integrated risk analysis framework and system for temporary and emergency change based on PSM is developed. The concept of this research is targeting to provide complete guidance with the aids of documents and software for implementation of temporary and emergency software. Objectives of this research are, to develop temporary and emergency MOC framework, to develop a management system on MOC and to validate frameworks and management system developed through a pilot study. The research process begin with analysing all the requirements in the OSHA PSM standard and including into critical action item in the framework. Framework on temporary and emergency cases is established based on the adopted permanent MOC framework and selected PSM standard requirement. Adopted risk assessment checklists have been proposed with an embedded risk rating to improve risk prioritisation. The developed framework was transformed into a model known as Management of Change Management System (MOCMS) to improve tracking of open and expiring temporary MOC case and ease the process to retrieve information. The validation process of developed framework and system have been conducted through a pilot study by obtaining real data from process plant and testing applicability of developed result by repeating real-life temporary change case using developed framework and software. Meanwhile interview session has been conducted to obtain user and expert feedbacks on the developed results.Results of this study comprised of an overview of the MOC process displayed by a PDCA cycle, a complete MOC process framework with an adopted checklist, and a MOC management system acting as a guidance and documentation software. In overall, the developed framework has complied with the current practice in real process plant where all the necessary forms and checklist used are covered in the developed framework. Besides, the developed framework has proposed more comprehensive and detailed action items, such as specific risk assessment for organisational change and detailed risk assessment checklist in technical and technological change. In addition, the developed management system equipped with the features of recording time taken for every action item has successfully tracked the time taken for a specific action item. It is found that the time required for the completion of risk assessment in the developed framework is relatively shorter than the original MOC risk assessment process. Therefore, the pilot study has confirmed the MOC framework met critical elements in the MOC of selected MOC regulation with improvement to identified issues. The performance of the MOC framework and software shall be measure on the timely completion of MOC action items, and improvement in In contrast, the management system is reliable to improve system documentation and information storage.

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LIST OF ABBREVIATIONS

CA	Compliance Audits
CCPS	Center for Chemical Process Safety
CFR	Code of Federal Regulation
CIMAH	Chemical Industrial Major Accidents and Hazards Regulation 1996
CM	Contractor Management
CSChe	Canadian Society for Chemical Engineering
COMAH	Control of Major Industrial Accident Hazard Regulation 2015
DOSH	Department of Occupational Safety and Health
HAZOP	Hazard and Operability Study
HAZID	Hazard Identification Study
HIRARC	Hazard Identification, Risk Analysis and Risk Control
KOSHA	Korea Occupational Safety and Health Agency
MI	Mechanical Integrity
MOC	Management of Change
MOCMS	Management of Change Management System
OP	Operating Procedure
OSHA	Occupational Safety and Health Administration
PDCA	Plan Do Check Act
PHA	Process hazard analysis
PSI	Process safety information
PSM	Process Safety Management
RBPS	Risk Based Process Safety
WSH	Workplace Safety and Health

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter highlights the general ideas of this study, along with a few sections. This chapter includes the background of the study, problem statement, research objective, research question, the significance of the study, the scope of the study, conceptual definition, and operational definition.

1.2 Background of Study

Process industries are generally covering any manufacturing activities, including processing raw materials into final products. Chemical, petrochemical or any industries including water purification, waste treatment or production of paper and polymers are examples of process industries (WSH Council, 2012). However, advancement in technologies may lead to a complex process that may create more hazardous working environment to human (Esserman & Mentzer, 2017). Nowadays, the development of process industries has been extensively fostered by the improvement of technologies and skills. The increasing complexity of the manufacturing process causes 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 (Knegtering, 2002).

Over the decade, there were process industries incidents occurred, leading to catastrophic effects towards humans, properties and environment. Table 1.1 shows the tabulation of significant process industries incidents over the world from the year 2010 to 2020. These incidents indicated that the current safety management approach has room for improvements in managing the risk and hazards in the process plant.

Table 1.1: Major Process Incidents in the Year 2010-2020

Accident and Location	Year	Causes	Losses (Fatality, Assets or Environmental Damage)	Source
Kleen Energy Natural Gas Explosion	2010	High volume and pressure natural gas was forced through piping to remove debris	Six fatalities and assets damage including generators, fuel tanks and other equipment	(CSB, 2010)
Deepwater Horizon Oil Spill	2010	Inadequate installation of faulty concrete cap and low maintenance	11 fatalities and environmental damage with spillage of 4-million-barrel oil	(EPA, 2017)
Chevron Refinery Fire	2012	Sulphur in oil corroded piping and led to leakage	Six minor injuries and air pollution caused 15,000 cases of respiratory ailments to form at nearby residence	(CSB, 2015)
Lac Megantic Rail Derailment	2013	An automated train carrying crude oil derailed causing fire and explosion	47 fatalities and mass evacuation of 2,00 town residence and forty-four building damaged	(Roy et al. 2020)
West Fertilizer Plant Explosion	2013	Contamination of fertiliser ammonium grade (FGAN) with materials and poor ventilation	15 fatalities and more than 260 injuries and damage to more than 150 offsite building	(CSB, 2013)
Tianjin Explosion	2015	Overheated dry nitrocellulose caused a series of explosion	1. 178 fatalities and 797 injuries 2. Approximate of 320 tons of sodium cyanide and other chemicals dispersed in the air	(Sen et al., 2016)
Visakhapatnam Gas Leak	2020	Styrene liquid kept over a period and chemical reaction increased pressure, leading to leakage	11 fatalities and over two hundred hospitalisation cases	(Kumar Sharma, 2020)

Malaysia is one of the leading countries in terms of oil and gas producing country in the world that are extensively working on industrialisation, particularly in process industries. This status had attracted many foreign investors to invest in these process industries. Petroleum is beneficial raw materials that produce different kinds of products, such as plastic resins, olefins and aromatics. National Petroleum Berhad (Petronas), Shell, Polyplastics Asia Pacific and other companies use petroleum as raw materials in the manufacturing process. It is undeniable that fossil fuels are bringing benefits to human in product manufacturing; however, it also brings a significant number of underlying hazards in the 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 et al., 2016).

Moreover, the most recent process incident happened in Malaysia were in March 2019, where a fire and explosion at refining and petrochemicals complex occurred in Malaysia's southern state of Johor. This incident caused five casualties, and it is believed that the root cause of fire originated from plant diesel hydrotreater unit, which uses hydrogen to remove sulphur waste from raw diesel. Figure 1.1 shows the emergency response of the incident at RAPID Pengerang. Another fire incident happened at the same location, which occurred at the plant's atmospheric residue desulphurisation unit (ARDS). This unit removed sulphur from fuel oil to produce gasoline in a residue fluid catalytic cracker. Referring to these cases, a catastrophic accident may happen even there are many safety management approaches introduced in the past decade. This situation shows that process industries in Malaysia vitally needs an effective safety management method. Major industrial accidents will affect not only personnel in the workplace but also innocent residents around the area. Financial losses, low company reputation and compensation are enormous when a company experience accident (Kwon, 2006).

Figure 1.1: Fire and Explosion Incident at RAPID Pengerang

Source: Barry (2020)

Process Safety Management (PSM) is one of the management approaches widely applied in process industries to manage process-related hazards (Aziz & Shariff, 2017). It is also 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 of the manufacturing process. PSM is not only a system, but the result of this approach may go beyond personal safety in terms of process safety and eventually create a sustainable operation of the facility. This system can be modified into a business system and practice in every layer of the organisation (CCPS, 2016). Regulations and standards have been established to ensure the efficiency of PSM implementation in process industries in terms of managing all related aspects of the process. 29 CFR 1910, Seveso Directive, COMAH 2015 are some of the established PSM regulations in enforcing the implementation and providing guidelines to industries practitioner to implement PSM. Over recent years, many techniques and concepts have been developed to improve the limitations and to fit the new changes, which come along with new technologies innovations. For instance, risk-based process safety (RBPS) has been introduced to target on managing technologies, human, management systems failures, external circumstances and natural phenomena. Besides, research and innovations on specific PSM elements procedures, qualitative and quantitative risk evaluations, as well as software have been conducted to improve the effectiveness and to overcome the limitations of PSM (Galante et al., 2014; Hooi et al., 2014; Xie & Guo, 2018).

We are living in an ever-changing world where changes occur fast in a flash at any time. What happened today might change tomorrow. An organisation shall manage in quickly adapting to changes 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 organisation. Managing changes in a complex manufacturing process are challenging as industry safety practitioner shall be able to foresee and manage all possible consequences brought by the changes (Koivupalo et al., 2015). Management of change (MOC) element in the PSM system is providing an overview and guidelines on how highly hazardous industries shall manage change without neglecting any essential aspects to ensure the safety of a premise. MOC in PSM emphasised on evaluating, analysing and preparing a company to potential consequences brought by changes in the manufacturing process. However, the current MOC element is proved to be insignificant in terms of effectiveness in improving process safety (Naicker, 2014).

Changes in a process plant could be permanent, temporary or emergency based. The temporary change is usually applied for a specific duration. It shall come with a stated starting and closure date of the change. In contrast, emergency change comes in haste without further consideration, but only focusing on minimising further destruction and life-saving (CCPS, 1995). However, short-term changes are always treated negligently by applying changes without complete risk assessment. The consequences of neglecting temporary changes are well displayed in Flixborough incident. The occurrence of the incident was due to a temporary change on the reactor to complete maintenance of corrosion. A bypass was installed to connect between reactor No.4 and No.6 when it was discovered that the reactor No.5 is experiencing serious leakage of cyclohexane. Figures 1.2 and 1.3 show the aftermath and situation of Flixborough incident. This temporary change was not well controlled and contributed to the happening of the explosion (Piong et al., 2017). Any simple changes without proper management will be the underlying hazards in bringing catastrophic outcomes. Management of change is critical in ensuring changes are well managed and under control (Joseph et al., 2005).

Figure 1.2: Aftermath of Flixborough Incident in June 1974

Source: Rusell & Blosse (2019)

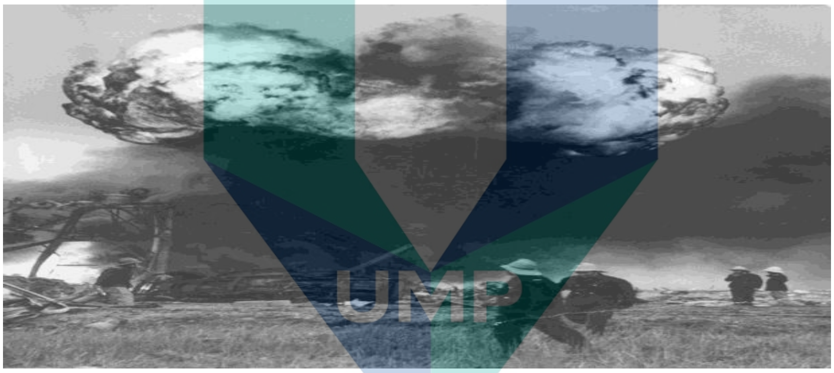


Figure 1.3: Smoke and flames emitted into the environment

Source: Rusell & Blosse (2019)

Mechanical integrity, emergency response and control as well as contractors management seems to be the elements invested and worked on by most of the companies compared to other elements (Naicker, 2014). In addition, MOC is also proven to be one of the most neglected in both Taiwan and Pakistan (Anwar et al., 2019; Chen et al., 2010). However, MOC is an element interlinked with several elements after any changes implemented in the manufacturing process. Several elements will be triggered in MOC. Employee participation (EP), Process Safety Information (PSI), Process Hazard Analysis (PHA), Operating Procedure (OP), Training (TNG), Mechanical Integrity (MI), Pre-Startup Safety Review (PSSR), Contractor (CON) and Compliance Audit (CA) are the elements interrelated with MOC.

Although the nature of PHA element is designed as risk recognition and control, it is not a compulsory element in all kind of new changes. PHA is complex and focused on detail process hazard and controls on every single node of the operational process (Baybutt, 2013). PHA shall be conducted when the new proposed change involves the modification of a few nodes, which may create new scenarios in the existing process. For instance, changes in terms of raw materials specification may impact more than a node of process scenario. This requires revalidation or new study of PHA on the recent changes (Baybutt, 2014, 2015). PHA includes several methods, including What-If analysis, hazard and operability study (HAZOP), failure mode and effect analysis (FMEA), Layer of Protection Analysis (LOPA) and many more. HAZOP and LOPA are the commonly adopted PHA method in recent years. PHA is a lengthy process involving a group brainstorming session in addressing all potential scenarios in the process (Kletz, 2009). Therefore, it is less likely to utilise the PHA as new changes risk assessment, especially on temporary and emergency change with time and resources constrain. Instead, the outcome of PHA shall be the primary reference of MOC risk assessment to avoid overlooking of hazards that may affect the existing process control.

This study is to contribute in producing systematic MOC framework and system to ease human work task in terms of managing situation before and after implementing change. A simpler yet comprehensive risk analysis shall be available for temporary and emergency changes, which come with the nature of time constraint. Traditional proposed methods on MOC execution are more towards time-motion based that consist of many underlying weaknesses. A comprehensive MOC framework focusing on 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).

In this study, the MOC system with integrated risk analysis is proposed to minimise these limitations. Introduction of technology factor in MOC system included in this study could enhance the effectiveness of the MOC implementation program.

1.3 MOC implementation and Challenges

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

However, the conditions could be complicated in terms of 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 the technological-based industry (Knegtering & Pasman, 2009). The complicated process could be burdensome to manage safety level solely relying on human mind without technological support. This could create rooms for safety weaknesses, especially during the hectic period leading to catastrophic industrial accidents. Technological-based aids in storing emergency operating procedures and related information enables the human operator to react accordingly (CCPS, 1995; Kameumoualdi, 2010).

As the complexity of the operation process increases, the work of managing safety level gets difficult if relying solely on using manual method. Managing the change is challenging, requiring to be disseminated quickly. It also requires related knowledge and information to address the hazards. Reporting and reviewing task may be complicated as more paperwork is required. Moreover, applying changes on the operation process is a complex procedure and relatively challenging, which requires assessing the need of improvements and training of personnel, potential challenges and so on (Koivupalo et al., 2015; Zwetsloot et al., 2007). French et al., (2011) stated the same opinion as Zwetsloot (2014) where human behaviour is merely impossible to perform characterisation of risk and reliability test on the complex environment, which may restrict personnel from entering during operation. This requires great attention of process safety personnel in which inadequate risk assessment and analysis may eventually add unexpected risk towards altered process (Chosnek, 2010). As the process gets complex, the human factor will be another underlying hazard in Management of Change (MOC) as factors including fatigue, communication breakdown, no proper job handover is happening almost every day in the workplace. This is a critical consideration factor, as 90% of process-related accidents are contributed by human failure (Abu-Khader, 2004; Bridges & Tew, 2010). Integrated system on MOC, which is well-developed and planned, may minimise the burden on safety-related process personnel in planning work on the implementation of changes in the operation process. This improves production efficiency and customer satisfaction (CCPS, 2016).

MOC is one of the elements under PSM to evaluate, anticipate and manage all possible consequences that may occur after implementing change in the 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 on Mechanical Integrity and Emergency Response & Control elements instead of MOC. In addition, Koivupalo et al. (2015) addressed that the current MOC approach is applied after changes instead of before. The actual function of MOC was wrongly translated. This is one of the reasons that cause the industry to ignore the importance of MOC. MOC element is the element worth for employer to pay attention in terms of operational control. This can be seen from statistics made by previous studies in which poor MOC contributes 9.1% (Piong et al., 2017) and 19% (Ye et al., 2012) of process safety accidents. Moreover, Gambetti et al. (2013) addressed that approximately 80% of major accidents root cause was due to MOC failure. In every 1000 work tasks, 5-10% tasks require MOC, while there might be 5 to 10 changes of high risk (Gambetti et al., 2013).

Hoff (2013) stated that more focus should be placed towards MOC efficiency aspects in the context of the business process to avoid unnecessary complexity in the manufacturing process. Many organisations have introduced various types of safety management tools to reduce the consequences of changes made in the manufacturing process and the organisation. This is because industrial practitioners view the managing changes made in the organisation as a situation rather than a management tool (Koivupalo et al., 2015). Many organisations seem to wrongly translate the function of management of change, thus neglecting the importance to invest in MOC. Moreover, weaknesses in storing of many MOC related data is causing a burden for industry practitioner to practice MOC because of the non-systematic and inadequate procedure and system (Bakar et al., 2017; Piong et al., 2017). In addition, poor documentation in the tracking of MOC cases may build up the number of incomplete MOC cases, which may eventually turn insufficient temporary changes into a potential hazard on the premise (Chosnek, 2010).

1.4 Problem Statement

It is significant to highlight on temporary and emergency cases in MOC procedures as these changes are more likely in contributing to the occurrence of major accidents. Based on the data obtained from an accident cause analysis, 13.4% of accidents were due to poorly managed MOC in the plant. This is even critical when it comes to temporary or emergency change with limitation of time on risk assessment. Based on the study conducted on the typologies of MOC failure, it is found that breakdown or failure system change and temporary system change contributed 30.1% and 10.1% of MOC failure which contributed two of the highest percentage of MOC failure (Piong et al., 2017). Common process safety risk assessment will tends to implement systematic assessment on complex process which commonly applied in Process Hazard Analysis (PHA). Urgent changes especially on temporary and emergency shall comes with time-efficient yet comprehensive to be the pre-safety assessment before implementation of urgent change. However, initiation of Process Hazard Analysis during temporary and emergency MOC planning stage would be relatively challenging as the time limitation and group brainstorming session may place a constraint to the flexibility in producing effective outcomes (Baybutt, 2013, 2015). Therefore, short term change procedures with effective risk asessment, including temporary and emergency, are necessary to minimise the current gaps and human complacency towards safety procedures.

According to Zwetsloot et al., (2007), previously proposed approach on Management of Change (MOC) in the organisation are practising time-motion based method. This method has created a limitation for 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 the 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 the safety check. Another drawback of time-motion based MOC approach is that it focuses less on predicting possible consequences on changes made on the process. Previous time-motion based approach is strictly followed on the time allocated on each action items given in the framework. This approach has overlooked some essential supporting action items, which could be one of the underlying weaknesses of the current MOC framework in detecting consequences and errors. Current MOC framework is focusing too much on performing a task within a period given and hence performing work using a checklist with underlying errors and weaknesses.

Apart from time motion-based, MOC has limitations in time constraint and urgency to resume operation, which contributes to neglection of time consuming step such as risk assessment. Simplification on risk assessment, absent of updating operating procedure and so on caused neglection in MOC due to urgency (Piong et al., 2017). Gambetti et al., (2013) mentioned that the MOC process requires long lead times due to several factors. For instance, a meeting shall be conducted with affected departments and specialist to address control measure on potential risk in the change. Documents related to process hazard analysis (PHA), process safety information (PSI) and other elements are required to review and evaluate the change. However, diagnosis-based method has some negative attribute in terms of neglection of significant risk due to human factor and limitation in estimation of the completion time (Galante et al., 2014). Improper risk and mitigation measures may be wrongly prioritised due to the absence of risk rating or quantitative measures to provide weightage of each risk. In addition, limitation in terms of predicting completion time would be another challenge in managing risks for changes, which comes with a time constraint for planning works. Therefore, it is necessary to propose a comprehensive yet time-efficient risk assessment method, inculcate risk rating or quantitative measures in terms of justification of risk severity and prioritise mitigation measures when it comes to limited resources and support.

Documentation for all related work task and risk assessment is required for all kind of changes. It is obviously time-consuming to perform all the steps, especially for temporary and emergency MOC changes. Centre For Chemical Process Safety (2016) addressed that it would be an added advantage if time and duration concept is included in MOC. Previous MOC approach applying time-motion based has become a fault in the system whereas improvised MOC system had removed this approach. Current MOC approach has weakness in predicting the required duration to perform the first phase of the MOC system until the decision making phase. Prediction on time required to perform every action item under MOC may provide milestones and timing target to achieve desired goals.

One of the key factors in the success of the MOC program is that each related elements, such as PHA, PSI, operating procedure (OP) and risk assessment come as a 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 action item between MOC procedures, time prediction and organisational risk assessment were not extensively studied. The present studies addressed these shortcomings of the MOC system leading to poor MOC implementation program. Therefore, a new framework and management system is proposed to minimise the weakness for limitation in time prediction, prioritisation of risk and record of logging and storage comes into a more convenient yet less burdensome way.

Overall, the framework is designed to propose a risk assessment checklist in the management of temporary and emergency changes. The process is suitable for temporary and emergency change with limited planning time as the proposed framework is comprehensive and timely-efficient. Every action item in the framework comes along with respected risk assessment form suitable to be modified in handling temporary and emergency cases.

1.5 Research Questions

This study was conducted to determine the following questions:

1. What are the steps that should be taken to implement temporary and emergency change in an organisation based on Process Safety Management (PSM)?

2. What could aid in the implementation of the management of temporary and emergency change process with time constraint and time-motion based on risk analysis?

3. How to ensure the developed MOC framework and system is reliable and valid?

1.6 Objectives

Objectives of this study can be categorised into the main objective and specific objectives as follows:

1. Main objective:

   To develop an integrated risk analysis framework and system for temporary and emergency change based on Process Safety Management.

2. Specific Objectives:

   i. To construct a framework for implementing temporary and emergency Management of Change (MOC) with the integration of risk assessment.

   ii. To develop MOC system that aids in the process of managing temporary and emergency change with complete risk analysis with time constraint.

   iii. To verify efficiency and reliability of developed MOC system through system testing.

1.7 Scope of the Study

The present research is guided by the following scopes to ensure the research addresses the objectives and is completed within the stipulated time frame.

1. Development of integrated temporary and emergency Management of Change (MOC) framework from change initiation, risk analysis, change implementation, tracking and closure for process industries

2. Establishment of online risk analysis checklist with Microsoft Excel and to be stored in developed MOC Management System

3. Improvement on adopted risk assessment checklist by introducing risk rating commonly applied in Hazard and Operability Study (HAZOP) examination.

4. Development of MOC Management System with Microsoft Access based on the developed framework.

5. System testing on the developed framework and management system by collecting real data and repeating temporary change case with developed result at chemical plant.

6. Collection of feedback from focus group on developed framework and management system through interview and survey questionnaire.

7. Analysis of focus group user response survey result to determine reliability and usability level of developed management system.

1.8 Significance of the Study

Process safety management (PSM) consists of 14 elements interconnected to cover almost all the safety aspects in highly hazardous industries. Looking on the perspective of PSM implementation among countries, the extension of PSM implementation in Malaysia is non-mandatory as compared to other developed countries where PSM are widely applied with enforcement in most of the industries (Bakar et al., 2017). United States, United Kingdom, and Japan are developed countries with established regulation specifically on PSM. Bakar et al., (2017) addressed that the government shall make encouragement on the application of PSM in Malaysia. The execution of PSM is anticipated to be voluntary based for all the industries in the daily operation process. More studies on PSM helps in determining a milestone target to the government to take initiatives on PSM implementation in Malaysia. Local research and improvement made on PSM elements can contribute valuable and reliable information to the public on the efficiency of PSM in establishing safety environment (Gerbec, 2017). This can be referred to Piper Alpha and Bhopal incidents where the accident takes place when temporary bypasses have been conducted while waiting for maintenance work to complete. Human beings are more likely to tend to bypass safety procedure when a process is only required for a short period, and when short-term change procedure is absent in place. This study is aimed to contribute to industrial practice in terms of the management and planning of any urgent changes without compromising the control of safety, especially in process industries.

Implementation of information and communication technology (ICT) in MOC will produce immediate responses towards changes that shorten the time required in a MOC cycle (Hooi et al., 2014). Application of technical support, such as web-based storage system and user-friendly human-machine interface (Conger & Fulmer, 2003), are some alternatives available as Health and Safety (HS) tool to overcome the weakness of manual method in safety. A well-developed and integrated management system would help in tracing back previous temporary cases and related risk assessment. New similar temporary MOC might be able to skip a certain risk assessment that shortens the stress of time constraints. Moreover, this management system can also be utilised in the tracking of changes made during an emergency in which the stored data may help in the planning of emergency response. Koivupalo et al., (2015) addressed that there is a need for a 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 be utilised without a highly skilled person to operate the system. Usage of software can aid in decision making if there are a large number of reports involved in the analysis stage (Gnoni et al., 2013). It will be an added advantage to a system with the flexibility, which can efficiently control the changes and updates of existing documents (CCPS, 1995). Moreover, the implementation of technological aid would help in minimising human limitation in terms of tracking and follow-up actions of all kinds of MOC cases. The employment of existing Microsoft Access software will reduce the financial pressure in the implementation of technology into the management process, beginning with the direction to move forward into Industrial Revolution 4.0.

1.9 Thesis Organisations

This thesis consists of five chapters. Chapter one (Introduction) includes a brief introduction on the timeline of process industries incidents in worldwide and Malaysia, Process Safety Management (PSM), and Management of Change (MOC) implementation challenge. This chapter also includes the problem statement, which provides the basis and rational direction together with research objectives and thesis organisation.

The second chapter (Literature Review) reviews on process safety elements related to MOC along with the development and criteria of each PSM standards on MOC around the world. Comparison of established standard and guidelines has been conducted as a reference in developing the framework in this study. The published individual and integrated frameworks, risk assessment and MOC software are discussed.

The third chapter (Methodology) presents the overall study flowchart. The detail of research works from MOC standard requirements analysis, framework and model development, and verification of the proposed concept through real plant data is elaborated in this chapter.

The fourth chapter (Result and Discussion) focuses on the development of the temporary and emergency framework. The framework has integrated requirements from selected regulation and risk assessment in each action item. The model of MOC Management system is developed and verified through case studies utilising real plant data.

The fifth chapter (Conclusion and Recommendation) concludes the findings from this research, arranged accordingly to the sequence of the main study. Recommendations are given due to their significance and importance related to current studies.

1.10 Operational Definitions

This section presents the definitions of operational terms commonly used in Process Safety Management (PSM) concept and Management of Change (MOC).

1.10.1 Employee Participation

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

1.10.2 Process Safety Information (PSI)

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

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

1.10.3 Process Hazard Analysis (PHA)

Process hazard analysis element requires the employer to develop a thorough, systematic and organised approach in anticipation, evaluation and control of processes that use hazardous chemicals (US OSHA, 1994).

Process hazard analysis is a thorough, organised and systematic approach used to evaluate and control hazards involved in operations. PHA includes several methods 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).

1.10.4 Operating Procedure (OP)

Operating Procedure element provides direct and explicit instruction to conduct activities 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).

1.10.5 Training

This element guides 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 particular process (US OSHA, 1994).

Training includes initial training for a 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).

1.10.6 Contractors Management (CM)

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

1.10.7 Pre-Startup Safety Review (PSR)

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

1.10.8 Mechanical Integrity (MI)

Mechanical integrity element ensures 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).

1.10.9 Hot Work Permit (HWP)

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

1.10.10 Management of Change (MOC)

This element emphasises on management on all modification to equipment, procedures, raw materials and operating process which is not "replacement in kind". Replacement in kind is the replacement of the same specification of equipment or materials that do not introduce any new hazards. Hazard recognition, evaluation and proposed control measures shall be conducted and evaluated before any changes are implemented (US OSHA, 1994).

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

1.10.11 Incident Investigation

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

Incident investigation shall be conducted in every incident that has potentially resulted, or in a catastrophic release of a hazardous chemical. Investigation team shall consist of at least an expert in the operation process. This includes a permanent employee when the incident involves a contractor or any persons who experienced the incident investigation (WSH Council, 2012).

1.10.12 Emergency Planning and Response (EPR)

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

1.10.13 Compliance Audits (CA)

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

1.10.14 Trade Secret

Trade secrets are an element that requires an employer to provide all essential information for standards compliance on other elements disregarding possible trade secrets (US OSHA, 1994).

1.10.15 Temporary Change

The temporary change is defined as any change to be implemented for a specific period. The common definition of temporary change is those changes to be implemented for six months and not more than 12 months (Tew, 2014).

1.10.16 Emergency Change

Emergency Change is an essential step of response in an emergency, especially in the case of life-saving, to prevent further damage to the property, environment and process line. This nature of change allows the practitioner to address changes during the emergency after the change is implemented to avoid further destruction (Hansen & Gammel, 2008).

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter reviews previous studies and research conducted on Process Safety Management (PSM), Management of Change (MOC) framework and technology system, which can be utilised as a safety management tool. There are several research studies found investigating the weaknesses of PSM in Malaysia and the limitations of current MOC approach affecting the effectiveness of MOC implementation.

2.2 Evolution of Process Safety Management and MOC Standards Around the World

Process Safety Management (PSM) is a safety management approach established specifically for highly hazardous industries involving hazardous process. PSM aims to achieve a goal to prevent the occurrence of a major industrial accident causing catastrophic consequences (H. Luo, 2010). This approach focuses on the development of systems in ensuring that technological, organisational, and equipment factor are maintained appropriately (Aziz & Shariff, 2017; OSHA, 1992). PSM comprises of 14 elements emphasising on anticipation of risk, risk analysis and control to enhance the safety level of hazardous process (Bakar et al., 2017). There are significant improvements in terms of process safety over the years on the implementation of PSM. Implementation of PSM and enactment of PSM regulation in the United States has improved in terms of provision towards facilities with hazardous chemicals, and incident investigation on all types of incidents to be a continuous improvement action (Brabson, 2010). Besides, there were significant improvements in Korea after seven years of PSM implementation, including reduction of more than 50% of fatalities and near misses, improvement in quality, productivity and reorganisation of technical data of process industries. There is also an observed reduction in emergency shut down cases and losses in property damage (Aziz & Shariff, 2017; Kwon, 2006).

Process Safety Management (PSM) system has been established for over 30 years consisting of 12 elements at the very first concept. These elements cover organisational, technological and equipment aspects to create a safe environment in a premise. Centre for Chemical Process Safety (CCPS), a division of American Institute of Chemical Engineers (AIChE), is the first organisation issued on PSM standard. Initially, the PSM approach focuses on the human factor and eventually revised in the year 2007, changing its attention towards process-related safety. PSM is then renamed into Risk-Based Process Safety (RBPS). Instead of covering the human factor by a single element, RBPS then involves human factor throughout six out of 14 elements (Bridges & Tew, 2010). The emergence of the PSM system around the world was triggered by numbers of catastrophic accidents that caused severe impact towards human and environment. The emergence of PSM concepts in various countries, such as the United States, Korea, Europe and the United Kingdom, was mainly due to the occurrence of catastrophic incidents.

2.2.1 PSM in the United States

In the early 20th century, industrialisation and industrial revolution moved on to the second phase. Badische Anilin und Soda Fabrik (BASF) chemical plant located in Oppau, Germany experienced an explosion in the year 1921 destroying the premise, causing death to at least 430 people and damage to approximately 700 houses around the plant (Macza, 2008). Two decades later, Bhopal incident in 1984 caused a catastrophic release of Methyl Isocyanate (MIC) triggering OSHA US to pay attention towards all premises in the US that manufacture MIC (Aziz & Shariff, 2017). Figure 2.1 shows the timeline of PSM development in the United States.

Figure 2.1: US PSM Regulation Timeline

Source: Aziz & Shariff (2017)

In the year 1990, the Occupational Safety and Health Administration, OSHA has begun to work on managing safety on the industry involving the hazardous chemical. Federal Register (55 FR 29150) was published by OSHA to be used as a standard named as “Process Safety Management of Highly Hazardous Chemicals” on July 17. OSHA receives approximately 4000 pages of testimony and more than 175 comments 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, entitled as Process Safety Management of Highly Hazardous Chemicals (Aziz & Shariff, 2017; US OSHA, 2000). Table 2.1 shows the 14 main elements in OSHA PSM.

Table 2.1: Overview of OSHA PSM Elements

PSM Element	Description
Employee Participation	Ensure that workers and their representatives are consulted and have access to information regarding all PSM elements.
Process Safety Information	Maintain complete and accurate information on the process technology, process equipment, hazardous characteristics and physical properties of all chemicals and intermediates for all covered processes.
Process Hazard Analysis	Identify and assess process hazards for each covered process, and take action to manage risk.

Source: OSHA (1992)

Table 2.1 Continued

PSM Element	Description
Hot Work Permit	Ensure that appropriate measure is taken at any time non-routine works, specifically hot work, such as welding operations are performed on or near covered process areas that might introduce the potential for increased risks of fires and explosion.
Training	Provide initial and refresher training with a means of verifying employee understanding for all employees involved in operating a covered process.
Contractor	Ensure that subcontractor operations do not compromise the level of safety on or in the vicinity of a process using Highly Hazardous Chemicals (HHCs).
Operating Procedures	Provide clear written instructions for safely conducting activities at each covered process that address operating limits, safety and health considerations, and safety systems and their functions.
Pre- Startup Safety Review	Perform safety reviews for new and modified facilities prior to operation when a modification is significant enough to require a change in the process safety information.
Mechanical Integrity	Ensure the integrity and safe operation of process equipment through inspection, testing, preventive maintenance, and quality assurance.
Management of Change	Establish and implement written procedures to manage changes (except for replacements in-kind) to process chemicals, technology, equipment, and procedures, and to facilitate procedures that affect a covered process.
Incident Investigation	Using a written procedure, provide a team investigation of any incident which results in, or could reasonably result in, a catastrophic release of a highly hazardous chemical. Each investigation must be documented in a written report and findings and recommendations resolved promptly.
Emergency Planning and Response	Establish and implement an emergency action plan for the entire plant that complies with 29 CFR 1910.38(a) and addresses small releases.
Compliance Audits	Ensure that the PSM program is operating in an integrated and effective manner in compliance with PSM requirements.
Trade Secret	Ensure all information is available to support the PSM Rule. When necessary, confidentiality or nondisclosure agreements may be used.

Source: OSHA (1992)

There are a few process safety management standards established in United States including 29 CFR 1910.119 by US Occupational Safety and Health Administration, Risk Based Process Safety by Centre for Chemical process Safety and 40 CFR 68 by US Environmetal Protection Agency. to promote a better implementation of process safety management concept and especially on MOC requirements.

2.2.1.1 PSM Regulation on MOC in US Occupational Safety and Health Administration

The United States Occupational Safety and Health Administration (US OSHA) established PSM standards in February 1992, known as the Process Safety Management of Highly Hazardous Chemicals. However, PSM standards in the US are only made after experiencing a series of disastrous chemical events. These events had brought catastrophic consequences to all parties, which eventually led to the promulgating of PSM standards to increase the safety level in chemical industries (Long, 2009). Fourteen elements were incorporated into the standards to manage all industry aspects of technological, personnel, and equipment factors (Aziz & Shariff, 2017). Requirements on MOC by 29 CFR 1910.119 is stipulated in Table 2.2. Criteria stipulated under Table 2.2 were detailed requirements retrieved from 29 CFR 1910.119, Process Safety Management of Highly Hazardous Chemicals -- Compliance Guidelines and Enforcement Procedures (1994).

Table 2.2: 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)

2.2.1.2 PSM Regulation on MOC in US Center for Chemical Process Safety

Centre for Chemical Process Safety (CCPS) was created in the year 1985 by the American Institute of Chemical Engineer (AIChE) to develop and publish the latest technical information in major industrial accident prevention specifically on the chemical-related industry. Risk-based process safety (RBPS) is then created to provide a framework of process safety management to the public. RBPS recognizes that all hazard occurrences are unequal. RBPS approach is built upon four foundation pillars: commit to process safety, understand hazards and risk, manage risk, and learn from experience. The RBPS requirement for MOC is shown in 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 the review process
Decision making	Change authorization
	Ensure authorizers addressed important issues
Complete follow-up activities	Records update
	Changes information delivery to related personnel
	Establishment of risk control measures
	Records storage

Source: CCPS (2014)

2.2.1.3 PSM Regulation on MOC in the US Environmental Protection Agency (EPA)

United States Environment Protection Agency (EPA) was established in the year 1970 to ensure environmental protection is made through research, enforcement, and standard-setting (EPA, 2018). EPA has then promulgated the plan called Risk Management Program (RMP) regulation enacted to contribute to chemical accident prevention. RMP (40 CFR 68) aims to mitigate the risk of chemical accident at the local level, provide guidance in emergency preparedness and response plan, and disseminate knowledge on chemical hazards to the public (Aziz & Shariff, 2017). 40 CFR 68 requirement on MOC is shown in 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 a covered process
68.75 (b)	Criteria shall be addressed in the written procedure
68.75 (c)	Information delivery and training to affected employees by the change implemented
68.75 (d)	Update process safety information (if necessary)
68.75 (e)	Update operating procedure (if necessary)

Source: EPA (2000)

2.2.2 PSM Evolution and Regulation on MOC in Europe and the United Kingdom

Several tragedies in Europe and Asia triggered Process Safety Management (PSM) related regulations among the United Kingdom (UK) and European countries. In Flixborough UK (1974), the Nypro site chemical plant was extensively damaged by an explosion. It is believed that plant modification, including removal of reactor and installation of the bypass, had been made without conducting an assessment on anticipating potential outcomes of such decisions. 28 workers were killed, and the fire had blazed over ten days. There are many flaws in the plant operation involving failure in maintenance procedures, operation procedures, management of change procedure, etc. (HSE, 1975).

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

In 1984, the worst air pollution tragedy happened at Bhopal, India. The lethal gas named methyl isocyanate (MIC) was released to the environment from leaking storage tanks owned by Union Carbide. Nearly 36 tons of MIC gas released into the atmosphere forced the evacuation of at least 200,000 people. More than 3,800 people were killed and caused burning to respiratory and chest tightness to over 200,000 people. This tragedy contaminated drinking water, soils, and even pond water. The fetus and newly born babies were adversely affected by the disaster (Bowonder, 2012).

Piper Alpha, UK (1988), an explosion and fire event had destroyed Piper Alpha offshore platform. Piper Alpha was once Britain's largest single oil and gas producing platform in history that supplies 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 to the event. Gas has been released and ignited while firewalls fail to defend the platform from a further explosion. This has resulted in 165 deaths, and the platform's installation has been completely blown out (NSC, 2013).

CIMAH 1984 is then enacted, followed by a series of catastrophic accidents, including Flixborough, Bhopal, Piper Alpha incidents. This regulation was developed from the Advisory Committee on Major Hazards (ACMH) and Seveso I Directive from the European Commission (HSE, 2016). Control of Industrial Accident Hazard Regulation 1984 (CIMAH) was first enacted in the year 1999, acting as a guide to industries to comply with Seveso Directive I. CIMAH 1984 was then adopted by Malaysia to prevent the occurrence of industrial accidents. CIMAH 1984 was then improvised into CIMAH 1999 and changed to Control of Major Industrial Accident Regulation (COMAH) 2015. COMAH 2015 was enacted to prevent and mitigate major accidents that may cause permanent damage or harm to people and the environment (HSE, 2015b). The MOC requirement in COMAH 2015 is shown in Table 2.5.

Table 2.5: COMAH 2015 on Management of Change

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

Source: HSE (2015a)

2.2.3 PSM Evolution and Regulation on MOC in China

China has been one of the leading countries in the manufacturing industry; meanwhile, it also leads in the occurrence of disastrous accidents. From the year 1979- 2010, several chemical industrial accidents happened and caused severe effects on the surrounding. One hundred three lives had been killed, and around 900 people were injured. Therefore, regulations and guidelines for process safety management in petrochemical corporations (AQ/T 3034-2010) have been established to enhance the petrochemical industry's safety level in China. AQ/T 3034-2010 requirement on Management of Change (MOC) is shown in Table 2.6.

Table 2.6: AQ/T 3034-2010 on Management of Change

AQ/T 3034-2010 (4.9)	Explanation
4.9.1	Establishment of written procedures related to changes to protect human, environment, property and company reputation
4.9.2 (a-e)	Criteria shall be addressed in a 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 to guidelines on petrochemical process safety management (AQ/T3012-2008) (11).

Source: State Administration of Work Safety (2010)

2.2.4 PSM Regulation on MOC in Canada

Process Safety Management (PSM) in Canada is applied based on voluntary initiatives program. Canada does not establish its own legislation to enhance PSM implementation among highly hazardous industries but mostly adopted from the Centre for Chemical Process Safety (CCPS). This Process Safety Management Guide was prepared by the Process Safety Management Division of the Canadian Society for Chemical Engineering (CSChE), which intended to provide introductory guidelines for the Canadian PSM practitioner on PSM implementation (CSChE, 2012). CSChE PSM Guide requirement on Management of Change (MOC) is shown in Table 2.7.

Table 2.7: CSChE PSM Guide on Management of Change

CSChE PSM Guide	Explanation
5.0 Management of chang	Criteria shall be addressed in written procedures.
5.1 Change of process technology	The proposed operation shall subject to review and approval b qualified personnel. Qualified personnel shall be available when authority is neede at short notice.
5.2 Change of facility	Hazard assessment of equipment on proposed changes. The procedure established shall be available for minor and major changes, simple yet approved by qualified personnel.
5.3 Organizational change that may have an impact c process safety	The transition period and the new organization shall be addressed. The departure of staff or any organization units changes shall not interfere with the accountability and safe control of the operation in the premises.
5.4 Variance procedures	A 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 programs Conduct appropriate risk management
5.6 Temporary changes	Should subject to the condition as permanent changes The time limit shall be clearly defined

Source: CSChE (2012)

2.2.5 PSM in Korea

The petroleum refining industry in Korea emerged in 1964, producing 8.26 million tons of ethylene annually in 2015. Korea is the 6th largest country in ethylene production, following the United States, Europe, China, and Saudi Arabia. Some catastrophic industrial accidents happened in Korea, which contributed to major industries. In October 1989, the Yeosu Chemical plant exploded, causing 16 deaths and 17 injuries. In March 1991, a chemical spill caused river pollution and affected freshwater supply to the community. Apart from the major accident in

Korea, catastrophic industrial accidents worldwide have made the Korean government realise the importance of managing highly hazardous industry safety.

KOSHA (Korea Occupational Safety and Health Agency) was established in the year 1996 to manage Process Safety Management (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 areas, including:

1. Submission of process safety management plan report
2. Review of process safety management plan report by safety committee before submission
3. Evaluation of Process Safety Management plan report by KOSHA
4. Enforcement of Process Safety Management plan report
5. Monitoring of PSM implementation by the Korea Labor Institute

2.2.6 PSM in Singapore

Process Safety Management recommended practice in Singapore was established in the year 1993. The overall concept of PSM in Singapore was modelled closely to US PSM regulation, 29 CFR 1910.119, and API RP 750. The general concept of the PSM elements is similar to US PSM regulation, consisting of 14 elements that are targeted to mitigate the risk of major industrial accidents involving hazardous substances (Go, 2010). No changes or additional requirements has been made on the 14 elements adopted from 29 CFR 1910.119. In 2001, the Chemical Industry Code of Practice on Safety Management System was developed from the previously recommended practice. Meanwhile, a new Singapore Standard, SS506: Part 3: 2006 - Occupational Safety and Health (OSH) Management System – Requirements for the Chemical Industry was established following the enactment of the Workplace Health and Safety Act 2005 in 2006 (Goh, 2012; Yang et al., 2015).

2.2.7 Process Safety Management and PSM Regulation in Malaysia

Despite other developed countries such as United States, United Kingdom, Japan, and European countries where Process Safety Management (PSM) is widely implemented in manufacturing industries, Malaysia is considered way behind compared to these countries. There are a few highly hazardous industry premises in Malaysia that have adopted PSM in operation. This is due to current practice in Malaysia are voluntary based implementation of PSM standard as there is no enforcement made on the standard implementation. However, it lacks sufficient evidence on PSM's effectiveness in its premise (Bakar et al., 2017). In Malaysia, highly hazardous manufacturing industries are still practising some standard safety management tools that are insufficient to cater to hazardous levels in their industries. At the end of the last century, Hazard and Operability Study (HAZOP) assessment, Layers of Protection Analysis (LOPA), and Fault Tree Analysis (FTA) were the common approaches adopted by the petrochemical industry. These approaches functioned in controlling hazardous conditions, and yet accidents still happen. This shows that these approaches are imperfect enough to cover all the underlying hazards in highly hazardous industries, leaving a large gap of failure to occur at any time (Knegtering & Pasman, 2009). Common manufacturing industries and highly hazardous industries shall adopt different safety management approaches as their consequences are widely different. Accidents originated from highly hazardous industries due to the failure of the management system could be fatal and leave long-term effects on the environment and humans (Ness, 2015).

PSM shall be widely implemented in Malaysia, particularly in industries possessing hazardous substances and processes. This is because Malaysia's safety culture is not thorough and effective in all layers of the community. PSM is an open-ended yet performance-based standard that can be modified according to the situation of the premise. PSM practitioners are having flexibility in designing their own policies 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 the latest PSM knowledge to industries (Luo, 2010). The history of major industrial accidents in Malaysia provides proof to the public that an integrated system shall be implemented to increase industrial safety status to a greater extent. This can be stipulated from the Bright Sparkler accident (1991) at the plant located at Sungai Buloh, 9m away from the agricultural land. When new product testing was conducted, the tragedy happened near dried chemicals and fire sparks flew to the canteen, which stored thousands of finished and semi-done products. The plant explosion had caused 23 deaths and 103 people suffered injuries of various degrees of burns. Poor safety awareness and safety management tools are the main contributors to this disaster. This plant had breached several regulations on Occupational Safety and Health Act 1994 (OSHA 1994), Factory and Machinery Act 1967 (FMA 1967), and Environment Quality Act 1974 (EQA 1974). Testing explosive product nearby chemicals, the building of plant site near a residential area, and improper storage of explosive products are examples of Bright Sparkler company having a relatively low awareness and knowledge towards safety and its consequences unsafe acts.

Bakar et al., (2017) addressed that industries focusing on common safety practices and personal safety cause ignorance of hidden failures such as equipment integrity and reliability, as well as technological failure in terms of process safety. Koivupalo et al. (2015) stated that organisation with goals of sustained success would focus on personal safety and health as well as environmental factors regardless of both the working environment and nature. PSM shall be adopted in industries that have a hazardous process to provide a relatively all-rounded approach to managing safety issues. Existing safety management tools could also be implemented along with PSM to cover the limitations of PSM. However, as more studies and research have been made on PSM, the current PSM system is sufficient to cover most of the premises' safety aspects. This is proved in the Occupational Safety and Health Administration (OSHA) PSM citations suggesting that all PSM elements can identify potential hazards that could lead to disastrous incidents through 19 case studies (Luo, 2010).

Process Safety Management (PSM) statutory provision in Malaysia refers to the Occupational Safety and Health Regulation Control of Industrial Major Hazard 1996 (CIMAH). This regulation was enacted by the Department of Occupational Safety and Health in Malaysia after learning from a series of catastrophic industrial accidents, including the Flixborough incident (1974) and the Bhopal incident (1984). The enactment of CIMAH 1996 was also influenced by major local incidents in Malaysia where fire and explosion incidents occur at Bright and Sparklers in 1984 (Aziz & Shariff, 2017; Rampal & Nizam, 2006). The concept of CIMAH 1996 is adopted from CIMAH 1984, which was enacted by the United Kingdom, UK. This regulation is enacted to control major process industries; however, the concept of this regulation is not established according to existing PSM standards. Table 2.9 below tabulates the coverage of CIMAH 1996 on related PSM elements. The limitation of this regulation is the lack of detailed requirements on every specific PSM element, especially on MOC; therefore, comparison can only be made on the average coverage.

CIMAH applies to industries which involve handling, stored, or producing a certain amount of hazardous materials. There are two categories in this regulation: Major Hazard Installation and Non-Major Hazard Installation (Aziz & Shariff, 2017). Major Hazard Installation is industries involving handling hazardous materials exceeding threshold quantity, as stated in Schedule 2. In contrast, Non-Major Hazard Installation handling hazardous materials are less than the threshold quantity stated in Schedule 2 (DOSH, 1996).

Table 2.8: Coverage of CIMAH 1996 in Process Safety Management Elements

PSM	CIMAH
Employee Participation	Obligations of Manufacturer and Employee
Process Safety Information	Particulars of Installation focusing on process chemical information (Schedule 5)
Process Hazard Analysis	Report on Industrial Activity consulted by Competent Person (Schedule 6
Contractor	-
Mechanical Integrity	-
Hot Work Permit	-
Operating Procedures	-

Source: Aziz & Shariff, (2017)

Table 2.8 Continued

PSM	CIMAH
Emergency Planning and Response	On-site and Off-site Emergency Plan
Incident Investigation	Major accident notification (Schedule 3)
Compliance Audits	Audit and Penalty
Trade Secret	-
Training	Training for a person working on the site (Schedule 6)
Management of Change	Modification report (Schedule 6)
Pre-Startup Safety Review	-

Source: Aziz & Shariff, (2017)

2.3 Comparison of PSM Standards on MOC

There are numbers of Process Safety Management (PSM) standard varied among countries according to own requirements. All the PSM standards share some similarities and minor differences in terms of specific requirements. The comparison is summarized in Table 2.10 shown below. All selected PSM standards share similarities in covering the establishment of operating procedures, risk assessment, and mitigation. 29 CFR 1910.119, 40 CFR 68, and AQ/T 3034-2010 have the same requirements on MOC. It is believed that AQ/T3034-2010 has adopted PSM standards from the United States as PSM regulation in China. Meanwhile, RBPS, COMAH 2015, and CSChE PSM Guide are more focusing on authorization on change approval, which differs from other PSM regulations. 29 CFR 1910.119, 40 CFR 68, and AQ/T 3034-2010 focus on updating related PSM elements affected by the proposed change, training, deliveries of change, and change communication upon change approval. CHShE PSM guide is relatively unique compared to other standards as it requires to mention the time period for temporary change and highlight organisation change criteria in the standard. CIMAH 1996 which adopted in Malaysia is not included in the comparison listed in table 2.9 as it is not a lateral comparison as compared to other standards. This is because CIMAH does not have any specific requirements on MOC practice in the industries but only requirement to notify related government body on the changes for amount of hazardous substance at the premise.

Table 2.9: Comparison of MOC Requirements among PSM Standards

	PSM Standards					
Requirement	29 CFR 1910.119	40 CFR 68	COMAH 2015	RBPS	CSChE PSM Guide	AQ/T 3034 2010
Written Procedures	✓	✓	✓	✓	✓	✓
Training and Deliveries	✓	✓		✓		✓
Update of other PSM elements	✓	✓		✓		✓
Responsible authorities to initiate change			✓	✓	✓	
Documentation	✓	✓	✓	✓		✓
Risk assessment and mitigation	✓	✓	✓	✓	✓	✓
Change of Communication	✓	✓				
The time period on temporary changes	✓					✓
Organization Change					✓	

In this study, 29 CFR 1910.119 has been selected as the primary reference of PSM regulation in developing a framework for temporary and emergency cases. This regulation has the most flexible requirements, which covers most of the essential criteria. This includes the measures in minimizing weaknesses in the MOC approach such as authorization, time period, changes towards other PSM elements, and competency assurance in terms of changing roles and responsibilities. Furthermore, US OSHA has established compliance guidelines and enforcement procedures that provides comprehensive guidelines and criteria to be met. All the requirements and criteria shall be inculcated in the developed framework in this study.

2.4 Management of Change Element in PSM

Staff rearrangement and process improvement or alterations are some common changes that may occur in any manufacturing industry. These changes might seem harmless in normal production factories but not in highly hazardous industries. A single minor change in highly hazardous industries could be fatal and destroy the environment and property. These elements are included in the four big categories under Process Safety Management (PSM), which are:

1. Technological factor
2. Equipment factor
3. Process Chemical factor
4. Human factor

Management of Change (MOC) ensures changes will not produce unexpected new hazards or an increased risk of existing hazards (CCPS, 2014). In these industries, assessments shall be conducted to anticipate the potential risk and consequences that may happen after a change is implemented.

Environmental Protection Agency (EPA, 2000) stated that five aspects should be considered under MOC for an efficient approach:

1. The technical basis for the proposed change
2. Impact on safety and health brought by the change
3. Modification to operating procedure
4. The necessary time period for the change
5. Authorization requirements for the proposed change

MOC shall be an essential element worth attention from employers as changes could positively and negatively affect the actual process. If change planning is not well managed, the consequences of change applied are 100% negative to the premise. However, it is believed that the current MOC framework is still lacking, causing industries to ignore focusing 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 MOC's importance, or the current MOC approach fails to meet their expectations in process safety. The current MOC system has limitations in failing to document, maintain, and provide an adequate framework to manage changes. Process changes related to reports and records are not kept appropriately at an easily accessible place (Bakar et al., 2017). Table 2.10 shows the common criteria to be evaluated in temporary and emergency change.

Table 2.10: Open Action Items in Temporary and Emergency Changes

Criteria	Comments
Extension of temporary change	Does the change require an extension? If required, hov long?
Has due to temporary change return to the status quo?	Is the change returned to the original condition or mak the change permanent?
Fulfilment of all requirement in normal change	How to ensure all criteria and requirements in MOC are satisfied?
Tracking and verification of close action items	How to verify closed action items completion level an meet the objective of recommendation?

Source: Hansen and Gammel (2008)

Based on accident cause analysis conducted by Kwon (2006), inadequate MOC systems have contributed 13.4% (11 cases) of the accident root cause. The time period of MOC effectiveness is another limitation of the current MOC approach. The control proposed by the MOC procedure will be easily ignored after a period, even in a short period. The MOC framework's proposed control may only be practised for a few months for adaptation and neglected after the period of "adaptation" (CCPS, 2016). This is an underlying risk in which the new operating procedure proposed shall be practised permanently after a change has been implemented until the next modification is made. Moreover, temporary system change has been one of the top three failures in a research study, influencing the effective MOC implementation in operation practice (Piong et al., 2017). However, the top two failures, as shown in Figure 2.2, shall not be neglected. Here, requesting system change and breakdown of system contributed the main and second highest percentage of MOC failure. Lesson from these past incidents shall be inculcated into the consideration of MOC framework development.

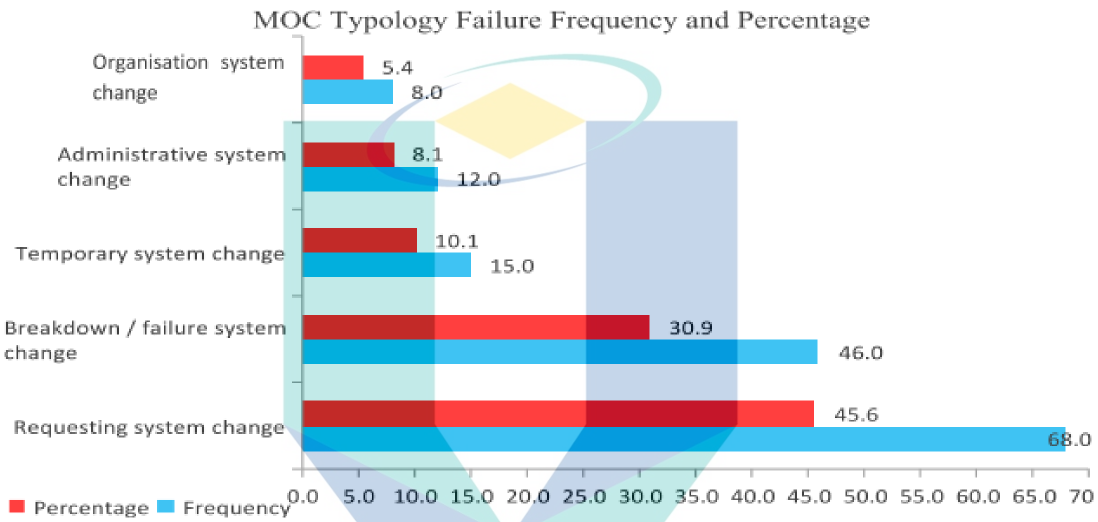


Figure 2.2: Distribution of Management of Change Typology Failure

Source: Piong et al. (2017)

Other than that, the current MOC system is only applicable to planning the operation process changes. Center of Chemical Process Safety (2014) suggested that the MOC system can be expanded to cover capital projects that combine MOC results with business considerations. The design phase of an improved MOC system is recommended to consider principles used in MOC, which could be applied to large-scale projects effectively and efficiently. 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 also conduct risk evaluation and analysis before proceeding with any business changes to avoid financial loss. Therefore, it is possible to expand the MOC framework to a broader coverage, as it functions similarly to the business risk analysis process.

2.5 PSM Elements Relationship to Management of Change (MOC)

Management of Change (MOC) is an interdependent element where several elements shall work together to come with evidence for decision-making. Although Process Safety Management (PSM) contains fourteen elements in total, some elements are interrelated with MOC in the process change procedure, as shown in Figure 2.3. Referring to Figure 2.3, it is observed that there exist elements interrelated with MOC, and some elements will be affected by MOC. For instance, employee participation and process safety information are interrelated elements, with double arrowhead required in MOC's planning stage to make changes according to the implemented change. Meanwhile, elements such as mechanical integrity, process hazard analysis, and operating procedure elements are the elements affected by the changes implemented in MOC, arrow pointing away from MOC as shown in Figure 2.3. Besides, outcomes or results of compliance audits and incident investigation are the elements, arrow pointing towards MOC would require a review of the MOC process for further risk mitigation and improvement. Table 2.11 shows the details on each element functioning in MOC (Aziz et al., 2016).

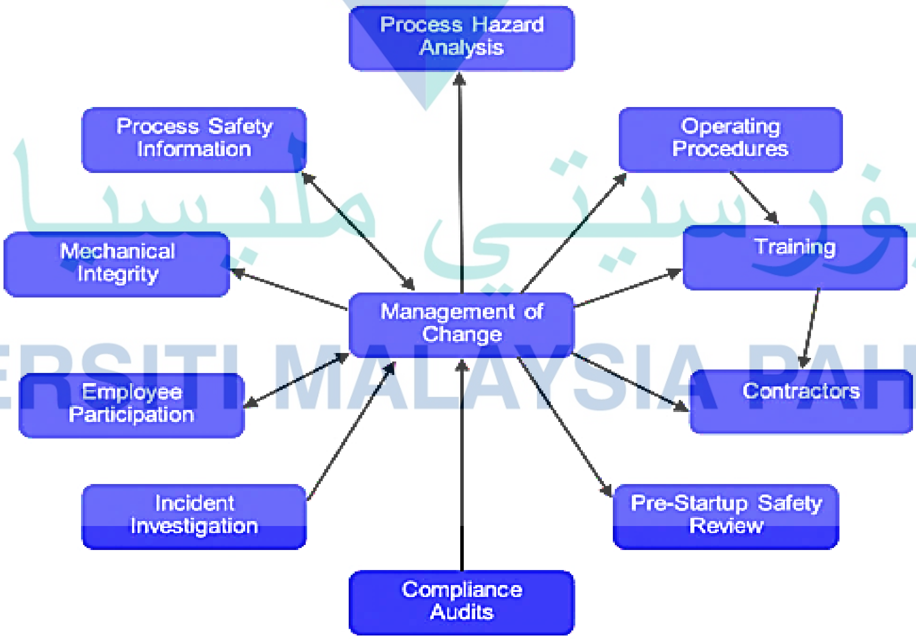


Figure 2.3: Interrelationship between PSM elements with MOC

Source: Pacanins (2014)

Table 2.11: Interrelation between PSM Elements and MOC

PSM Element	Interrelates Element	Details
MOC	EP	• An approved change of process should be notified to all affected personnel prior to start-up
	PSI	• Up-to-date PSI is required to support the generation of MOC to address the technical soundness of proposed change and assess the potential safety and health impact • PSI must be updated accordingly if process change results in a change of PSI
	PHA	• While not mandatory, PHA may be performed to assess the impact of the proposed change on process safety
	OP	• OP must be updated accordingly if process change results in a change of OP
	TNG	• Plant personnel should be trained in the process change if the job tasks will be affected by a change prior to the start-up process
	MI	• Maintenance personnel should be trained in the process change if the job tasks will be affected by a change prior to the start-up process
	PSSR	• PSSR recommendation must be resolved prior to start-up in change
	CON	• Contractor workers should be informed and trained in change prior to start-up with the change in place if necessary
	CA	• MOC information and documentation should be assessed during the audit process

Source: Aziz et al. (2016)

2.5.1 Technological Factor Elements

Technological factor-related elements are dealing with controlling safety in terms of technology such as programming, software, operation process, etc. Technological factors are covered by process hazard analysis and operating procedures.

2.5.1.1 Process Hazard Analysis (PHA)

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

1. Prioritized actions to conduct analyses following the schedule established.
2. Application of the appropriate method in process hazard identification and evaluation.
3. Establish a relationship between identified hazards with potential impact and propose controls on each identified hazard.
4. PHA shall be performed in a team with personnel experts in engineering and process operation, suitable methodology, and evaluation procedures.
5. Establish an information management system in storing related records and the written schedule.
6. PHA shall be updated and revalidated every five years.
7. PHAs and updates of a process shall be retained for the life of the process.

2.5.1.2 Operating Procedure (OP)

The operating procedure element is aimed to provide a precise yet efficient work procedure in each operational process parallel with the process safety information obtained. Established procedures shall address each operating phase's steps, safety considerations and systems, and operating limits on each process (US OSHA, 1994).

2.5.2 Equipment Factor Elements

Equipment is the main asset in the production industry in which machinery, automated robots, safety valves, and so on are categorized under equipment. Major accident due to equipment failure contributes the most significant number to the statistics of major industrial accidents. 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.

2.5.2.1 Mechanical Integrity (MI)

The mechanical integrity element in PSM ensures all equipment used in the manufacturing process is designed, assembled, installed, and frequently maintained following the established schedule. This system emphasizes recognising and understanding every equipment and instrumentation, hence developing a series of measures to ensure equipment is performing at its best efficiency. A standard operating procedure, related training on equipment handling, maintenance schedule, and control steps on deficiencies found are covered under this element (US OSHA, 1994).

2.5.2.2 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 the construction of facilities and equipment follows design specifications. A safety control system, operating and emergency procedure, and maintenance schedule on every equipment is provided and adequate (EPA, 2000).

2.5.3 Process Chemical Factor Elements

Process chemical factors involve ensuring information every hazardous chemical used in the process are known and considered. An operating procedure, maintenance schedule, and personnel training are examples of some elements that require sufficient information on chemicals. At a minimum, safety data sheet addressing categories of hazards possessed, labelling requirements, the composition of chemicals, etc. are the necessary information provided by chemical suppliers (DOSH, 2013).

2.5.3.1 Process Safety Information (PSI)

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

1. Toxicity information
2. Permissible Exposure Limit (PEL)
3. Physical data
4. Reactivity data
5. Corrosivity data
6. Thermal and chemical stability data
7. Potential hazardous effects of inadvertent mixing of different materials

2.5.4 Human Factor Elements

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

2.5.4.1 Training

Training is an essential element in the human factor. This process is essential in transforming newly employed workers in mastering necessary techniques, skills, and knowledge related to the work task. Non- trained workers are considered as a hazard in which they might operate equipment and instrumentation wrongly. External factors, including financial stress and time constraint, are often the root causes of ignorance of safety efforts where safety and risk awareness slowly fade away (Knegtering & Pasman, 2009). Therefore, this element ensures newcomers understand the nature of work task, basic hazard identification skills, and safety requirements on related work tasks. US OSHA (1994) suggested that an effective training program shall include initial, refresher training and documentation on training progress and improvement.

2.5.4.2 Emergency Planning and Response (EPR)

EPR element addressed the requirement on immediate actions that shall be taken by employees when the process goes out of control. The emergency response differs in different situations, such as the 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) which are:

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

2.5.4.3 Employee Participation (EP)

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

2.5.4.4 Contractors (CTR)

Element on contractors requires highly hazardous industries to select contractors to perform work on the premises. The screening of contractors shall be performed before selecting contractors who can perform the work task without compromising employees' safety and health. In this context, contractors include subcontractors that are not hired by employers as permanent workers but only temporary work projects on the premises. Contractors are considered outsiders who require safety briefing on safety precautions and emergency action plans during first entry to the premise. This is because highly hazardous industries are not allowed to compromise any unexpected hazards that may cause a disastrous accident (US OSHA, 1994).

2.6 Importance of Management of Change

Management of Change (MOC) should be an essential element in which the employer shall pay attention to the benefits of implementing this approach. The application of changes without good planning may cause severe consequences in 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 an accident to happen. This situation is in accordance with Reason's Swiss Cheese Model, as shown in Figure 2.4. This model portrayed every swiss cheese slice as a control measure; meanwhile, holes presence in the cheese slice are the active failures and latent conditions. For instance, each slice of the cheese could represent one process safety element in the process industries. A poor MOC may act as the first slice of cheese in which the overlooked areas form the holes on the cheese. When new changes require updates on process hazard analysis, operating procedures or emergency response plans will form the cheese slice after the MOC.

An incident may occur when it passes through all the holes on each cheese slice when all the affected elements are not updated to prevent or control the incident.

An accident will occur when all the failures and weaknesses are aligned simultaneously, as shown by the arrows passing through all the holes in the cheese slices reaching the outcome. For instance, the first layer represent management decisions and knowledge deficiencies. Poor management decisions in terms of managing safety or existing knowledge deficiencies in the operation process may create holes on the cheese slice that provides opportunities for failures. Meanwhile, other cheese slices may represent human errors and inadequate management systems. Inadequate management systems such as low maintenance of equipment (Mechanical Integrity), absence or non-effective process hazard analysis, and outdated process safety information may create more holes on the cheese slice that act as latent conditions of incidents. When MOC is applied, it could be the stimulus that contributes to an incident with all the inaccurate and inappropriate information.

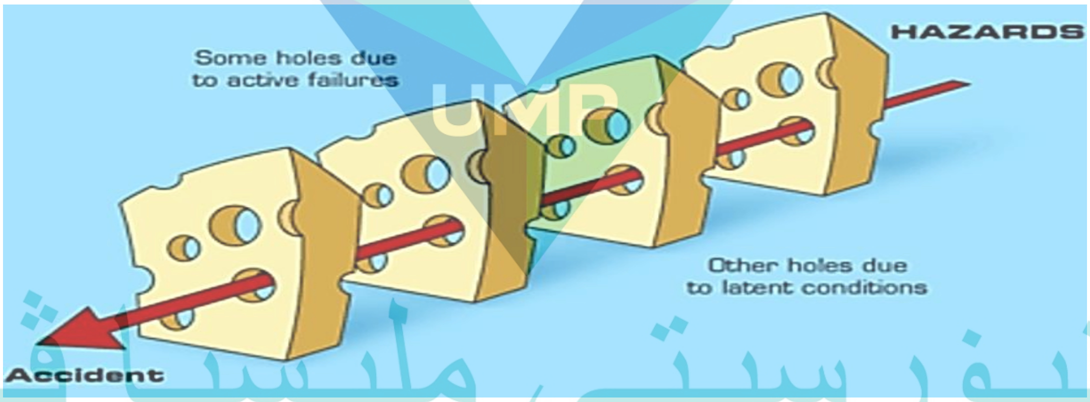


Figure 2.4: Reason's Swiss Cheese Model

Source: Reason (2000)

There are a few major industrial accidents that happened due to the absence or poor MOC procedure. Bakar et al. (2017) conducted a case study on 770 major accident cases obtained from available accident databases. Each PSM element is ranked according to the effectiveness and frequency of failure in accident prevention purposes. MOC has contributed about 9% of all the accident occurrence. One of the major accidents has stipulated the importance of MOC in highly hazardous industries. In 1990, a wastewater tank exploded at the ARCO chemical plant located in Channelview, Texas. This incident occurred due to a significant reduction in nitrogen purge during maintenance; meanwhile, the temporary oxygen analyser was unable to detect flammable gas accumulation in the tank. This is even critical when it comes to temporary and emergency change which human tends to complacent on the safety procedures due to short term implementation period or panic during emergency situation. Temporary bypass of system, shutting down of system due to mechanical breakdown are the common temporary change in process industries where the operation team would consider it is a part of normal process. However, the communication and risk management of interim change will place a greater hazard when temporary MOC is not initiated. Definition of emergency could varied among indutries however it shares the common similarity where any situation that could leads to loss of life, environment or property loss shall declared as emergency. For instance, any uncontrolled released of hazardous gas, overheating of boiler or potential deviation of normal process that could leads to uncontrollable situation are some of the examples of emergency change that worth to be tracked and studied.

Moreover, studies proved that MOC was one of the most neglected aspects of process safety. This is portrayed in a case study conducted in Taiwan. Industrial safety workers were not aware of the definition of change that requires MOC, especially on changes that happen frequently or too complicated in tracking (Chen et al., 2010). Meanwhile, in Pakistan, local process safety regulations do not cover all the process safety aspects, including MOC. There was no coverage of legal requirements on MOC aspects in implementing process safety management (Anwar et al., 2019). The absence of an appropriate MOC system was the largest contributor to the incident where no risk assessment was made to analyse the potential hazards and consequences. Employees are not educated with the consequences of their maintenance procedure. Furthermore, the pre-startup review is not conducted after maintenance work is done.

A successful enterprise shall manage and exploit changes effectively in the business world, turning the unpredictable situation into a business opportunity. Therefore, an enterprise will require an effective MOC system to survive in an ever-changing world. MOC has an advantage in not only applicable to process safety but also in terms of business perspective. MOC system covers planning and proposing tactical control actions on potential risks (Koivupalo et al., 2015; Kontogianni et al., 2017). Zwetsloot et al. (2013) also addressed that integrated yet effective MOC framework is necessary to manage complex systems and organisations. MOC is relatively challenging to ensure a company stays resilient from hazards and underlying risks. For example, a premise planned to increase productivity rate to meet the market demand must increase flexibility in the operating procedure and process installation. MOC system is essential in planning the suitable changes that shall be made on equipment and technology (Knegtering, 2002).

Other than that, any new improvement or technology requires evidence in building confidence in users and consumers. Management often considers the benefits behind changes proposed before any investment decision is made (Utne et al., 2012). MOC system is providing scientific evidence by reviewing and analysing accident reports. Safety standards on a proposed change or modification may aid in the employer's decision making. It shows evidence through statistics and previous lessons that are strong in reliability and validity (Wang et al., 2017).

Centre For Chemical Process Safety (2016) addressed that the degree of potential hazards varies among facility and operation processes. Improvement of PSM element effectiveness will be more significant in higher hazard facilities. This is because the highly hazardous facility cannot compromise any single minor mistakes on process or equipment modification. For example, a highly hazardous industry will require stronger MOC system in managing changes as this industry deals with reactive chemicals that easily react with oxygen gas. Managing risk in the highly hazardous industry involves selecting effective preventive barriers that are important in mitigating risk. Analysing hazard levels of residual risk, cost, and benefits shall be considered under the MOC element to establish suitable safety interventions by considering financial and process safety aspects (Wang et al., 2017).

2.7 Temporary and Emergency Change Failure Case

Temporary and emergency changes have been one of the root causes contributing to process incidents. Some of the significant process accidents in the past decades, such as the Flixborough incident, ARCO Channelview Explosion 1990, Equilon Enterprise Refinery 1998, and a chemical plant explosion in Takaoka, Japan, are examples of incidents that positively contributed to the failure of temporary and emergency change management.

Flixborough incident on 1st June 1974's fire and explosion happened at Nypro (UK) Ltd. The incident caused 28 casualties, significant damage to the neighbouring structure, and a catastrophic effect on the public and environment (HSE, 1975). It was due to a temporary change made on the reactor whereby a stainless-steel pipe was used as a bypass between reactors R4 and R6. This temporary change has been implemented for two months while waiting to rectify the faulty R5 reactor unit. The temporary change was not adequately evaluated on the underlying risk, potential consequences, and updates of related operating processes and drawings (Chosnek, 2018; HSE, 1975).

ARCO Channelview explosion happened when there was a failure of flammable vapour detection during the compressor's restart. This incident took place on 5th July 1990, leading to 17 fatalities and approximately 100 million USD losses. The incident's leading event was due to the nitrogen compressor's servicing, which requires interruption of the existing wastewater process. The original wastewater tank was exposed to the risk of mixing of peroxides and caustic. Accumulation of high oxygen concentration was failed to be controlled with analyzer detection and supply of nitrogen purging. The temporary change was not correctly evaluated as a wastewater tank was not included in the normal operating process (Ness, 2015).

Equilon Enterprise Explosion, 1998 is one of the best examples in presenting the importance of good emergency change management in the process industry. This incident was due to an unexpected process interruption due to a power outage (Brunner, 2001). There is a delay in cooking until tarry oil in the cooking unit had started to cool and solidify during the two-hour power outage.

Steam gas was failed to be injected into the cooking unit due to the plugging of the piping, causing the remaining flushing off residual substance process to be interrupted. Workers were directed to remove the drum head's bolts by wearing personal protective equipment (CSB, 2016). However, the attempt failed to control the explosion's hazard to the workers and supervisor. Poor management of the sudden deviation of the operation process created a significant unsafe condition for the highly vulnerable workers to negative consequences.

Besides, change management at a chemical plant incident in Takaoka, Japan, has stipulated the consequences of poor emergency change management in process conditions. The incident took place where instrument air experienced failure and required emergency shutdown to discharge cracked gas. However, the emergency shutdown procedure was ineffective and complicated to react to the changes conducted. The delay on the intercooler valve failed to prevent blow-out of combustible gas and led to fire and explosion of the compressor unit (Dobashi & Tamura, 1968).

Overall, change management is crucial in ensuring the safety of the operating process and the efficiency of other PSM elements in controlling potential process hazards. Temporary and emergency changes shall be paid extra attention. This nature of change has often been neglected by industry due to complacency and presume the short-term changes are harmless to the process.

2.8 General Concept of MOC: Plan-Do-Check-Act (PDCA) Cycle

A Plan Do Check Act (PDCA) model was applied to provide a general review of the MOC framework to educate related personnel on the MOC system. The year 1991 PDCA cycle was applied in this study as this model is suitable for the science of improvement study. PDCA cycle comprises four steps, as shown in Figure 2.5, which is a plan, do, check, and act. This model highlights important objectives in every stage of the cycle. For example, the planning stage highlights the essential criteria before implementing changes such as critical risk assessment, prediction on potential impacts, and so on. Related risk assessment and data collection shall be carried out for further analysis of the potential change's feasibility. Do is the stage where change is initiated. Any unexpected observation or situation shall be recorded. The checking stage is the monitoring of the MOC framework conducted earlier to ensure no overlooking of essential action items, which may affect the reliability of risk assessment outcomes. Lastly, the act stage is to review the MOC process to identify underlying faults or weaknesses and improve the future. PDCA cycle model was established to provide an overview of the MOC system before and after changes applied in the manufacturing process.

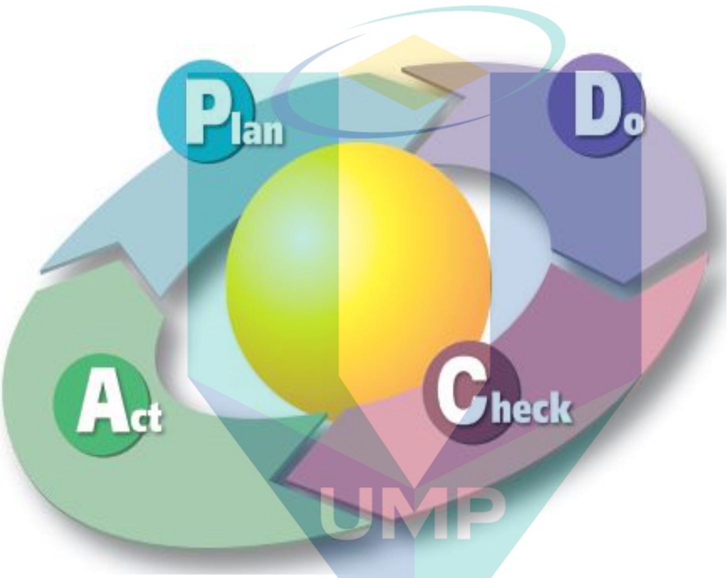


Figure 2.5: Plan-Do-Check-Act (PDCA) Cycle

Source: ILO (2011)

PDCA cycle in Figure 2.6 comprises human, technological, management, and goals to be achieved throughout the process. According to Gerbec (2017), the planning of MOC starts with the collection of information on the potential temporary change. Evaluation of technical and organisational aspects shall be considered to prepare an effective plan implementation. Planning of change management method shall address impacts in the production process, the necessity of changes on every process, and full risk assessment on the specific process if a change is required. When change is required, a change proposal shall be produced, and the progress of the operation process shall be monitored to manage any unexpected consequences. The actual change process must be monitored regularly to ensure the change will not cause any hazards to the premises. Change implementation process and plan shall be reviewed and improved for more systematic MOC procedure. The developed framework focuses on highly hazardous industries in terms of manufacturing, primarily chemical industries. In overall, PDCA cycle is a suitable concept to be adopted to portray the overall concept to the related parties on the complete cycle of MOC. This is because a complete MOC framework of MOC are consisting of several layers and it would be over extensive to certain parties such as management level or lower line of workers. PDCA cycle could summarize the entire MOC process to whoever required to know the general concept of MOC.

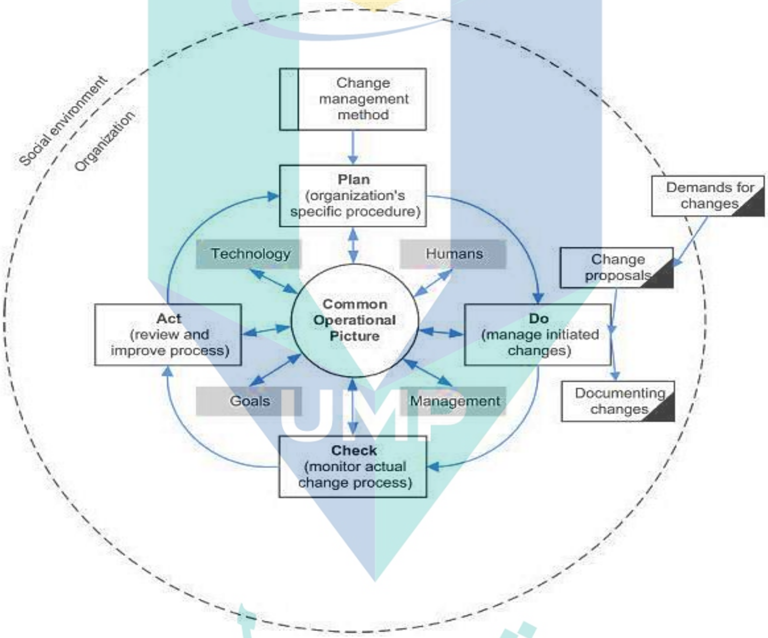


Figure 2.6: PDCA cycle model

Source: Gerbec (2017)

2.9 MOC Framework Concept in Previous Studies

A framework shall provide an overview to end users on a system process on early planning of budget, the time required, and related risk assessment. A system framework shall include all necessary details and information for the process (Majid et al., 2015). A complete Management of Change (MOC) framework shall inculcate technical dimensions and impacts brought by the change. This can be determined by various types of risk assessment to aid in decision making. Organisational dimensions shall also be addressed in the framework, including workers' distribution and training on related change. Other than that, consecutive steps on a specific action item shall be anticipated when the result obtained is not as predicted (Gerbec, 2017). An example of the framework is shown in Figure 2.7.

Based on Gerbec (2017), the researcher has introduced brand new ideas in terms of a risk assessment approach in MOC compared to previous practices. Current practices would perform HAZOP, HAZID, and other PHA approaches in risk assessment of proposed change, which could be time-consuming to gather expertise and discuss the potential hazards. MOC process begins with a change proposal and identification of the type of change. There are checklists attached along with criteria in each change category, including organisational 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 risks arise.

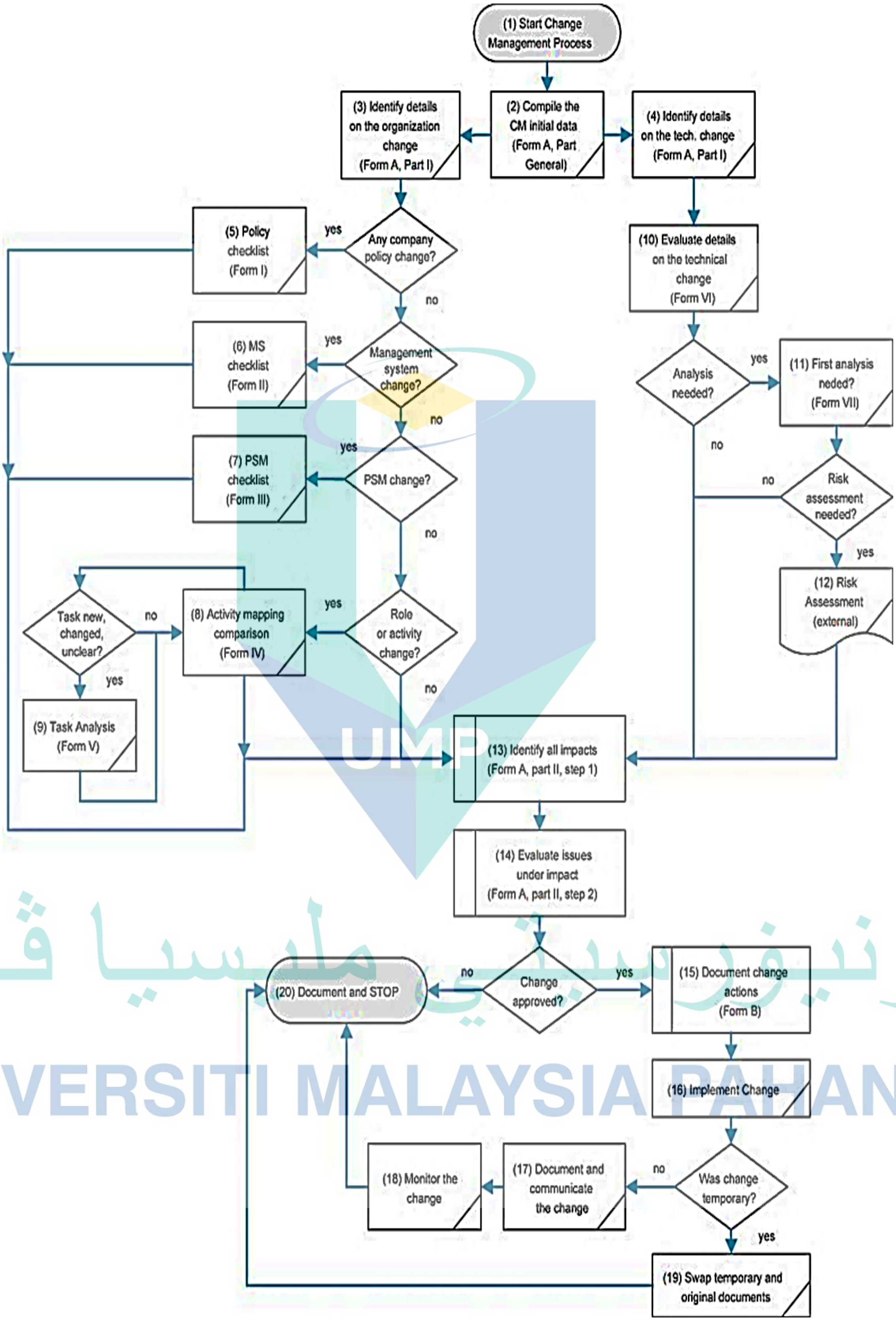


Figure 2.7: Example of MOC framework

Source: Gerbec (2017)

As shown in Figure 2.7, the standard MOC procedure focuses on implementation and documentation parts. Follow-up and continuous monitoring shall be inculcated in the MOC procedure to ensure no new underlying hazards arise from the implementation of change. Communication of change, an update of related PSM elements, and necessary time period for temporary change are action items that can be introduced in this MOC procedure to ensure more coverage of change management. MOC framework developed by Gerbec (2017) was extensive in managing permanent change especially on all potential risks in organizational and technical areas. However, the method proposed is only suitable for permanent change with plenty of planning time. Temporary and emergency change are possessing a time limitation characteristic where risk analysis shall be effective and time efficient in identifying all potential outcomes. Nevertheless, risk assessment checklist proposed in this research study is worth to be adopted and modified to fit the nature of temporary and emergency change. Moreover, there is another potential improvement can be made on the risk prioritization from the established checklist. Risk rating is not inculcated into current checklists established by Gerbec (2017). Risk rating approach shall be adopted to aid in decision making when there is limited resources available for mitigation measures.

Center for Chemical Process Safety (2008) published an example of the MOC system procedure workflow chart showing a general concept with recommended essential action items. An example of the framework is shown in Figure 2.8 and Figure 2.9. Request change form shall be the initiation step of the MOC procedure. Once the change is approved, the proposed change shall be evaluated whether it meets the definition of change as established. A multidisciplinary review on potential hazards and associated risks shall be conducted. If a multidisciplinary review is unnecessary, a simple review shall be conducted to address potential hazards accompanied by the proposed change. Pre-implementation tasks shall be completed before the proposed change is implemented. Meanwhile, controls shall be applied along with change implementation to control associate risks. The post-implementation tasks shall be carried out to review the effectiveness of control measures established.

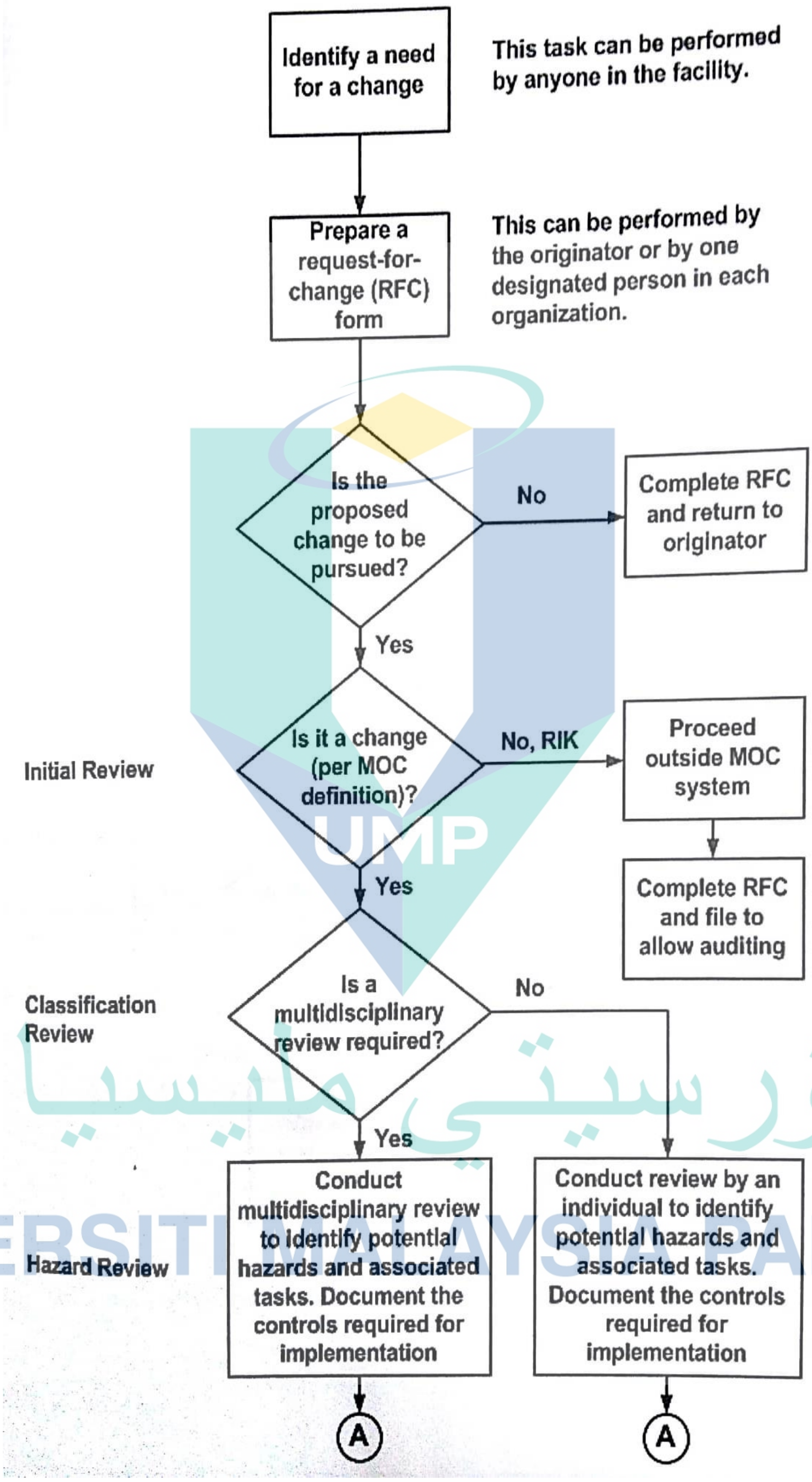


Figure 2.8: Example of MOC System Procedure Work Flow Chart

Source: Center for Chemical Process Safety (2008)

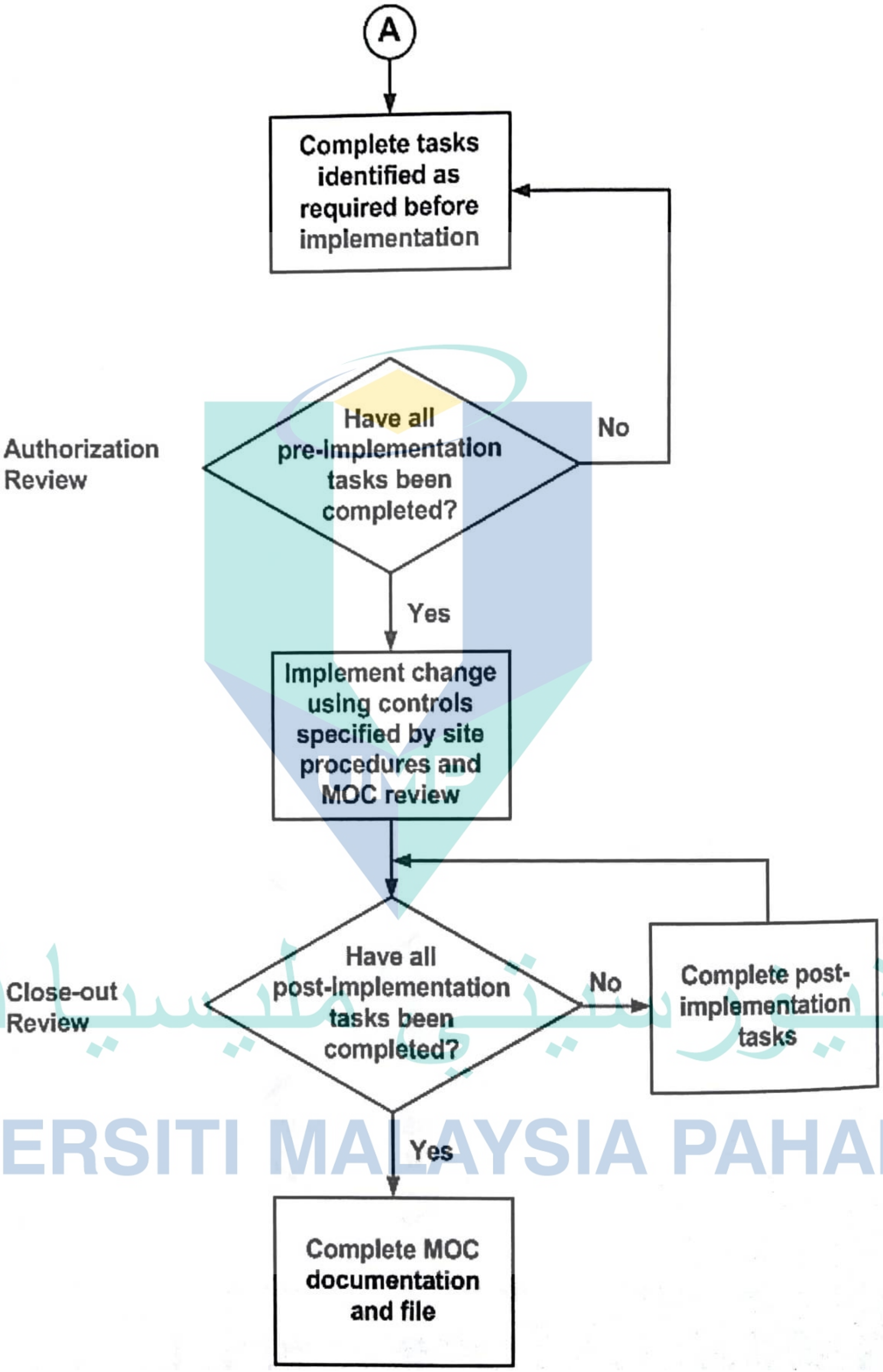


Figure 2.9: Example of MOC System Procedure Work Flow Chart (Continued)

Source: Center for Chemical Process Safety (2008)

2.10 Common Risk Assessment Approach

Risk assessment is a systematic management approach applied to manage risk at the workplace. It involves identifying, analysing, evaluating, monitoring, and reviewing all the potential risks (Galante et al., 2014; Gul & Ak, 2018). Risk assessment is a crucial part of safety management as risks are the foundation of all control and mitigation measures to ensure the protection and safety of related parties.

In Management of Change (MOC), risk assessment occupies the crucial part of all action items in predicting all potential hazard that comes after the proposed change. The application of changes is decided based on associated risk and adequacy of mitigation measures in controlling hazards. Process Hazard Analysis (PHA) is the element that covers risk identification and assessment for the proposed change. Information provided in PHA will help employers and employees reduce the consequences of unwanted or unplanned releases of hazardous chemicals because it is directed toward analysing potential causes and consequences of fires, explosions, releases of toxic or flammable chemicals, and major spills of hazardous chemicals. Thus, in such a facility process, safety management is a priority to ensure such occurrences never happens. For example, process hazard analysis would require revision based on the newly proposed risk to provide mitigation measures on the potential new hazards. Process Hazard Analysis may also refer to the risk assessment on the long term operational risk and control on the new changes in MOC, especially for temporary cases with limited planning and preparation time.

2.10.1 Hazard and Operability Study (HAZOP)

Hazard and Operability Study (HAZOP) is the most common risk assessment approach adopted in the process industry. The approach adopted in this method is addressing hazard scenarios based on operation process nodes and implication of the hazard scenario towards people, community, assets, and environment. HAZOP study focuses on the potential deviation of the process, which may evolve from the original design (Baybutt, 2015). Standard guide words such as More, Less, and As Well As are provided to the HAZOP study group to determine possible deviations on the specific process section.

However, it is undeniable that the HAZOP study possesses some common intrinsic characteristics that are unsuitable to be implemented as temporary and emergency change risk assessment approaches. The main characteristic of HAZOP requires an extra expenditure on expertise support to generate the study result (Cameron et al., 2017). This has eventually led to potential issues in terms of economy, time, and human resources arrangement for the study. For example, the company has to spend extra to invite experts for the proposed change and allow existing process safety staff to leave normal routine activities to join the HAZOP session, which may last for days or weeks. Process experts are the keys to a successful HAZOP study, as inexperienced personnel may fail to identify all potential scenarios (Baybutt, 2013).

Moreover, urgent temporary and emergency changes with time constraints will create challenges in producing a quality HAZOP study result. HAZOP study requires a detail discussion on every potential deviation to avoid overlooking of a hazard scenario. The urgency of schedule completion and time pressure may cause the tendency of overlooking essential criteria in the study (Baybutt, 2013).

2.10.2 Layer of Protection Analysis (LOPA)

Layer of protection analysis (LOPA) is another semi-quantitative diagnosis-based approach which has a similar function as HAZOP in risk assessment. LOPA practise scenario-based assessment to address all sorts of related underlying risks and hazards. This methodology reviews the current safety protection measures or layer to control potential risk and develop risk mitigation layers to reduce the possibilities of incident occurrence. This concept targets to achieve inherently safer process conditions. As shown in Figure 2.10, LOPA involves analysing existing safety control levels varied from the basic process control system, safety instrumented system, physical contamination, and emergency response. This concept included a response towards hazard scenarios to contain it within the protection level to avoid hazard scenarios progressing into a more severe impact.

However, LOPA's nature is to provide an evaluation of the frequency and failing probability of each protection layer on the well-established safety control system. This methodology is relatively applicable to completing qualitative hazard analysis where all the potential scenario, consequences, and mitigation measures have been established (Summers, 2003). Besides that, the LOPA study shares the similarity as HAZOP and other diagnosis-based approaches. It requires the forming of the LOPA study team to study the criticality of each protection layer and calculate the probability (Baybutt, 2017). A group brainstorming session is undeniable in promoting creativity and variation in analysis; however, this will also limit personnel creativity in processing information. Time pressure and reliance on teammates may limit human creativity and flexibility in the reflection of all given information and study parameters (Baybutt, 2013, 2015).

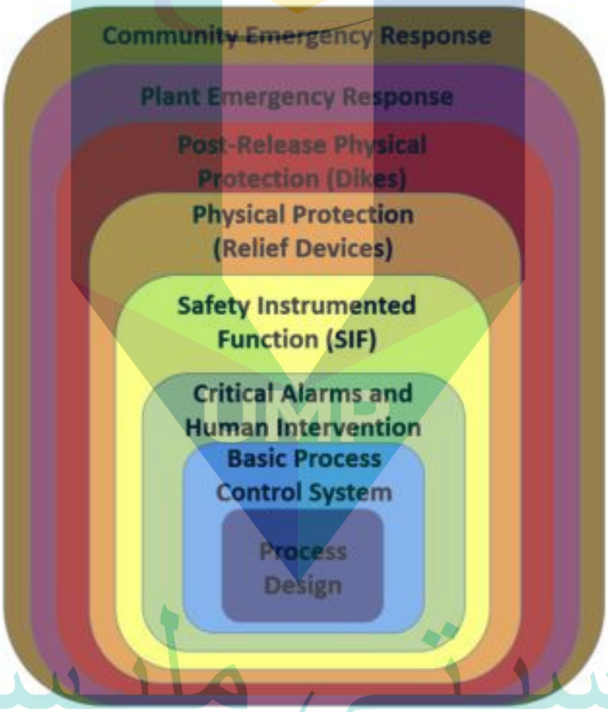


Figure 2.10: Layer of Protection Analysis Concept and Parameter

Source: Hong et al. (2016)

2.10.3 Checklist-Based Risk Assessment

Checklist-based risk assessment is the common approach generally applied in most of the inspection, audits, and standard safety assessments. This method's advantages are the checklist can be custom made and designed according to the real situation at plant and prevent overlooking of critical criteria (Gris Seoane, 2001). However, it could be advantageous to have listed parameters to avoid overlooking criteria for temporary and emergency changes. Baybutt (2013) highlighted that a comprehensive checklist with detailed criteria would help in improving risk diagnosis-based assessment in replacing brainstorming sessions into methodical and structured analyses. For instance, the lack of creativity during HAZOP and other diagnosis-based risk assessments may limit the imagination of potential deviation (Cameron et al., 2017). A detailed checklist may help minimize the human factor gap in terms of overlooking essential criteria, especially when it comes to fatigue, time constraints, and creativity limitation.

The common risk assessment approaches adopted in the process industry are HAZOP and LOPA, which focus on the qualitative diagnosis-based approach on risk diagnostic and identification method. For instance, HAZOP applied parameters, guideword, and deviation to aid in risk identification and brainstorming of potential risk, consequences, and control measures. However, limitations in terms of completion time planning and consideration of human factors are the common diagnosis-based approaches (Galante et al., 2014).

In a nutshell, checklist based-risk analysis would be a better option in this research study as risk assessment can be measured qualitatively or quantitatively for better risk prioritisation and decision making (Luo et al., 2018). Risk assessment with the aid of qualitative risk analysis and reference from information PHA will provide a better understanding of the new risks with the existing process conditions. Checklist risk assessment method in the management of change may aid in brainstorming of all potential hazard and risk with guide description on the checklist with limited time. Risk assessment in this study aims to be the pre-safety assessment to efficiently highlight significant issues and risk on the proposed change and present to stakeholders and management support in a methodical way. Temporary and emergency change requires time and cost-efficient risk assessment method, which enable practitioners to identify all the crucial criteria and improve on process control by referring to process hazard analysis results.

2.11 Introduction of Technology in MOC

Industrial Revolution evolved in the year 1760, where the manufacturing process started a new transition to the manufacturing industries all over the world. Over three centuries, the industrial revolution is now moving into the fourth transition, named as Industrial 4.0 (Marr, 2016). The current revolution represents the starting point of manufacturing industries transforming into an era dealing with technological gadgets. Automation, data exchange, and robots are the basic elements representing Industry 4.0. Apart from the manufacturing process, all departments in the manufacturing industry shall be ready to face a new round of challenge in the new era of the Industrial Revolution.

However, the conditions could be complicated in terms of safety perspective as current safety management techniques and tools cannot handle a brand new "smart factory." Accident prevention and mitigation methods should be improved following the pace of the technological-based industry (Knegtering & Pasman, 2009). The complicated process could be burdensome to manage safety levels solely relying on the human mind without technological support. This could create rooms for safety weaknesses, especially during the hectic period, which could lead to catastrophic industrial accidents. Technological-based aids in storing emergency operating procedures and related information enables the human operator to react accordingly (CCPS, 1995; Kameumoualdi, 2010).

Kletz (2001) stated that humans have a higher tendency to make errors when required to perform tasks beyond mental and physical disability. The author claimed that humans would not escape from making mistakes unless he/she is not a human. Although human errors are claimed as not the root cause of industrial accidents, this could be one of the contributing factors (Kletz, 2001b). In the management of change, many procedures and actions items require attention by an assessor. Compliance of standard, criteria in assessment checklist, result's analysis, and so on shall be conducted to perform a whole Management of Change (MOC) system. This could be an enormous burden to humans to perform it without any aiding tools acting as a reminder for each action item under the MOC framework. As workload gets complex and heavy, an integrated management system shall be introduced to safety management to aid in process safety (CCPS, 2016). Arruda

(2006) also agreed on the same opinion in which databases and previous intervention shall be involved in the MOC framework.

There are various kinds of software and applications made available in the market that are designed to cover extreme parts that humans cannot perform. For example, technology can be manipulated to ease documenting, sharing of information, or reviewing previous records. The software tool would be useful in storing large or previous reports for future review purposes (Gnoni et al., 2013). All these can be done by moving fingertips instead of the traditional approach of using hard copies.

Technology can provide a more precise overview of the MOC system on each step, what standard they should comply with, and what kind of gaps exist in their system. This methodology has been proved by a case study conducted in a local refinery. Prototype model developed based on emergency planning and response (EPR) is applied in the premise and has proven to aid in managing Process Safety Management (PSM) standard compliance (Majid et al., 2016). Examples of Microsoft Access management system are shown in Figure 2.9 and Figure 2.10. These examples show the standard interfaces in Microsoft Access. This system is a simple software system that does not require skilled personnel to operate and readily available in Microsoft Operating System with an economical price compared to customized software. However, there are limitations of the interfaces introduced in the system, as many interfaces are involved in terms of tracking specific items. Repetition of data input steps is required because all interfaces are not linked with one another and thus time-consuming to insert all related information into a system. Multiple interfaces also may cause difficulties in terms of simplifying information for communication purposes.

Apart from that, another electronic MOC (eMOC) was explicitly designed for Eastman Chemical Company holding several functions, including record keeping, approvals, notification, tracking, reporting, and audit trails. One of the advantages of this eMOC is constructed to function in the intranet of the company, which would be accessible to all employees (Garland, 2004). Examples of eMOC are shown in Figure 2.11 and Figure 2.12. However, this system is only constructed for Windows 7 and below operating system as it was designed in 2004. Other than that, attachments related to MOC cases are stored in a compressed folder, which may not be user friendly in terms of retrieving specific files. Furthermore, tracking open and close cases is required to check case by case instead of a particular interface to report consolidated information. Improvement of tracking and follow-up interface can ensure efficient control on the change after the implementation of a proposed change.

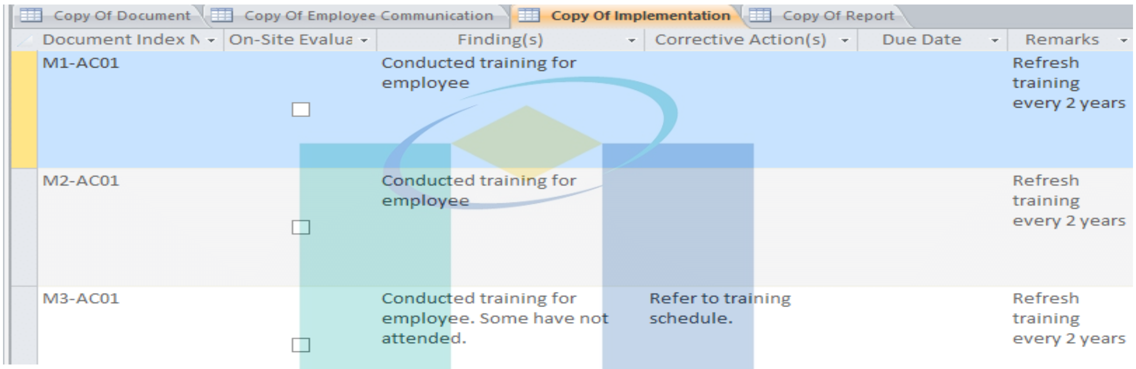


Figure 2.11: Example of Microsoft Access Management System

Source: Majid et al., (2014)

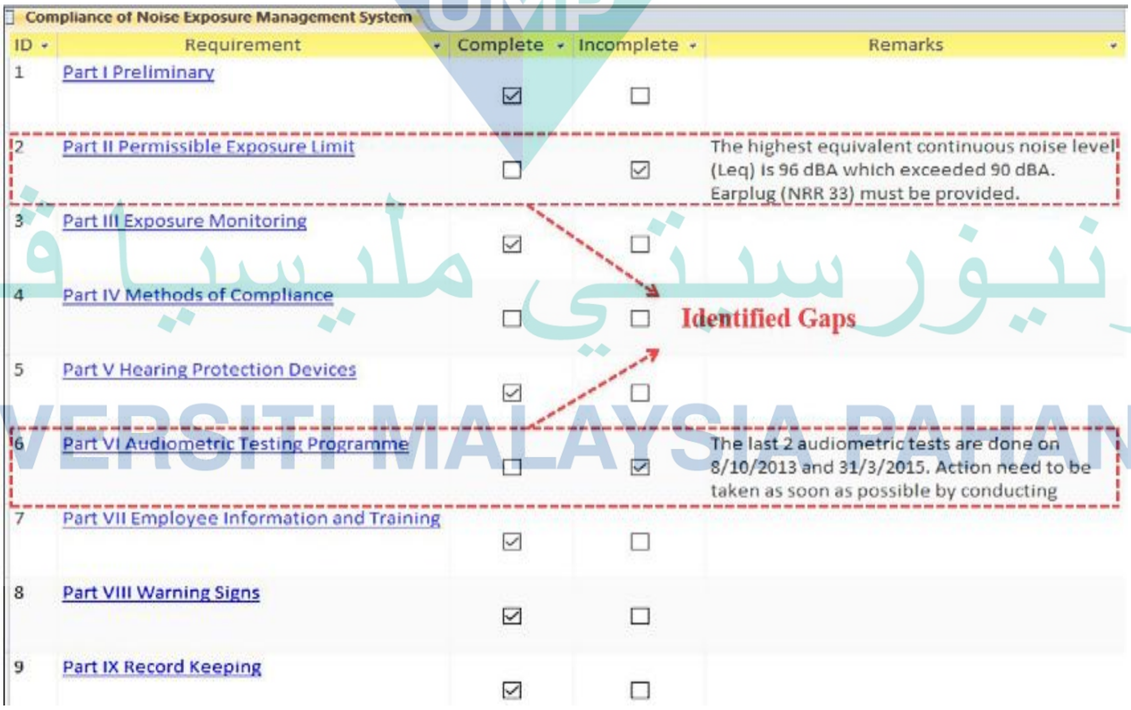


Figure 2.12: Example of Microsoft Access Management System Main Interface

Source: Leong & Aziz, (2017)

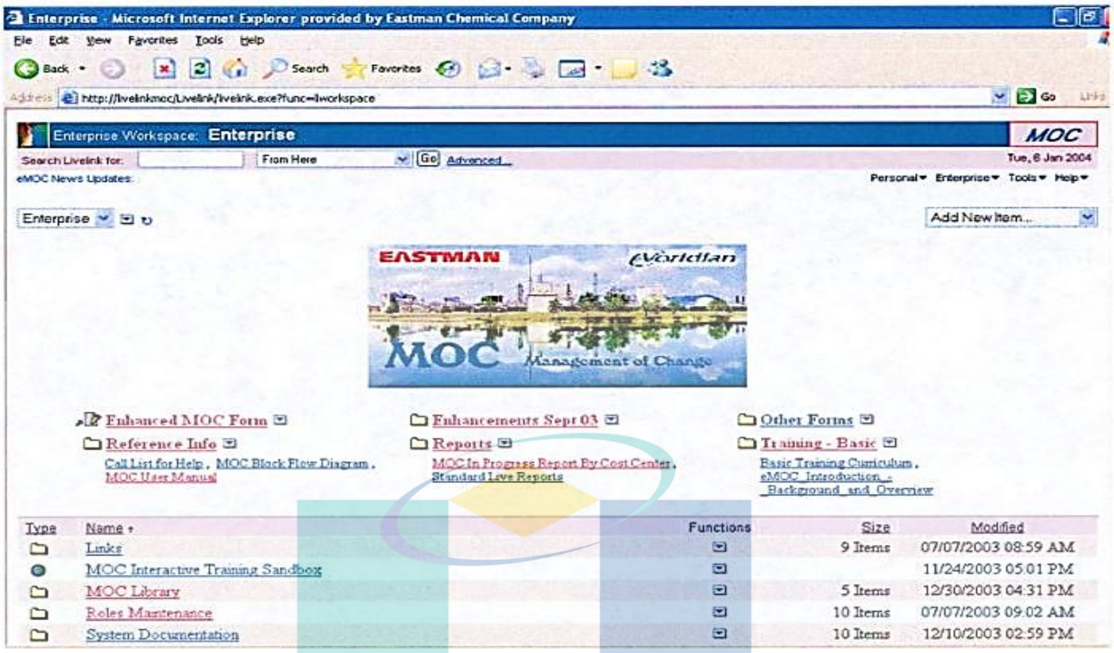


Figure 2.13: Example of eMoc Home Page

Source: Garland, (2004)

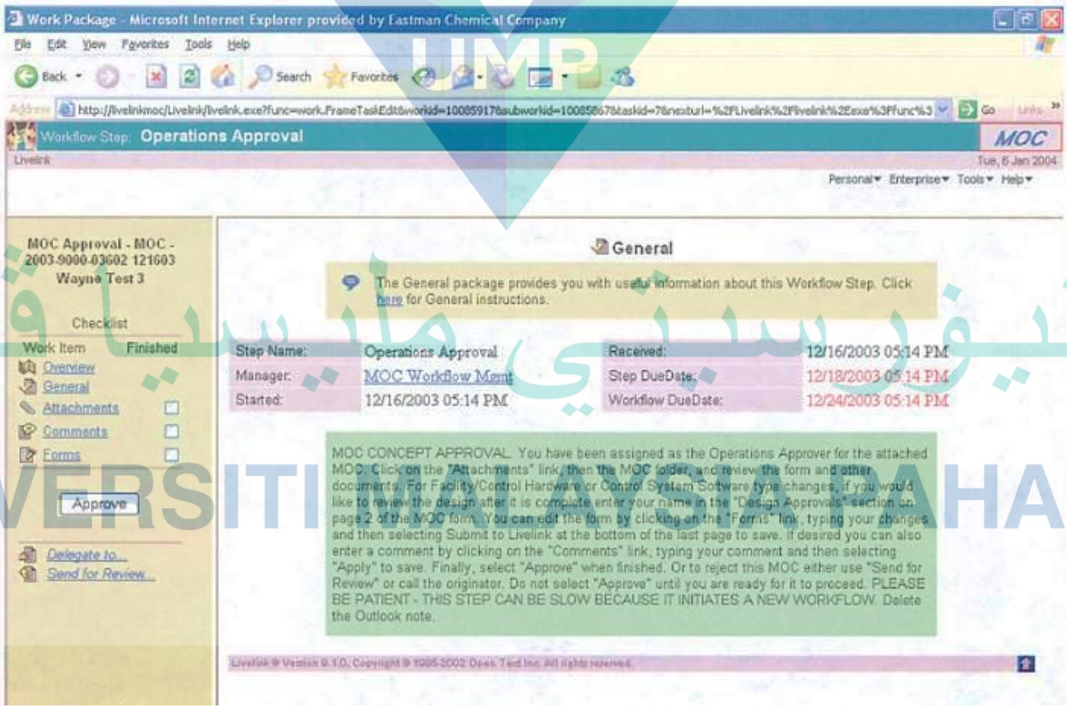


Figure 2.14: Example of eMoc Workflow Step

Source: Garland, (2004)

2.12 Summary

The major issue in the current Management of Change (MOC) implementation, especially on temporary and emergency change was due to a lack of risk assessment in addressing all the associated risks with these short-term changes. The literature review has shown the probability of temporary and emergency cases contributed as the root cause of MOC failure in industries. One of the root causes that contributed to this phenomenon was the time limit of these nature, restricting the completion of risk assessment. This could be due to the method of risk assessment adopted in the industries are inadequate for time pressure condition.

Secondly, the MOC element is one of the essential elements that interact with most of the Process Safety Management (PSM) element that are vital in managing safety in process industries. MOC is essential in process operation in which potential risk and consequences will be analysed before any changes are made. It is crucial where a good MOC process shall comply with local regulatory requirements and able to identify all the crucial elements to be covered in a complete process. The literature review above has introduced the concept of process safety management worldwide, including Malaysia. PSM standards in few countries, including the US, UK, Canada, Korea, and Malaysia, have been discussed and compared to each standard and regulation requirements.

There are relatively fewer research studies conducted on the MOC framework or process for temporary and emergency changes. The literature review above has discussed the current general concept of MOC framework on permanent change, which can be used as a reference in developing a temporary and emergency MOC framework. It can be modified into temporary and emergency change with time constraints and other related factors. Risk assessment is one of the essential action items that identify whether the proposed change would introduce new underlying hazards to the current process condition. The importance of MOC and technology in process safety has also been highlighted, showing the relationship between technology and the MOC system. Application of technology may enhance the effectiveness of the MOC system in standards compliance and documentation of related records.

From the above discussion, it is clear that the current MOC system practised in the industry requires further research with better coverage on the essential action items, especially towards temporary and emergency changes. These changes are not widely addressed, and there are limited studies conducted in this area. Moreover, MOC is a lengthy yet essential process that may influence the process industry's normal condition. Due to lesser studies on temporary and emergency change, hence current industries are lacking of a suitable risk assessment method which fits to nature of temporary and emergency change that comes with time limitation and risk prioritization on mitigation measures.Furthermore, MOC is a complex process where significant number of data and information are required for pre-assesment. Manual practice and traditional documentation method can no longer effectively track and manage MOC cases in this era. A complete and effective framework and technological support may aid in completing MOC critical requirements even though with time pressure.

In conclusion, this research chose a permanent MOC framework to be modified to fit for temporary and emergency changes without neglecting any essential statutory requirements. A statutory requirement has been chosen as the main statutory reference to ensure a developed framework aligns with statutory requirements and essential criteria in the MOC cycle. The established temporary and emergency framework is equipped with a respective risk assessment checklist to prioritise the importance of risk assessment in MOC without affecting limited time and resources allocated for these changes. Moreover, a MOC management system has been developed with the inspiration of the human factors' limitations and previous learnings identified in the above study. This management system is targeted to improve the efficiency of the MOC team in terms of data inventory and tracking of open MOC cases in the workplace. All the developed results have been validated via a pilot study to ensure the real process plant's feasibility and practicality.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter discusses the research method and procedures adopted to achieve the objectives of the study. The methodology is commonly referred to as the techniques applied to research data collection and analysis instruments. The concept of this research has applied exploratory research design. Exploratory research design enables researchers to acquire innovative insights in solving current issues or problems based on observations and literature searches on the identified areas.

Modern tool usage was addressed in this chapter, which shows how each objective's outcomes were achieved using these tools. This chapter consists of study techniques, study instruments, and validation techniques for this study. Figure 3.1 shows the overall process flow of the study. The literature review began when the research title was selected. It is done by searching for related information via the internet, books, and other sources. The comparison of established PSM regulations on MOC has been conducted to select the best regulation that provides detailed guidelines and requirements on every criteria and action items. The selection of integrating risk analysis elements was made by referring to the problem statements identified and searching related solutions to minimize selected issues. Next, the development of framework, MOC management system, and management system validation were conducted once all the preparation work and information are complete. A checking step was implemented to determine whether the developed MOC framework and management system fulfilled the selected PSM requirements and risk assessments to cover all areas of the operation process.

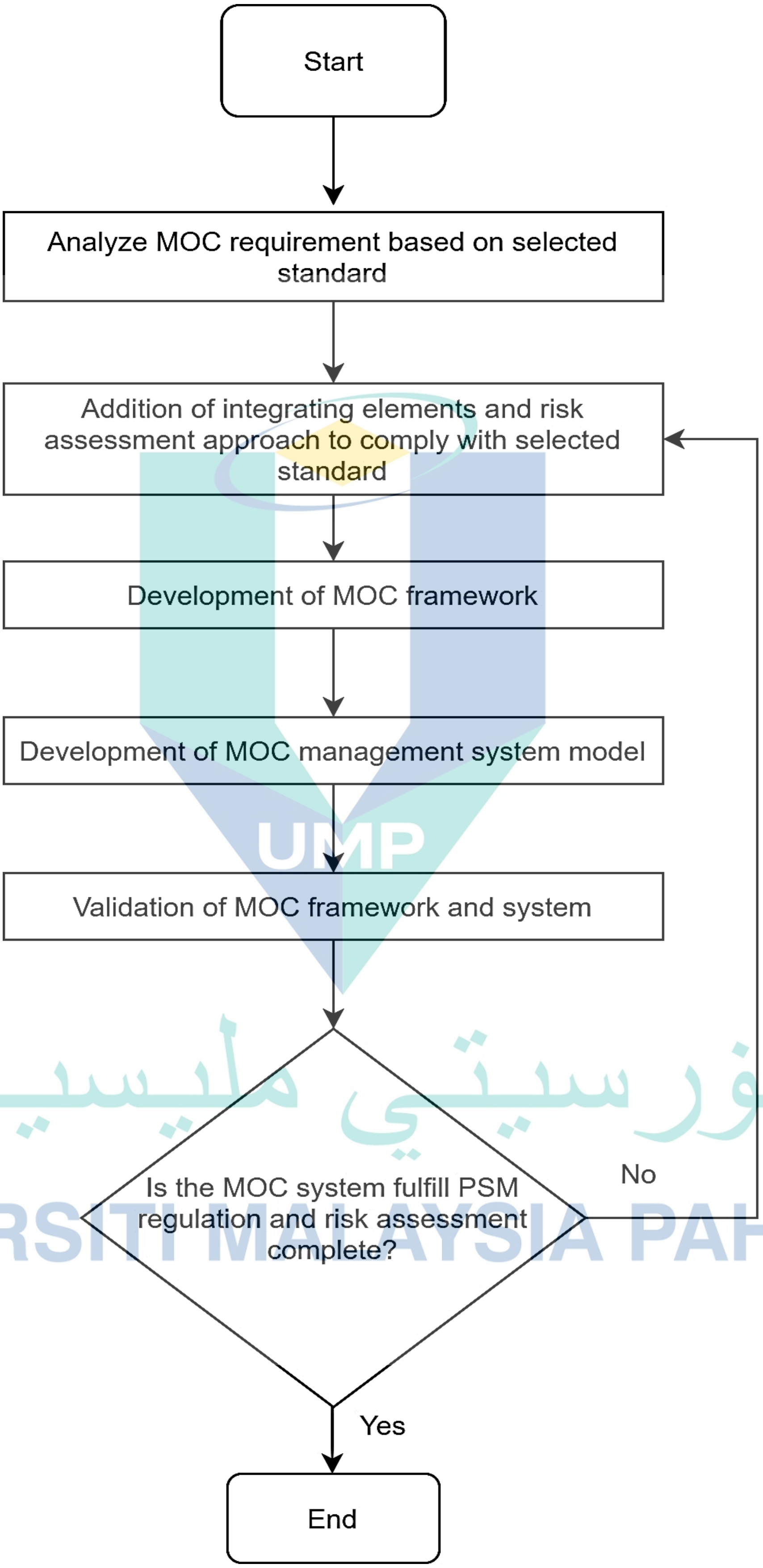


Figure 3.1: Overall Methodology Process Flow

3.2 PSM Standard Analysis on Management of Change Element

PSM standards were compared and analyzed on MOC elements in each standard and regulations. 29 CFR 1910.119, 40 CFR 68, RBPS, AQ/T 3034-2010, and PSM guide were studied in-depth on MOC requirements and criteria in each standard. Requirements and criteria in every selected standard are stipulated in Chapter 2, where further analysis is done on the literature review obtained. The literature review was conducted by deciding keywords and searching for previous research studies and journal articles. Examples of keyword used in this study include 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 for relevant journal articles, and valid information was cited in this study. To provide the macro view, the keywords such as "Process Safety Management", "Process Safety", "Management of Change", "MOC", "Change Management", "Change Management Framework", "Management of Change AND Framework", "Process Hazard Analysis" were used to obtain related literature with the research area.

3.3 Development of Plan-Do-Check-Act (PDCA) Cycle

Plan-Do-Check-Act (PDCA) cycle is applied to provide an overview of the whole MOC process from the beginning till the end. PDCA comprises four main stages: plan, do, check, and act. General ideas on each stage in the PDCA cycle are shown in Figure 3.2. In the first stage, the plan shall conduct related documentation work and identification of the area affected by the proposed change. Proposal on the change, general risk assessment, and administrative arrangement throughout the Management of Change (MOC) process shall be made within this stage. The legislative requirement shall be reviewed to ensure all the criteria were met once the MOC process is completed. Planning on the procedure in conducting MOC is vital to ensure all the essential action items are conducted and utilized in decision-making to implement new changes.

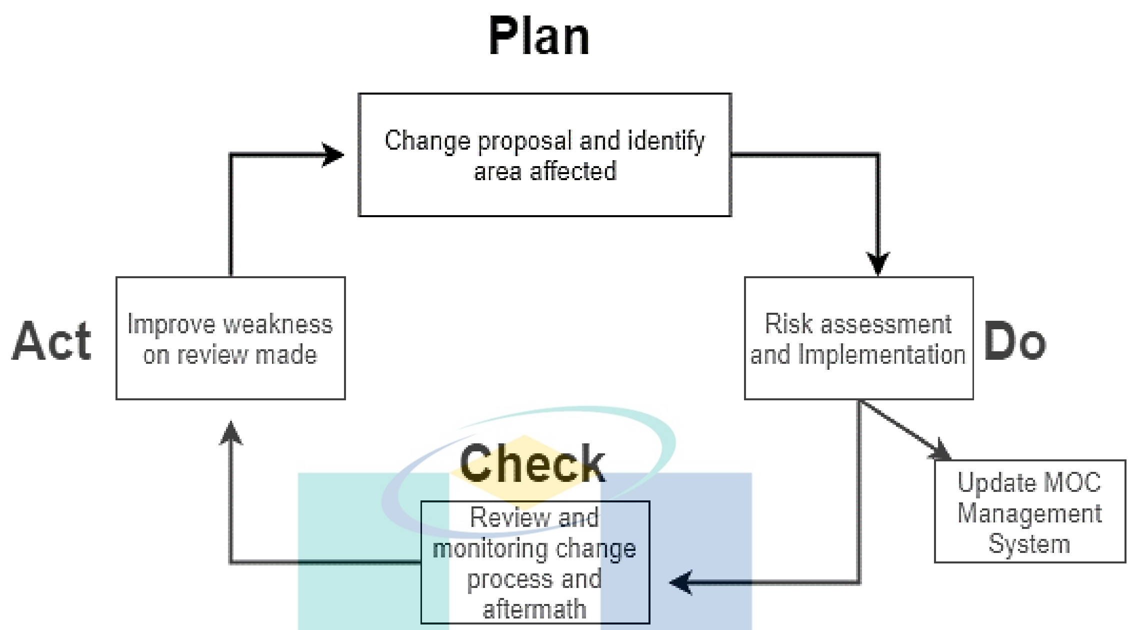


Figure 3.2: MOC PDCA Cycle

Do is the implementation or "action" step in which all the planned procedure and decision making were done in this stage. Specific risk assessment on the affected areas shall be conducted to identify the significant risks that may arise following the change. Improvised risk assessment forms are able to minimize the time motion based issue in previous research findings Results of risk assessment are essential in aiding decision making. Change can be implemented when those significant risks are controllable by the premise. In addition, the MOC management system, as established in this study, shall be updated in every MOC case. This system should also be updated to be used as a reference in the future, even though the change is rejected.

Review and monitoring of change shall be conducted under the check stage to keep track of the condition after a change is implemented. The operation process 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 for improvement in the current procedure. In terms of temporary change, a review on the due temporary change shall be conducted to decide whether temporary change shall be reverted to the original setting (status quo) or converted into a permanent change. The related arrangement shall be completed on any of the decision on the due temporary change.

An *act* is a stage that implements corrective action or improvement on the existing MOC procedure. This is not limited only to MOC but also be improved on implemented change. Extra control measures on the potential risk of the implemented change can be added to increase the related process's safety level. Actions on due temporary change shall be implemented at this stage.

Frameworks of MOC were developed based on standard selected in an earlier step for compliance of standard. Frameworks of temporary and emergency changes summarize all vital action items, standard requirements, and strategies to manage changes in process operation. Overview of the framework is constructed using Microsoft Word in flowchart format, providing a clear picture on each step to be taken in the MOC system. A feedback loop is applied at the end of the framework, emphasizing the completion of every action item in the framework. Frameworks in emergency and urgent temporary change with limited planning time are designed to shorten and compact crucial information to overcome time constraint issue. Meanwhile, standard temporary change may have a complete risk assessment and analysis before reaching the decision-making stage. Any incomplete action items require personnel to conduct incomplete action item before proceeding to the decision-making phase. This framework functioned under the planning stage in the PDCA model to collect related data and information on the potential impacts of the change.

This MOC framework is considered integrated if it inculcates all requirements on US 29 CFR 1910.119 regulation from the beginning until the end of the MOC process. PDCA cycle provides an overview of the process in which each stage is covered in this study. The planning stage, which requires various kinds of risk assessment checklist, is provided with a standard framework on every step. The remaining stages in the PDCA cycle were covered by the MOC management system, functioning to store all related reports, acting as monitoring aiding instrument on regulations compliance and database to store reports for long-term periods.

Appendix A shows the general checklist for the end-users to perform early identification of involved parties and equipment on the standard temporary change. Checklist in Appendix A is adopted from the Canadian Society of Chemical Engineering Guidelines on MOC (CSChE, 2004), whereas Appendix B is adopted from a MOC research study by Gerbec (2017). Requirements or criteria involved are directed to a specific section in Appendix B to perform a further risk assessment. In contrast, Appendix A portrays the PHA risk rating embedded into risk assessment forms listed in Appendix B. Figure 3.3 shows the sequence of appendices that completes each action item in MOC management system.

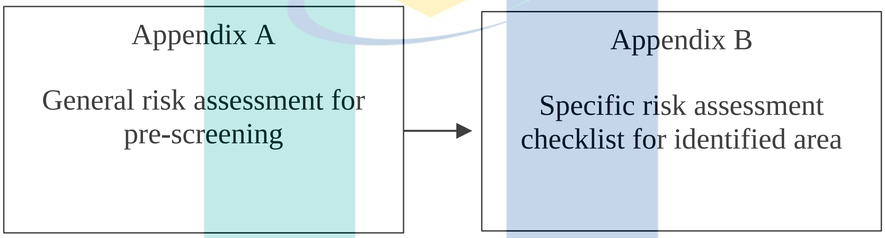


Figure 3.3: Sequence of Appendices Function in MOC Management System

3.4 Development of Management of Change (MOC) Framework

Management of Change Management system (MOCMS) was developed to demonstrate how the proposed framework can be implemented in this study. A user-friendly and systematic software was chosen as a database management system on MOC. This management system act as a guide to personnel on standard compliance and record documentation. Microsoft Access software was selected to develop the MOC system as this software does not require special skills in operating the system. Microsoft Access operation is much similar to Microsoft Excel, but Microsoft Access is relatively appropriate in developing the management systems. Interfaces were constructed, listing every standard that should be complied and relative action items to comply with the standard. Prediction on time required input on each action item is designed to overcome the current MOC framework that applies a time-motion-based concept.

Microsoft Excel is utilized for documentation and checklist software, which details every risk assessment checklist that shall 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 the documentation of all reports and risk assessment related to the MOC planning. These two software are applied to support each other. MOC management system is created by starting from a blank Microsoft Access database. Tables were created to store all necessary information in fields. Several forms have been created to provide data entry pages for the user. Assessment completion log is planned to be included and divided accordingly using different tables. Google Drive is cloud-based storage, used as external file storage for MOC related reports. Microsoft Excel is used to display the risk assessment checklist, which can be used in the softcopy and hardcopy format.

3.5 Implementation of Process Hazard Analysis Risk Rating in Risk Analysis

Process Hazard Analysis is the PSM element vital to the security exertion since it gives data to help administration and administrators enhance well-being and settle on better choices to diminish hazards. This examination is particularly imperative in the vitality business, where dangerous materials are frequently looked after, and the requirement for strict arranging and following is high. It plans to help the vitality business divisions better comprehend and execute the PSM standards to enhance its security execution. PHA is a cornerstone of process safety management programs. The quality of the PHA performed directly affects the level of risk tolerated for a process. The lower the quality of a PHA, the more likely higher risk will be tolerated. This risk assessment checklist is chosen over other options because the structure and coverage of items in the checklist are designated for process safety. It has incorporated most of the critical elements in the HAZOP and HAZID approach, commonly used as tools of risk assessment in PHA.

Based on the underlying lying weaknesses as identified in Chapter 1, it is found that risk rating could be embedded to categorise the significance of the change caused to the organisation and process operation. The risk rating is allocated at the end of every identified hazard and impact. This may aid in the planning of resources and financial investment on control measures on high rating risk. Other than that, risk rating on risk assessment may help in decision-making on implementing changes in the organisation. In this study, a PHA risk rating is embedded in the risk assessment checklist (Galante et al., 2014). The risk rating is shown in Appendix B. This risk rating is selected since it addresses occupational safety, financial loss and any potential environment and property impacts. Tables 3.1, 3.2, and 3.3 display the details and criteria of risk rating in the adopted risk assessment checklist.

Table 3.1: Probability Level

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 sometime 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

Source: Galante et al. (2014)

Table 3.2: Severity Levels

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: death, 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: injuries or occupational illness resulting in one or more lost workday(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: injuries or occupational illness not resulting in a lost workday, minimal environmental impact, or monetary loss less than $100K

Source: Galante et al. (2014)

Table 3.3: 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			

Source: Galante et al. (2014)

The probability level to be filled in the risk assessment is according to the category stated in description and aspects. Probability level varied from "frequent occurrence" to "likely to occur sometime" until "highly unlikely to occur" in the specific plant. Severity level inculcated impact on personal safety, environment, and economic loss. The increment of severity varied among first aid, minor occupational injuries, permanent disabilities, or several life losses in terms of personal health, reversible or permanent irreversible environmental impact. However, the consideration of economic losses will inculcate significant loss amounts in process safety industries as any process incident may contribute to high financial losses. The severity of the financial loss varies from $100K to more than $1M US Dollar.

The final risk selection can be referred to Table 3.3, according to the category selected in the probability and severity level mentioned in Tables 3.1 and 3.2. Any risk with a category of catastrophic and critical severity and probability with possible and frequent risk is considered high risk. In contrast, any risk probability that falls under eliminated shall be exempted from establishing critical control action. For instance, if one of the consequences of the new change affects the personal safety of involved workers due to new procedure and process, the probability and severity level of the consequences to occur will be probable and marginal. Therefore, the risk will be severe. However, the justification shall be made according to the incident history and occurrence frequency in the same industry. The risk level of the same hazard and consequence may vary according to different process plants.

3.6 Development of MOC Management System

Management of Change Management system (MOCMS) was developed to demonstrate how the proposed framework can be implemented in this study. A user-friendly and systematic software was chosen as a database management system on MOC. This management system act as a guide to personnel on standard compliance and record documentation. Microsoft Access software was ultilized to develop and main platform of MOC system as this software does not require special skills in operating the system. Microsoft Access operation is much similar to Microsoft Excel, but Microsoft Access is relatively appropriate in developing the management systems. Interfaces were constructed, listing every standard that should be complied and relative action items to comply with the standard. Prediction on time required input on each action item is designed to overcome the current MOC framework that applies a time-motion-based concept.

Microsoft Excel is utilized for documentation and checklist software, which details every risk assessment checklist that shall 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 the documentation of all reports and risk assessment related to the MOC planning. These two software are applied to support each other. MOC management system is created by starting from a blank Microsoft Access database. Tables were created to store all necessary information in fields. Several forms have been created to provide data entry pages for the user. Assessment completion log is planned to be included and divided accordingly using different tables. Google Drive is cloud-based storage, used as external file storage for MOC related reports. Microsoft Excel is used to display the risk assessment checklist, which can be used in the softcopy and hardcopy format.

This management system is designed with several features to ensure that the system is user friendly without causing confusion and complication. Below are the steps of using Management of Change Management System (MOCMS):

i. Login through security page

ii. Browse through main dashboard for list of risk assessment interface

iii. Completion of forms and risk assessments

iv. Selection of "Add new MOC Case" for documentation steps

v. Tracking of open MOC cases or specific category of MOC

3.7 Location of Study

Pilot studies have been conducted in two real plants in Pahang, Malaysia. Evaluation and feedback from industries practitioners are essential in improving the developed management system, which fits the entire operation process. Industries practitioners act as end-users whose preferences shall be prioritized to create a user-

The validation of the developed MOC system was conducted through a pilot study approach. The validation process is performed at a Chemical plant X and petrochemical plant Y. friendly and effective system.

3.8 System Testing Approach

This pilot test focused on chemical industries on managing change in PSM. The operation method of the developed management system was presented and explained to the selected safety and health personnel. This is to fully utilize the management system created to ensure the reliability of the management system in aiding MOC system application. Interview session has been conducted with the operation team and process safety team members in both Plants X and Y. There were eight operation team members responsible for the management of change in Plant X. Meanwhile, three process safety team members in Plant Y were involved in the pilot test session including interviews and survey. Preliminary interviews focused on understanding the MOC process and procedure practised in both plants. This is to identify the gaps and similarities between real practise and the developed framework. Besides, the developed framework and MOC system were tested by repeating previous temporary cases in the plant to identify the feasibility and efficiency of managing new changes. Real-time data was inserted into the developed management system to identify practicability and gaps between real-life practices for further improvement.

A pilot study is one of the strong result validation methods as it tests an actual situation in the operation process. This allows the researcher to obtain proof on the practicality of the developed system apart from the theoretical explanation. This approach also has an advantage that enables the researcher to study the complex process of the industry in depth (Knegtering, 2002). Industry practitioners may identify the benefits and weaknesses of the developed systems based on the current and previous approaches applied.

3.9 User Response Testing and Analysis

Any new development of tool shall require testing on the real practice and collection of end user feedback to ensure developed tools are user friendly and practicable in real life practice. Therefore, a review of documentation and interview sessions on the pilot test results and feedback with industry practitioners has been conducted to optimize the developed MOC system.

The interview session was conducted based on the data collection process by asking question on actual practice onsite and advantage and disadvantage of current practice which mainly based on manual process. Meanwhile, an efficiency and system usability survey with likert scaling method has been conducted in both plant X and Y after completion of data collection and presentation process. This is to collect a standardised feedback and level of agreement of focus group. A sample of system efficiency and usability survey form is displayed under Appendix C. The survey result is analysed with Cronbach Alpha method which showing the positive correlation between compared items or criteria (Wadkar et al., 2016). Other than that, Cronbach Alpha method is widely applied in social science research which could display internal consistency of the respondents' attitude and response

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter discusses in detail the objectives and results of this research study. There are two types of Management of Change (MOC) framework developed to provide guidelines for end-users to perform action items in temporary and emergency changes. The framework shown in this chapter is established based on OSHA US regulation, 29 CFR 1910.110(l). Proposed risk assessment forms associated with the risk matrix are presented in this section. A MOC management system introduced in this chapter promotes the implementation and tracking of open MOC cases. This chapter also discusses the results of the pilot study on the developed framework, risk assessment checklist, and system software conducted at selected two chemical industries. Related documentation obtained via the pilot study is inserted into the developed Management of Change Management System (MOCMS) to show the system database's functionality.

4.2 Management of Change (MOC) Framework

The framework has been extensively used in all industries, especially in the manufacturing industry involving complex production processes. The framework is vital in displaying the fundamental structure of a process, guiding end-user to perform every essential action item. Both changes are developed with similar action items but differ in terms of work flowchart due to time constraints in both natures of change. Besides, emergency differs from urgent change where urgent change may be implemented for a specific period. In contrast, the emergency change will only be required to perform during an emergency to prevent further destruction and devastating consequences.

4.2.1 Temporary Change Framework

The temporary change is any change, not “replacement in kind”, to be implemented for a specific time period. In this study, any changes that can be applied for not more than six months are considered temporary change. The recommended temporary period is due to the consideration to gain management support and attention on the continuous attention towards temporary change. Any due temporary change shall request management review on the extension of temporary change or remove temporary change with a better solution to enhance process condition efficiency. However, it is subjected to the standard operating procedure practised in the respective organisation. Temporary in this framework is divided into two categories: non-urgent and urgent change.

4.2.1.1 Non-Urgent Change

Figure 4.1 shows the first section of the framework beginning with a general risk assessment checklist adapted from established guidelines to identify affected areas or departments by the change (CSChE, 2004). Form A, as shown in Figure 4.1, shall be used to record all the change related details. Form A also act as a change proposal providing a format for safety and health personnel to propose change initially as a notification before a completed Management of Change (MOC) cycle is conducted. The user shall then identify the proposed change as urgent or non-urgent. If the change falls under the urgent change category, an urgent change framework shall be implemented. This is discussed in section 4.2.1.2.

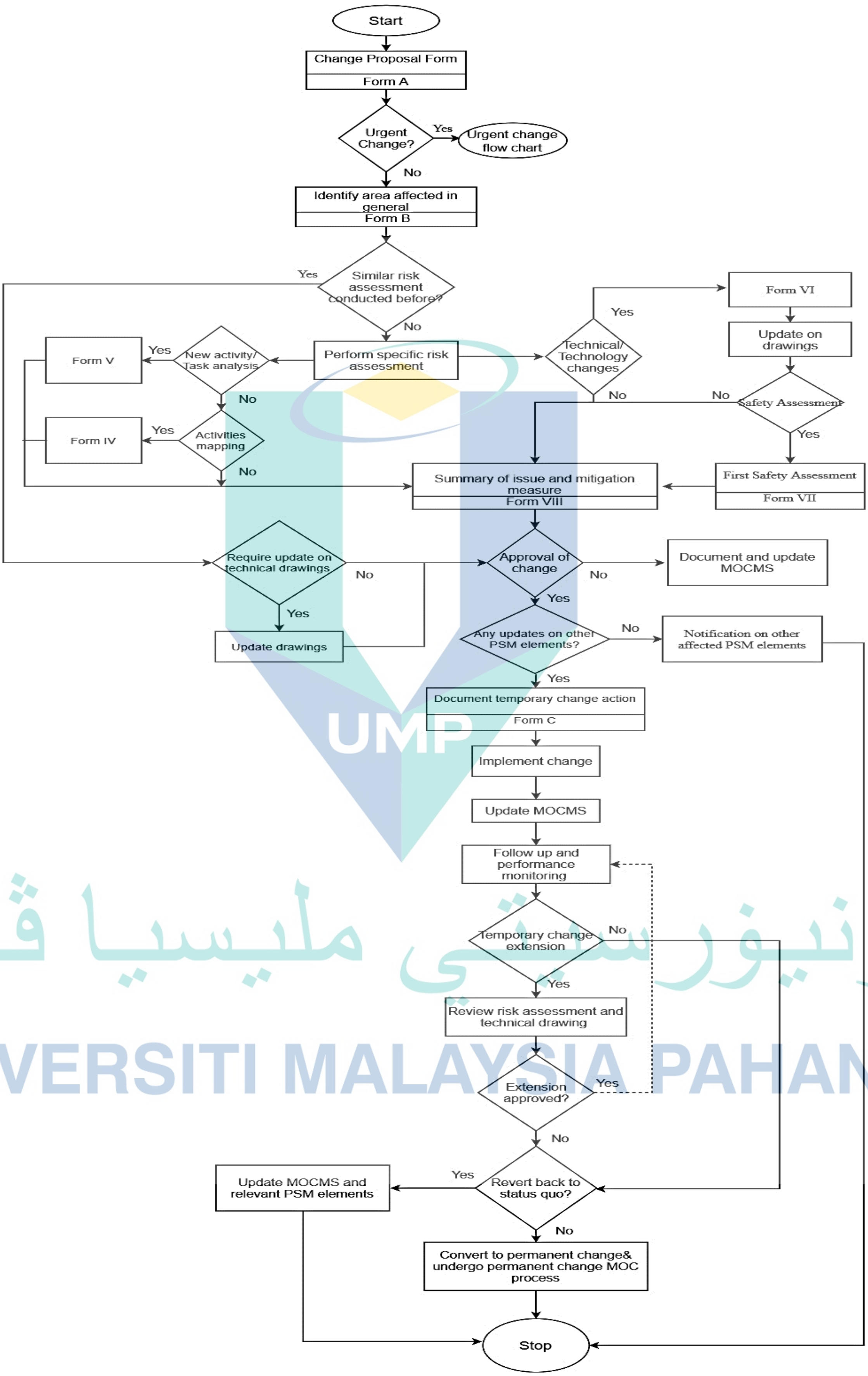


Figure 4.1: Temporary non-urgent change framework

A non-urgent change shall conduct a general risk assessment to identify the areas affected by the proposed, e.g. organisational or technical and technological aspects. Upon completion of the general risk assessment, a specific area risk assessment shall be conducted to assess the identified area. Every area affected by the change comes along with a proposed risk assessment checklist. The area affected in this risk assessment is separated into two categories: organisational and technology or technical changes. Action items for organisational change will be required to perform simple task analysis and activities mapping between new and old job tasks, Form V and Form IV. A new activity analysis shall be conducted to identify any underlying hazard in the change of the work task. This is similar to job safety analysis commonly practised in safety and health management. Activities mapping step is provided to enable the end-user to compare the proposed new and old tasks. This step will help identify the weakness of the old work task and discover whether the proposed new task can overcome existing weaknesses. All proposed risk assessment checklists will be discussed in detail in Section 4.4. Technical or technological change risk assessment shall proceed to Form VI, as shown in Figure 4.1. Update on drawing shall be completed if any alteration in equipment and system is involved in the change. Safety assessment is optional to be conducted if there is no significant change in equipment or chemical. Form VII shall be applied when a fire safety assessment is required.

Upon completion of the risk assessment, a summary of risk and mitigation measures shall be completed to highlight the risk prioritisation and change approval. The implemented change shall then update other related PSM elements, including process safety information, mechanical integrity, operating procedures, and so on. Operating Procedure (OP), Process Safety Information (PSI), and Mechanical Integrity (MI) elements shall be notified and updated when the change affects these elements. For instance, the OP element shall be updated when there is a new work task or process introduced in the process operation. On the other hand, the PSI element shall be updated when a new chemical is used in the process, while the MI element shall be updated when equipment is installed or changed in the maintenance schedule.

All approved change actions shall be documented in Form C. The change shall be recorded before and after implementation to ensure changes are managed well and monitored, especially in temporary cases. The MOC management system shall be updated after a change is implemented. MOCMS shall act as a tool in tracking the upcoming due temporary change in the premise. Extension of due temporary change shall be evaluated whether to extend the temporary change period and revert into original status. Risk assessment and related technical drawing shall be reviewed on any extension of temporary change. Approval of the change extension process shall be repeated to ensure the management and operation team are aware of the risk and planning of the new extension. In the conversion of temporary change into permanent, permanent MOC framework shall be initiated to ensure new risks are documented in hazard register or any related documentation. Any changes to the temporary change shall be reflected in MOCMS to ensure all data in the system reflect the latest information.

4.2.1.2 Urgent Change

Urgent change is one of the temporary changes that possess time restriction in planning and preparation work. Any proposed change implemented within one to two days shall be considered as an urgent change. A higher tendency leads to the neglection of MOC due to the urgency of the proposed change. The developed framework is a simplified process of normal temporary change but possesses a similar compulsory risk analysis process, as shown in Figure 4.1.

Due to time restriction in the nature of urgent change, this framework focuses on risk assessment action items to address all underlying hazards. The framework of urgent change is shown in Figure 4.2. Urgent change framework shall conduct a general risk assessment and proceed to specific technical/technological change risk assessment. First, safety assessment is made compulsory in the framework to ensure no overlooking of hazards behind any urgent changes. Change approval shall be initiated based on the summary of all risk assessment outputs.

The main idea of urgent change is to overcome the limitation of time in updating documentation of MOC. All documentation work, including implemented change action, change details, and update of any technical drawings, are proposed to be completed in the next working day. Any update on Management of Change Management System (MOCMS), follow-up, and following steps shall refer to the non-urgent change framework.

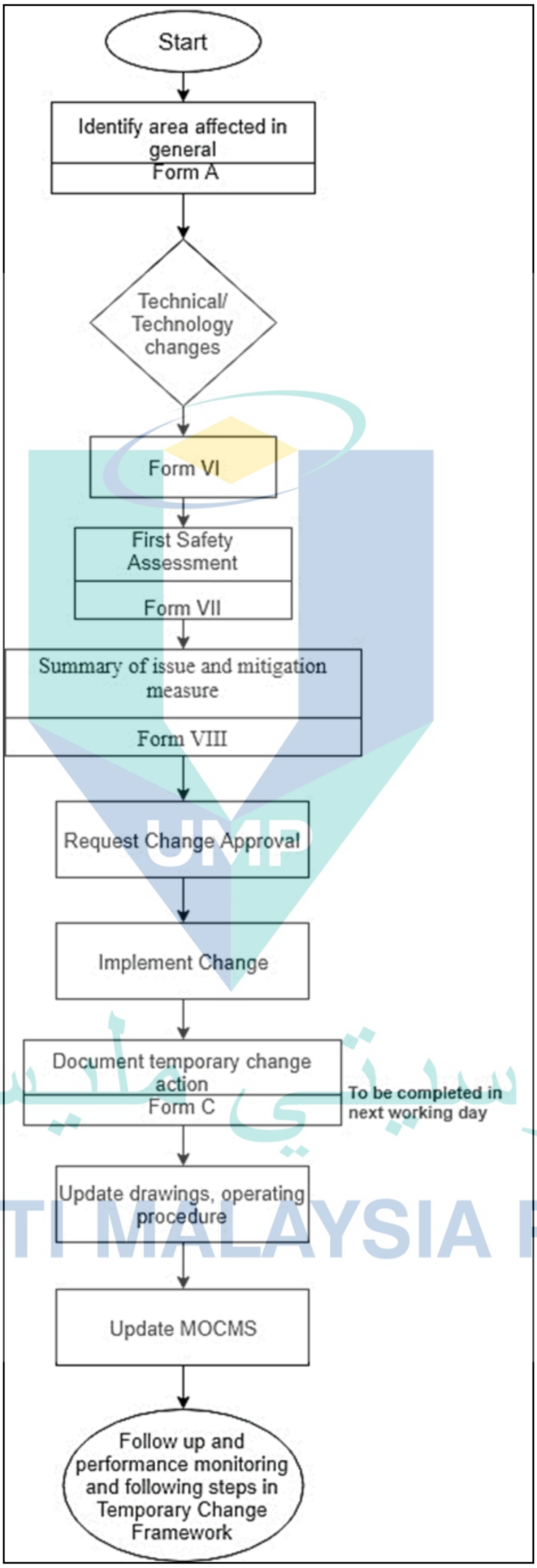


Figure 4.2: Urgent Change Framework

4.2.2 Emergency Change

Emergency Change is an essential step of response in an emergency, especially in life-saving, preventing further damage to the property, environment, and process line. During an emergency, the emergency operating procedures shall be the priority in response. In the developed framework, as shown in Figure 4.3, changes made during the emergency shall be recorded for future review, which could help in decision making and improvement in terms of emergency change and emergency response procedures. Documentation framework in emergency change is repeating the temporary change framework. Any changes during an emergency shall revert to the status quo to resume operation after the emergency. In this case, the status quo shall be the original setting or process according to the design specification. The user shall fill only Form C as a summary of change action taken during the emergency.

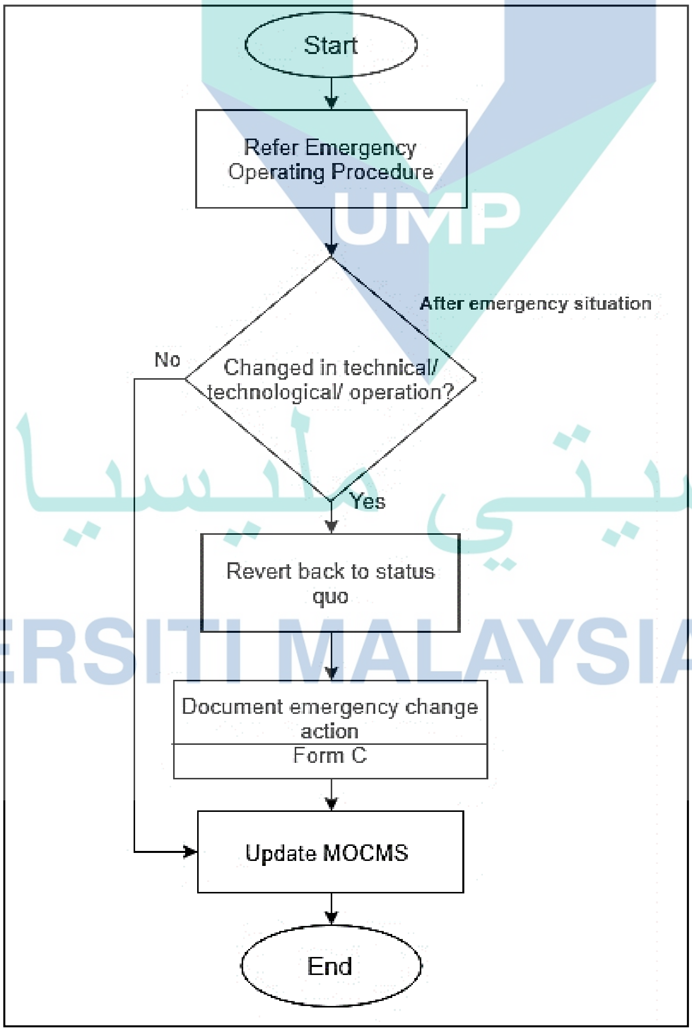


Figure 4.3: Emergency Change Framework

4.3 Risk Assessment with Proposed Risk Matrix

Risk assessment checklist and related MOC forms are adopted from Gerbec (2017)'s work with new improvements to fit this study. Improvised risk assessment checklist on technical and technological changes cover on the process, process conditions, inspection, and maintenance as well as technical documentation aspects. The improvised risk assessment proposed an additional PHA risk rating aiding in risk prioritisation and decision making (Galante et al., 2014). The concept of this risk assessment checklist is proposed to be a quick alternative of complete risk assessment for short term and emergency changes. This is useful when other hazard analyses and risk assessment, such as Hazard and Operability Study (HAZOP) and Hazard Identification Studies (HAZID), require a large amount of time and group of expertise for the brainstorming session. This section introduces the proposed risk assessment checklist with risk rating in the framework shown in Figures 4.1 and 4.2.

Based on the proposed temporary change framework, Form B is proposed to be a general risk assessment checklist that acts as a preliminary inspection checklist to identify areas affected by the proposed change. This checklist is adapted from the Canadian Society of Chemical Engineering Guidelines on MOC (CSChE, 2004). It covers areas including operation, safe work practises, maintaining safe plant condition, safety and health management, training, process safety management, emergency responses, contractor safety, occupational health, and regulatory compliance. Every area is equipped with specific criteria to aid brainstorming, evaluating the effects of each criterion, and prioritising control and mitigation measures. Action items shall be established along with all identified areas to avoid overlooking the critical areas affected by the proposed change. A sample of Form B is shown in Figure 4.4.

Form B
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		
• Identification of unsafe condition (including ability of operator to complete required tasks in given time frame)		
• Emergency operations		
• Knowledge/ expertise of workers		
• Development & maintenance of operating procedures	change temporary procedure	M
Process Safety Management		
• Management of change		
• Pre-startup safety reviews		
• Mechanical integrity	maintenance schedule	M
• Process safety training		
• Operating procedure	temporary procedure	M
• Compliance audits		
Emergency Response		
• Knowledge/ skill of emergency responders		
• Ability of crew to manage emergencies		
• Availability of emergency responders		

Figure 4.4: Sample of Form B with Real Case Data

Figure 4.5 shows the sample of organisational change related to the risk assessment checklist conducted at Plant X on the changes in job responsibilities from an engineering course trainer into operation team supervisor. For activities mapping and evaluation, Form IV has been conducted to compare responsibilities between the old role and the new role of the specific personnel. As shown in Figure 4.5, there are criteria listed in the form that guide users to identify important Health, Safety and Environment (HSE) responsibilities in the old role. This includes possibilities of appointed activities to be eliminated, any response to deviation, specific activities involved in assuring plant integrity, availability, managing HSE procedure, and any significant risk behind the specific activities of the old role. Meanwhile, this risk assessment form will focus on identifying any significant HSE hazards, extra workload or fatigue, competencies, and communication issues of newly appointed activities. This approach enables both workers and management to arrange the identified risks and gaps between old and new roles.

FORM IV - THE ACTIVITIES MAPPING AND EVALUATION																					
	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	Deliver training program	No	15	Med	Med	High	Med	High	Med	Med	Management of shift, personnel, operation schedule	25	NA	No	Compatible education background but lack of related work experiences	No	No	No	Management training provided upon change of job position		Yes
2	Develop module	No	40	Low	Med	Low	Low	High	Low	Low	Taking sample for quality checking	10	Involves with process equipment, chemicals	No	No	No	No	No	Onsite chemical handling training		Yes
3	Schedule training program	No	4	Med	Low	Low	Low	Low	Low	Low	Participate in plant shutdown & startup	30	Involves with process equipment, chemicals	Maybe	No	No	No	No	Onsite chemical handling training		Yes
4	Evaluate training effectiveness	No	5	Low	Low	Low	Low	Low	Low	Low											

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.

Figure 4.5: Sample of Activities Mapping from Plant X Organizational Change

An extension of the risk assessment checklist by Gerbec (2017) is made by implementing a risk rating column in the technical and technological risk assessment checklist. It has incorporated criteria of HAZOP guide parameters, including processes, process conditions, inspection and maintenance, technical documentation, and other issues. This is to aid end-users in prioritising hazards and risks that require adequate mitigation measures. A PHA risk rating is embedded into a risk assessment checklist as this risk rating covers both process safety and occupational safety context. An example of a risk rating embedded is shown in Appendix B. Probability, severity, and risk rating was newly added in the adopted risk assessment forms.

Nevertheless, the industry may use their internal standard of risk matrix where applicable according to respective practises. A sample of a technical and technological risk assessment conducted at Plant X is shown in Figure 4.6. This risk assessment was conducted on the change of battery limit area from a process area to another. This risk assessment checklist helps guide end-user to identify the impact, possible consequences, and mitigation measures. Risk rating shall be evaluated based on the identified consequence to justify the adequacy of the impact of identified mitigation measures.

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:

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 PROCESSES									
A.4 Temporary procedural changes		Startup & shutdown	plant operation	No production	to include step in procedure	D	4	LOW	YES
C INSPECTION & MAINTENANCE									
C.3 Changes to the equipment set-up									
C.4 Periodic equipment maintenance	yes	update maintenance schedule	maintenance acitvity	reduce valve reliability if maintenance not conducted following updated schedule	include in MOC work procedure for updates, folow up action by specific personnel	D	4	LOW	YES
D TECHNICAL DOCUMENTATION									
D.1 PFD drawings/data/files									
D.2 PID drawings/data/files	yes	change in P&ID drawings	PSI	Wrong information for maintenance and other related work that requires P &ID	include in MOC work procedure for updates, folow up action by document controller	C	4	LOW	YES

Figure 4.6: Sample of Technical and Technological Change Risk Assessment from Plant X

It is believed that this framework could contribute to creating awareness among safety practitioners on the importance of addressing temporary and emergency changes. The proposed framework has utilized a valid permanent change framework to be modified into temporary and emergency changes without neglecting essential action items in the MOC process, including change proposal, risk assessment, and performance monitoring. Other than that, this study has proposed a new qualitative risk analysis idea to aid in risk and mitigation measure prioritisation when it comes to constraining time and resources. This framework also highlighted organisational change always neglected in most of the MOC procedures. Notification and update on other related PSM elements are another highlight point of the proposed framework. The MOC shall cover other affected PSM elements with the new proposed change to ensure all related PSM elements are updated with the necessary information.

4.4 Management of Change Management System (MOCMS)

A Management of Change (MOC) management system is developed to guide end-users on the MOC process while acting as a storage database on MOC-related documents. This system stores lists of risk assessments checklist as shown in the MOC framework. It acts as active guidance for the merged MOC framework discussed earlier into the system. This guides end-users without referring to the flow chart.

1. Login Page

This system begins with a security page, as illustrated in Figure 4.7. It requires users to log in with username and password. It is designed to enable only MOC team members and related management personel to access the system. Workers' ID is applied as a login username to avoid any confusion among this system and company internal database. Only designated user which registered in the contact detail as shown in Figure 4.8 only eligible to log into the MOCMS system.

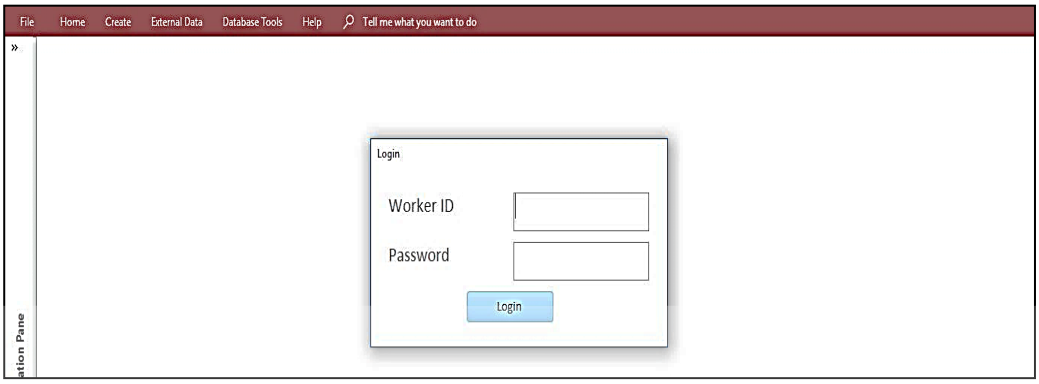
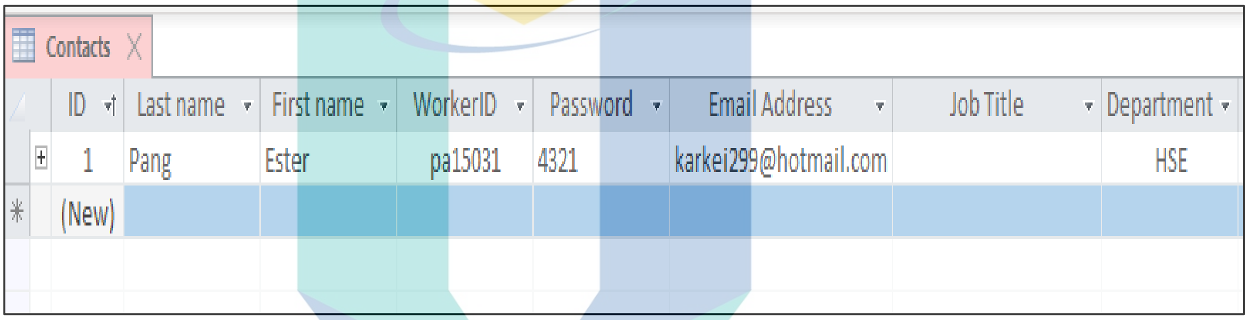


Figure 4.7: User Login interface of MOCMS



ID	Last name	First name	WorkerID	Password	Email Address	Job Title	Department
1	Pang	Ester	pa15031	4321	karkei299@hotmail.com		HSE
(New)							

Figure 4.8: Contact detail interface

2. Selection of Desired Interface in Main Dashboard

Based on Figure 4.9, the main dashboard interface appears after user login, which functions to guide users throughout the MOC process. There are three categories displayed in the dashboard, including data inventory, tracking, and filter search. Data inventory interfaces act as databases to store all copies of checklist and forms, input new MOC cases data and new user contacts to be added into the email contact list. There is a list of risk assessment form hyperlinks stored in the "List of Risk Assessment Checklist" interface to enable user access to specific forms. The interface will indicate all compulsory and optional checklist and forms to be completed according to the proposed MOC framework. The addition of a new MOC case and new user contact in the system showing a "Documentation" interface upon clicking on the dashboard button will be further discussed in the upcoming step. The user contact tab in this system functions to store all contact details of the process safety related to staff for communication purposes to store username and password for specific personnel to log in to the system.

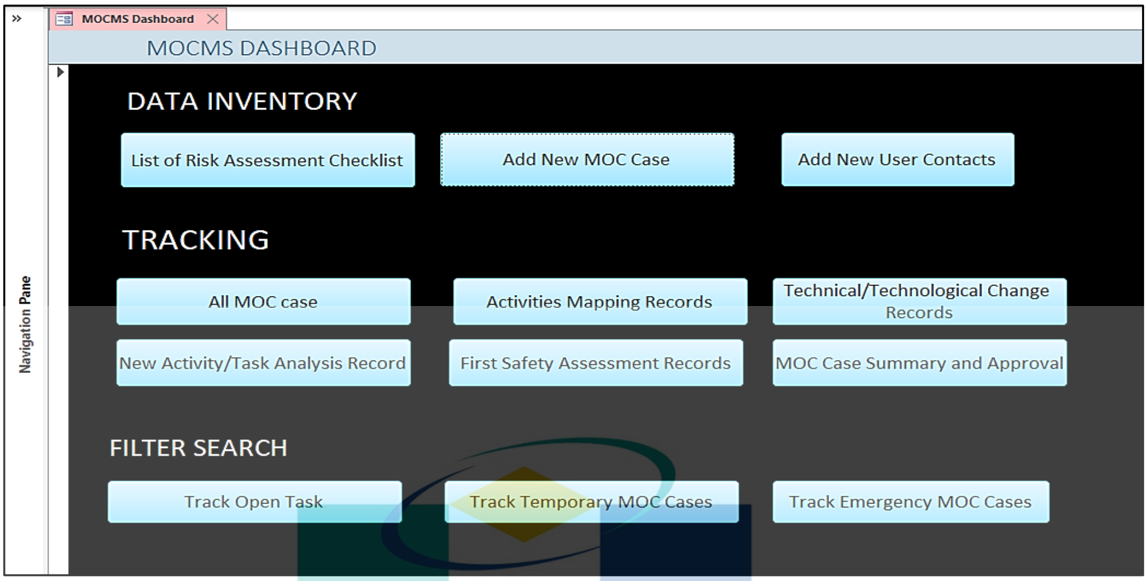


Figure 4.9: MOCMS Dashboard Interface

3. Initiation of MOC Proposal and Risk Analysis

Upon selection of "List of Risk Assessment Checklist" button in MOCMS Dashboard as shown in Figure 4.10, user may find all the links directed to all related forms according to MOC framework developed. Figure 222 shows the interface of "List of Risk Assessment" that would appear in the system. This interface will list down the compulsory forms to be completed meanwhile forms listed in the interface as shown in Figure 333 will be optional of completion as it will vary according to nature of change meanwhile summary steps of the risk analysis findings are compulsory to be completed prior to proceed for documentation process, as illustrated Figure 444

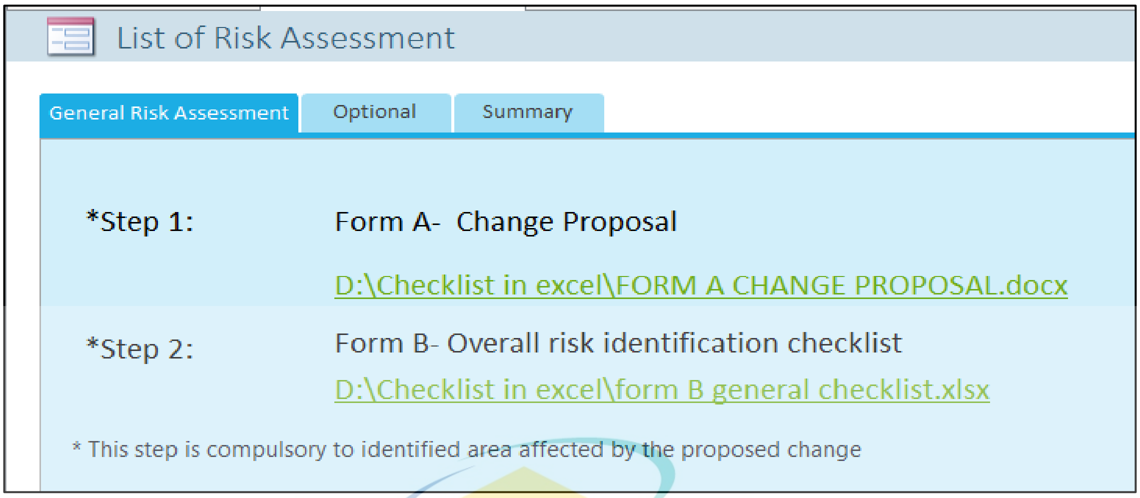


Figure 4.10: List of Risk Assessment Storage Interface

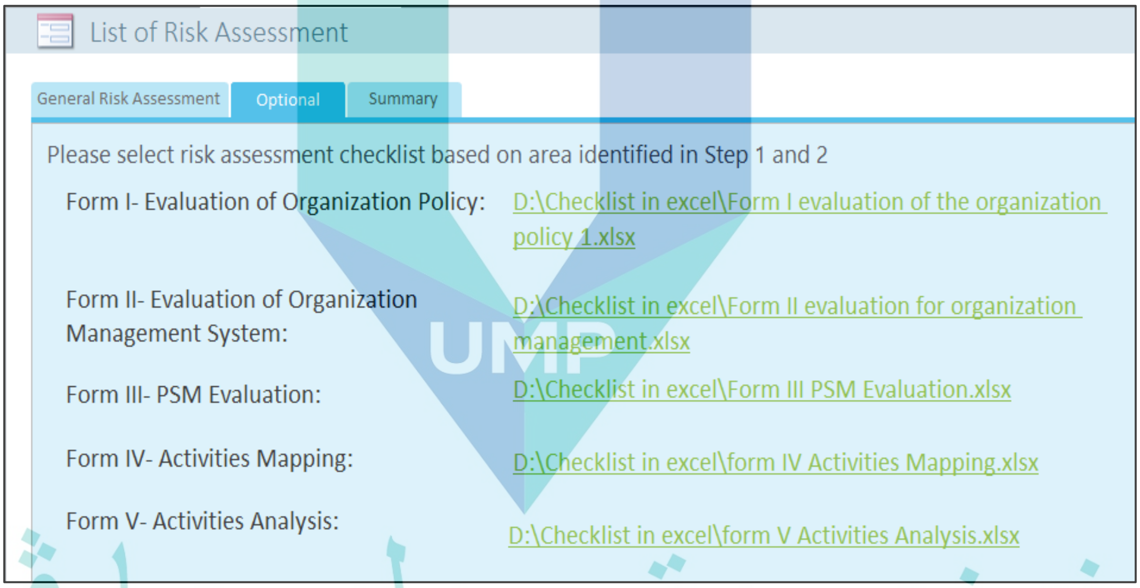


Figure 4.11: List of Optional Risk Assessment Storage Interface

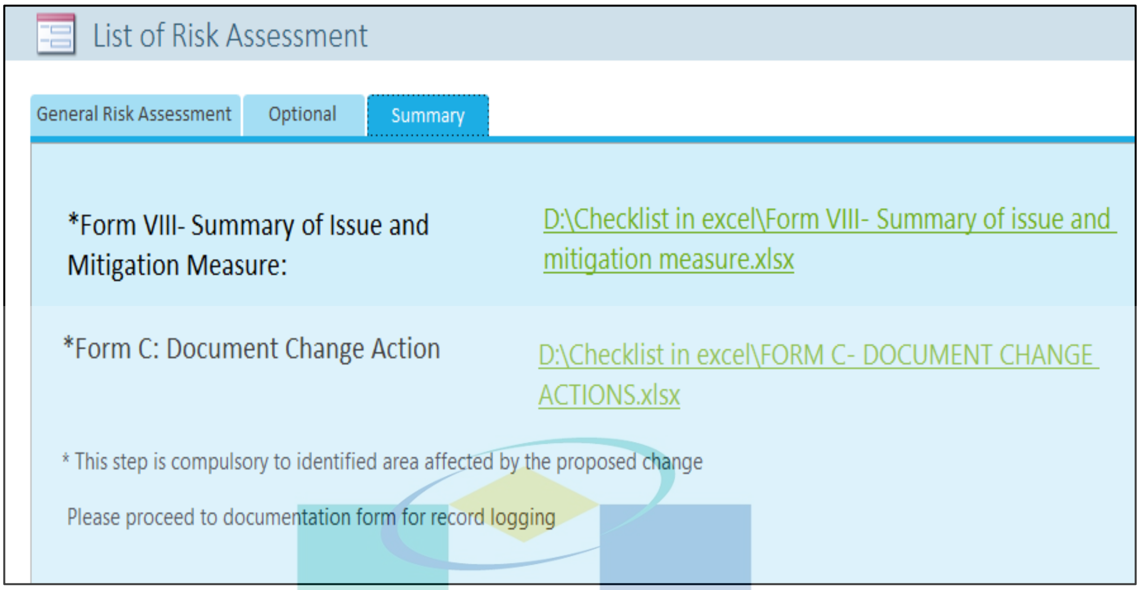


Figure 4.12: List of Summary MOC Forms Storage Interface

4. Data Entry or Documentation of Data

Documentation is another step in the MOC process that is important in future review and retaining evidence on regulatory compliance. A documentation navigation form is created to guide the user to input all necessary information into the system. This is the integrated data inventory interface that comprises five forms that store general data on new MOC cases, information on every specific risk assessment, and summary and follow-up action. An example of the navigation form is displayed in Figure 4.13. The interface shown in Figure 4.13 will appear upon clicking “Add new MOC case” button in the dashboard. All the data collected will be reflected in respective tables, as shown in Figure 4.14

5. Generation of Report from data input (optional)

An additional feature is added in the navigation form that enables users to email or generate reports on the specific MOC cases while completing the data inventory process. This is to improve on the efficiency in terms of obtaining approval via email or generation of a report. Figure 4.14 shows the sample report generated based on the data input in documentation interface as shown in Figure 4.13.

6. Checking or Amendments on Submitted Data

The tracking category in the dashboard is designed to ease the work to retrieve specific data from all action items. For example, end-users would like to retrieve data related to specific MOC case summary and approval documentation. This is to access the MOC case summary and approval interface to retrieve all summary and approval data for documentation. The same concept is applied to other tabs, including "Activities Mapping record," "Technical/Technological Change Record," "New Activity/Task Analysis Record," "First Safety Assessment Records," and "MOC Case Summary and Approval." All specific details of each action item are shown in Figure 4.15. The system database will collect information on the case title, case code, action by, approved by, the status of MOC for a specific action item, date begin, proposed due date, and actual completion database. There are several features presented to the problem and issues addressed. There are fields created, named with time begin and time completed, in risk assessment documentation forms. This feature is made available to overcome time-motion-based study, which is identified as a weakness in the previous MOC approach (Zwetsloot et al., 2007). As shown in Figure 4.15, this feature aims to help in recording the period required to perform every risk assessment. This can be used as a reference to predict the overall time required from the change proposal to approval. This is believed to be significant in solving the current time constraint issue in MOC (Gambetti et al., 2013).

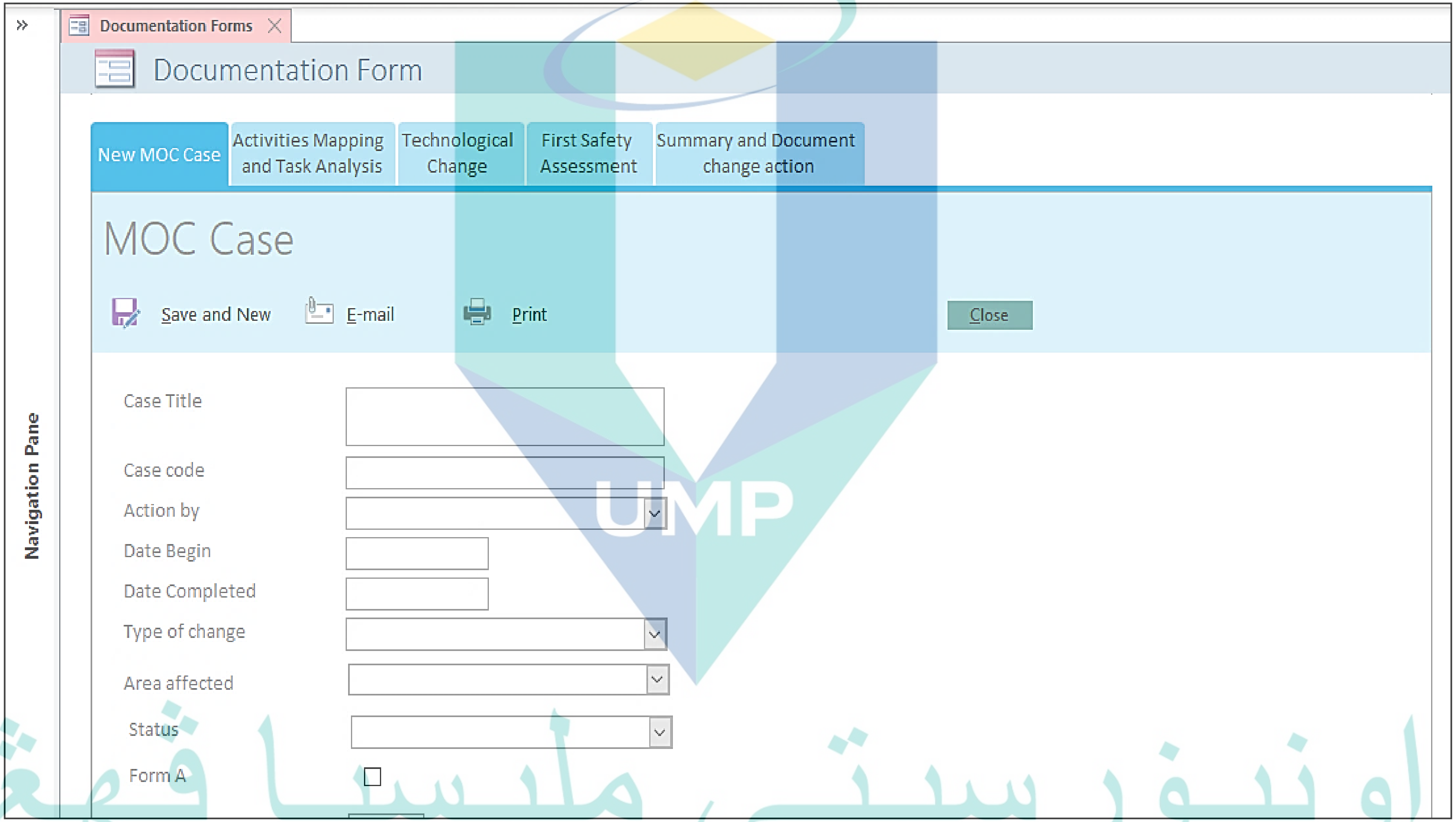


Figure 4.13: Documentation interface under new MOC case

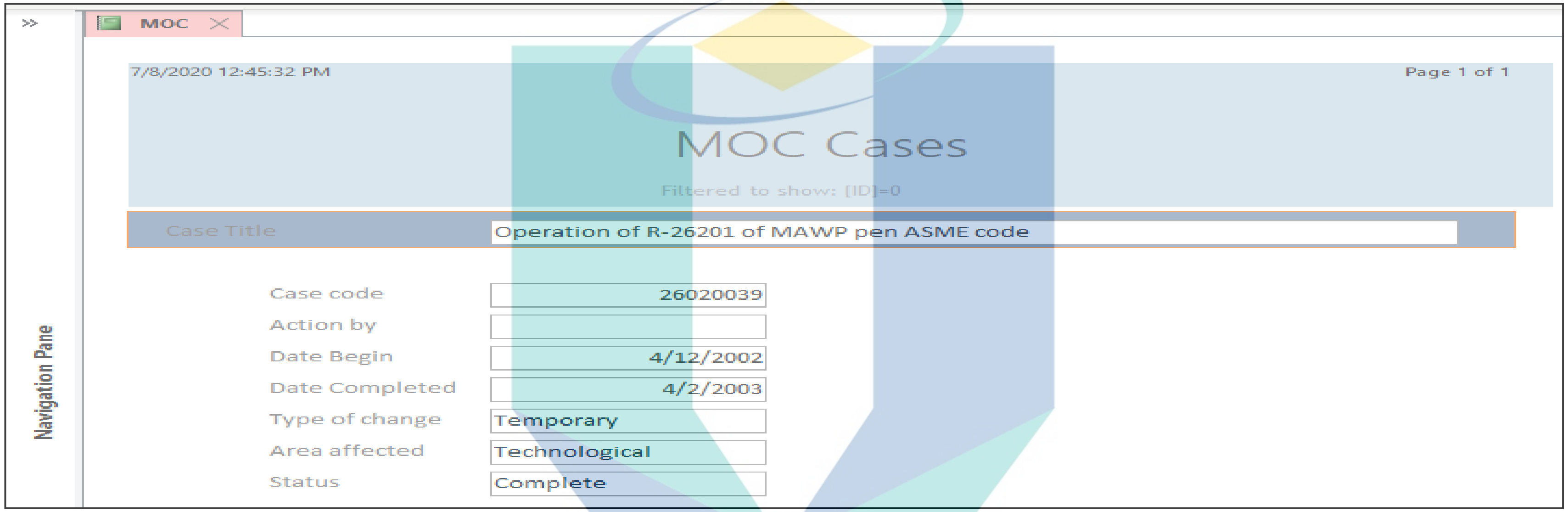


Figure 4.14: Report interface on specific MOC case

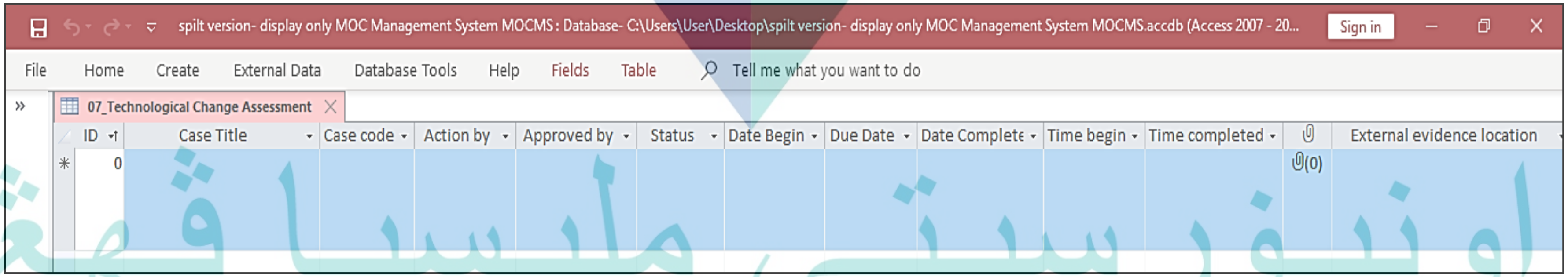


Figure 4.15: Blank Interface of specific data interface

7. Tracking of Open MOC Cases/ Filter Search of Specific MOC Cases

Meanwhile, filter search button in dashboard, as shown in Figure 4.16, is made available for the tracking of MOC cases according to categories, including open MOC cases, all temporary and emergency MOC cases. This feature is designed to reduce the burden of tracking open cases manually and minimize the overlook weakness identified earlier in the problem statement. Referring to Figure 4.16, a feature that addresses the type of change, whether permanent, temporary or emergency, would help the end-user easily track previous temporary change cases and related risk assessments. Temporary cases may often be the loop of an organisation in accident occurrence as risk assessment is often simplified or merely absent due to the implementation period. It can be seen from a few major accident cases, such as the Flixborough accident (Piong et al., 2017). A query is made available in the system for ease of tracking, listing all the temporary cases and related necessary information. Apart from that, another additional feature enables users to track the open task of MOC, which is yet to meet the due date. There is a status input allowing the MOC team to select whether the task is "Completed," "Pending," or "Incomplete." An open task query is designed to track MOC cases that hold the status of "Pending" or "Incomplete."

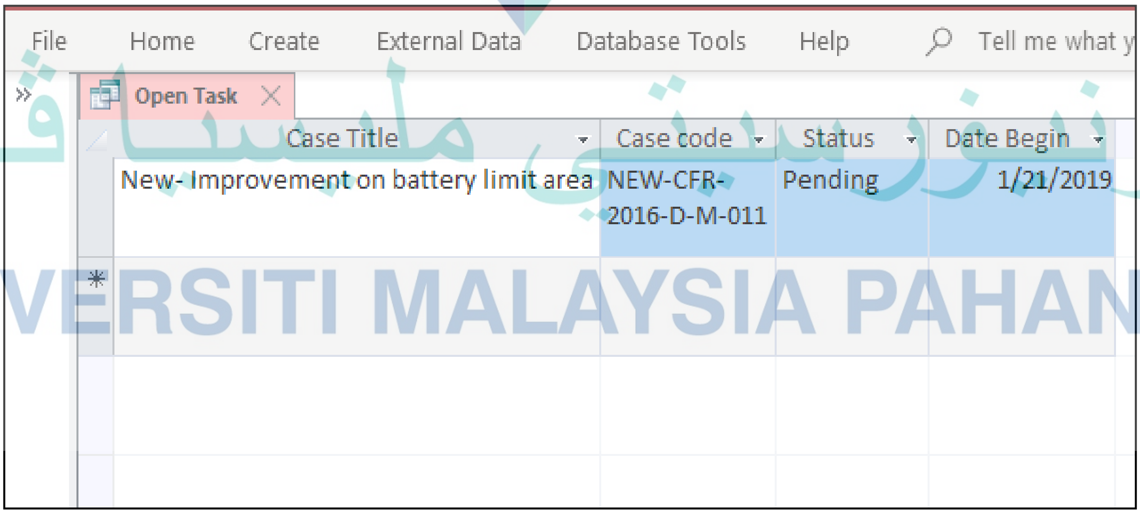


Figure 4.16: Open MOC Task Tracking Interface

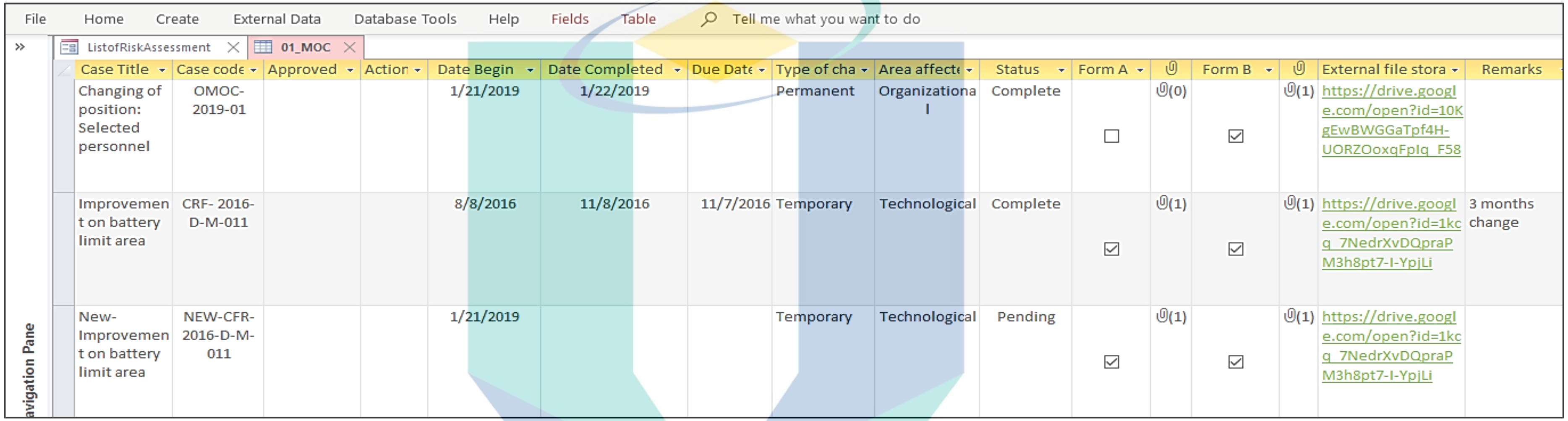
4.5 System Testing Outcome

A pilot study has been conducted in two plants in Malaysia, Plant X and Plant Y. Plant X is a petrochemical plant, while Plant Y is a chemical plant major in chemical manufacturing, chemical products, and preparation manufacturing. This pilot test was conducted to test the feasibility and collection of feedback on the established frameworks, risk assessment forms, and management system. An existing temporary Management of Change (MOC) case data was used to reconduct the MOC process using a developed framework and management system. Figures 4.17 and 4.18 demonstrate the MOC cases obtained in both Plant X and Plant Y. There were two temporary MOC cases and one permanent organisational case obtained from Plant X; meanwhile, Plant Y has contributed one permanent and one temporary MOC cases during the pilot study.

Developed frameworks, risk assessment checklist, and Management of Change Management System (MOCMS) were tested with one real existing temporary change to compare the efficiency in completion of the MOC process. The selected change was the improvement of battery limit area case in Plant X. In contrast, the repeated change process was tracked as "New-Improvement of Battery Limit Area," as shown in Figure 4.19. The process was repeated by a team of staff who did not directly participate in the actual change process to maintain the test's neutrality. Results showed that temporary change with developed frameworks is completed at least a day earlier than the actual time taken on the specific change. Moreover, the time efficiency on risk assessment can be tracked from the technological risk assessment interface, as shown in Figure 4.20. There are only 90 minutes required to complete risk assessment towards the change. In contrast, the actual change preparation required 48 hours due to staff availability and longer time taken for brainstorming sessions.

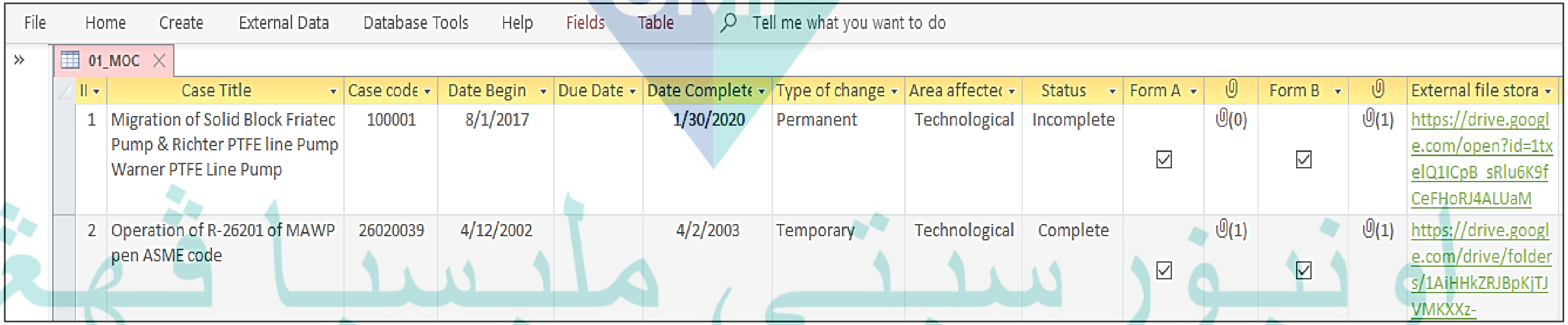
Furthermore, permanent cases, such as "Changing of Position" and "Migration of Solid Block Friatec" have been included in the pilot study. It is believed that these cases could contribute to test the functionality of organisational and technological risk assessment checklist with different scope. These cases could also identify the lack of current practices in the industry on the crucial action item. For example, there are no risk assessments conducted on the new role for the designated personnel on the organisational change. In contrast, the "Migration of Solid Block Friatec" case lacks follow-up and update of other PSM element action items. For example, the process safety information of Plant Y is not updated on the change for the solid block friatec case.

MOCMS has been used by pilot test participants to document logging and tracking of related MOC cases. There are two ways of documentation storage proposed in this system. All evidence files were also uploaded to cloud storage to serve as backup files when the management system is corrupted. Figure 4.21 shows one of the queries developed in MOCMS, which helps to track the list of temporary MOC cases. As shown in the figure, the query is designed to track temporary MOC cases, displaying all the vital information of temporary MOC cases with "Due date" and "Remarks." This query helps end-users to easily track the temporary case, which will meet the due date. This is to improve the management of overdue temporary change. There are two queries designed to track the open task and emergency change cases.



Case Title	Case code	Approved	Action	Date Begin	Date Completed	Due Date	Type of cha	Area affecte	Status	Form A	🖇	Form B	🖇	External file stora	Remarks
Changing of position: Selected personnel	OMOC-2019-01			1/21/2019	1/22/2019		Permanent	Organizational	Complete	☐	(0)	☑	(1)	https://drive.google.com/open?id=10KgEwBWGGaTpf4H-UORZOoxqFplq_F58	
Improvement on battery limit area	CRF- 2016-D-M-011			8/8/2016	11/8/2016	11/7/2016	Temporary	Technological	Complete	☑	(1)	☑	(1)	https://drive.google.com/open?id=1kcq_7NedrXvDQpraPM3h8pt7-I-YpjLi	3 months change
New-Improvement on battery limit area	NEW-CFR-2016-D-M-011			1/21/2019			Temporary	Technological	Pending	☑	(1)	☑	(1)	https://drive.google.com/open?id=1kcq_7NedrXvDQpraPM3h8pt7-I-YpjLi	

Figure 4.17: Permanent Organisational and Temporary Technological MOC case obtained from the pilot test in Plant X



ID	Case Title	Case code	Date Begin	Due Date	Date Complete	Type of change	Area affected	Status	Form A	🖇	Form B	🖇	External file stora
1	Migration of Solid Block Friatec Pump & Richter PTFE line Pump Warner PTFE Line Pump	100001	8/1/2017		1/30/2020	Permanent	Technological	Incomplete	☑	(0)	☑	(1)	https://drive.google.com/open?id=1txelQ1ICpB_sRlu6K9fCeFHoRJ4ALUaM
2	Operation of R-26201 of MAWP pen ASME code	26020039	4/12/2002		4/2/2003	Temporary	Technological	Complete	☑	(1)	☑	(1)	https://drive.google.com/drive/folders/1AiHHkZRJBpKjTJVMKXXz-

Figure 4.18: MOC case obtained from the pilot test in Plant Y

07_Technological Change Assessment

Case Title	Case code	Action by	Approved by	Status	Date Begin	Due Date	Date Complete	Time begin	Time completed	📎	External evidence location
Improvement on battery limit area	CRF- 2016-D-M-011			Complete	10/8/2018		1/9/2018			(1)	https://drive.google.com/open?i d=1eD4jW9p53yhWmKcFN4HF0X BCY-1WvKQT
New- Improvement on battery limit area	NEW-CFR-2016-D-M-011			Pending	1/21/2019		1/22/2019	1430	1600	(1)	https://drive.google.com/open?i d=1wbjiBAJOdUVd- gbc8M1LheDZXLe8w-2V

Figure 4.19: Technological Change Assessment on MOC Case in Plant X

07_Technological Change Assessment

ID	Case Title	Case code	Action by	Approved by	Status	Date Begin	Due Date	Date Complete	Time begin	Time completed	📎	External evidence location
1	Migration of Solid Block Friatec Pump & Richter PTFE line Pump Warner PTFE Line Pump	1			Complete	8/1/2017		8/1/2017			(1)	https://drive.google.com/open? d=1D44gSwHtrPpebflAKEQ1pym BJ1D9dqO
2	Operation of R-26201 of MAWP pen ASME code	26020039			Complete	4/12/2002		4/12/2002			(1)	https://drive.google.com/open? d=1LFmTwYcdITaQ- e0lTBznIHa0jYG8AXKY

Figure 4.20: Technological Change Assessment on MOC Case in Plant Y

Temporary MOC case

Type of change	Case Title	Case code	Date Begin	Date Completed	Action by	Area affected
Temporary	New- Improvement on battery limit area	NEW-CFR-2016-D-M-011	1/21/2019			Technological
Temporary	Improvement on battery limit area	CRF- 2016-D-M-011	8/8/2016	10/31/2019		Technological

Figure 4.21: Temporary change case query in MOCMS

4.5.1 Case Study Demonstration on Framework and Management System

The developed framework and management system has been pilot tested in Plant X by repeating the previous temporary cases to compare the generated result's effectiveness and practicability. Improvement of the battery limit area is the selected case in Plant X, where the existing documentation has been inserted into a developed management system to check on the compliance of essential documentation for management of change (MOC). The process began with filling up information in Form A for change initiation. All related forms and checklist are stored readily in the developed Management of Change Management System (MOCMS). Figures 4.23 and 4.23 show the interface of blank forms and checklist storage. This interface has stated forms and steps that are compulsory and optional according to changed situations. Based on the comparison of existing documentation, information collected in both change proposal forms were similar. Figure 4.24 shows the adopted change proposal form in the case study. Next, the change owner shall proceed to conduct a general risk assessment, Form B, to identify the scope of work affected by the proposed change. Form B includes most potential areas, such as process operation, safe work practice, safety and health management, training, process safety management, regulatory compliance, emergency response, and occupational health. This form act as a general preparation guide on the potentially affected areas to be included in consideration and change planning. Figure 4.25 displays the specific section of the general checklist, which was affected by the battery limit change case.

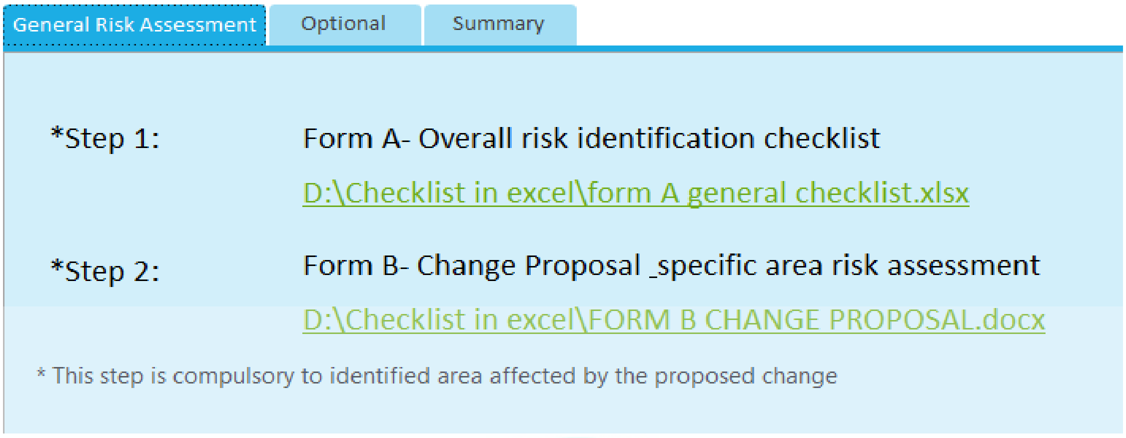


Figure 4.22: Related Form Storage Interface

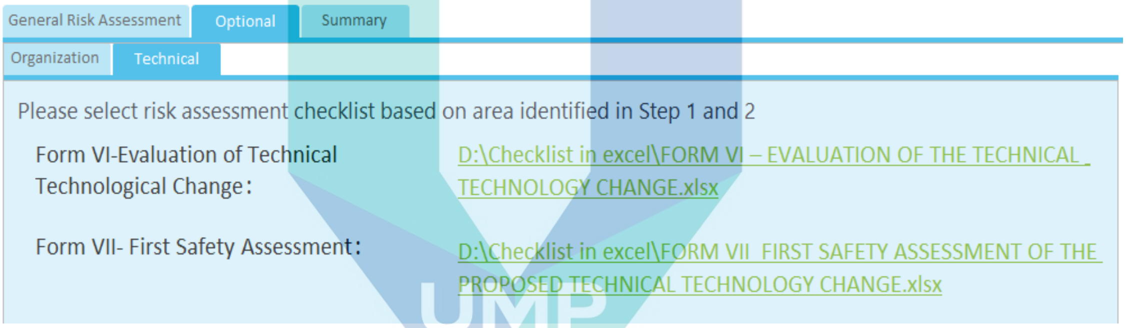
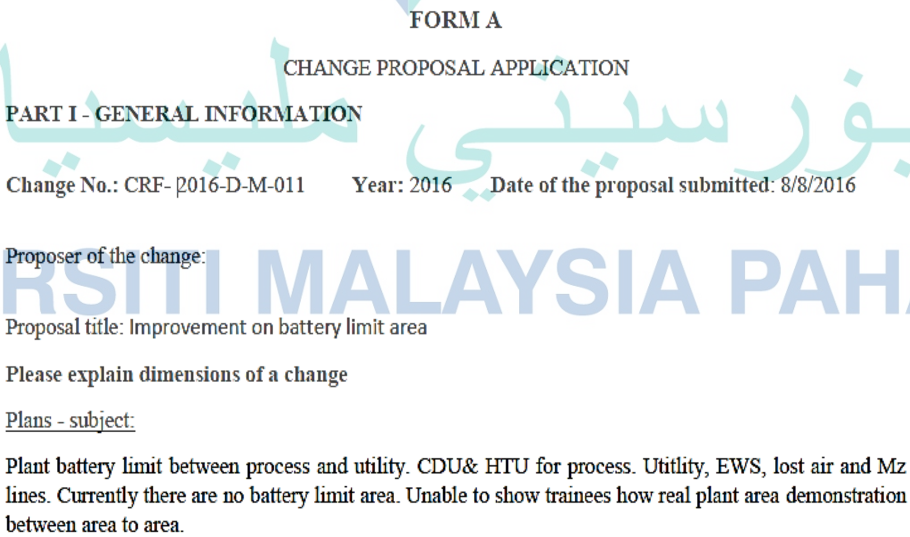


Figure 4.23: Technical Risk Assessment Checklist Storage Interface



FORM A

CHANGE PROPOSAL APPLICATION

PART I - GENERAL INFORMATION

Change No.: CRF- P2016-D-M-011 **Year:** 2016 **Date of the proposal submitted:** 8/8/2016

Proposer of the change:

Proposal title: Improvement on battery limit area

Please explain dimensions of a change

Plans - subject:

Plant battery limit between process and utility. CDU& HTU for process. Utitlity, EWS, lost air and Mz lines. Currently there are no battery limit area. Unable to show trainees how real plant area demonstration between area to area.

Figure 4.24: Change Proposal Form (Form A) on selected case

Form B
General Risk Assessment Checklist

Could the change affect S&H in the following areas	Effect	Priority (H/M/L)
Operation of the process		
• Development & maintenance of operating procedures	change temporary procedure	M
Process Safety Management		
• Management of change	temporary change MOC	M
• Pre-startup safety reviews		
• Mechanical integrity	maintenance schedule	M
• Process safety training		
• Operating procedure	temporary procedure	M
• Compliance audits		

Figure 4.25: General Risk Assessment Checklist (Form B) on selected case

Technical and technological change risk assessment shall be conducted as this is mainly involved in the technical area's changes. Figure 4.26 shows the risk assessment checklist completed for the selected case. Different change owners have performed this risk assessment as the original change owner of the specific case is not available. Based on the interview conducted with related personnel, the risk assessment for the actual change was only job hazard analysis focusing on personal safety instead of process safety. As shown in Figure 4.26, the MOC team involved in the proposed risk assessment checklist managed to identify additional process safety risks, such as updating technical drawings, maintenance schedule, and interruption of process condition. However, these criteria were not highlighted in the actual case risk assessment. The actual case risk assessment focused on the construction work where change was approved and implemented. There was an absence of preliminary risk assessment on the proposed change prior to the approval of the change. This has placed a significant underlying hazard towards Plant X, as the proposed change was not evaluated on the potential risk towards the process, human, and environment.

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:

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	**PROCESSES**									
A.4	Temporary procedural changes		Startup & shutdown	plant operation	No production	to include step in procedure	D	4	LOW	YES
C	**INSPECTION & MAINTENANCE**									
C.3	Changes to the equipment set-up									
C.4	Periodic equipment maintenance	yes	update maintenance schedule	maintenance acitvity	reduce valve reliability if maintenance not conducted following updated schedule	include in MOC work procedure for updates, folow up action by specific personnel	D	4	LOW	YES
D	**TECHNICAL DOCUMENTATION**									
D.1	PFD drawings/data/files									
D.2	PID drawings/data/files	yes	change in P&ID drawings	PSI	Wrong information for maintenance and other related work that requires P &ID	include in MOC work procedure for updates, folow up action by document controller	C	4	LOW	YES

Figure 4.26: Technical and Technological Risk Assessment Checklist on Selected Case

Inventory of MOC case was initiated in the system by surfing the MOCMS interface after completing change initiation and risk assessment. All the necessary information has been integrated into an interface, separated according to action items. Figure 4.27 shows the MOC case interface where both battery limit cases have been inserted into the system. As displayed in Figure 4.28, the information from both actual and newly tested cases matches the requirements stated in the system. The slight difference of both cases is that the actual change only comes with Job Hazard Analysis as an overall risk assessment for the implementation of change. In contrast, the proposed framework integrated process safety consideration by considering all potentially affected process safety elements through several layers of risk assessment. Figure 4.28 displays the interface of a specific action item from the developed framework, technical and technological risk assessment. Specific action items are designed to track separately in the system to track the completion time required, which targeted to improve time prediction of every action item and ease for further planning of a complete MOC cycle. All the related drawings and documentation that act as a reference can be stored in both software and cloud storage for double data protection.

Moving on, the summary of the identified issue and change approval form is set to be compulsory in the framework. This form act as official approval documentation for company management approval, as shown in Figure 4.29. However, the original change case does not come with any risk summary and approval form, as risk assessment is only conducted upon approval of the change. In contrast, change approval is tracked on the change proposal form. The developed framework and management system are pilot tested until the extension of the issue's summary and change approval, as the original change is completed in the past. Figure 4.30 shows the interface of summary and change approval tracking in MOCMS. This has posed a limitation to test in terms of follow-up action and review of change extension. However, the actual MOC procedure in Plant X only conducts performance monitoring of new change if the change is implemented for more than six months and above. This is the underlying risk practised in Plant X, where the performance of newly implemented change is not continuously monitored to avoid the occurrence of significant scenarios.

01_MOC

Case Title	Case code	Approved by	Action b	Date Begi	Date Complete	Due Dat	Type of change	Area affected	Status	Form A	📎	Form B	📎	External file stora	Remarks
Improvement on battery limit area	CRF- 2016-D-M-011			8/8/2016	11/8/2016	11/7/2016	Temporary	Technological	Complete	☑	(1)	☑	(1)	https://drive.google.com/open?id=1kcq_7NedrXvDQpraPM3h8pt7-I-YpjLi	3 months change
New-Improvement on battery limit area	NEW-CFR-2016-D-M-011			1/21/2019			Temporary	Technological	Pending	☑	(1)	☑	(1)	https://drive.google.com/open?id=1kcq_7NedrXvDQpraPM3h8pt7-I-YpjLi	

Figure 4.27: MOC Case Interface of Old and New Battery Limit Cases

07_Technological Change Assessment

Case Title	Case code	Action by	Approved by	Status	Date Begin	Due Date	Date Complete	Time begin	Time completed	📎	External evidence location
Improvement on battery limit area	CRF- 2016-D-M-011			Complete	10/8/2018		1/9/2018			(1)	https://drive.google.com/open?id=1eD4jW9p53yhWmKcFN4HF0XBCY-1WvKQT
New- Improvement on battery limit area	NEW-CFR-2016-D-M-011			Pending	1/21/2019		1/22/2019	1430	1600	(1)	https://drive.google.com/open?id=1wbjiBAJOdUVd-gbc8M1LheDZXLe8w-2V

Figure 4.28: Technological Change Risk Assessment Interface for Old and New Battery Limit Case

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	Startup & shutdown	A.4	Plant operation	No production	To include step in procedure		
2	Update maintenance schedule	C.4	Maintenance acitvity	Reduce valve reliability if maintenance not conducted following updated schedule	Include in MOC work procedure for updates, folow up action by specific personnel, change follow up action		
3	Change in P&ID drawings	D.2	PSI	Wrong information for maintenance and other related work that	Include in MOC work procedure for updates, folow up action by document		

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

Figure 4.29: Mitigation Measures Summary and Change Approval Form On Selected Case

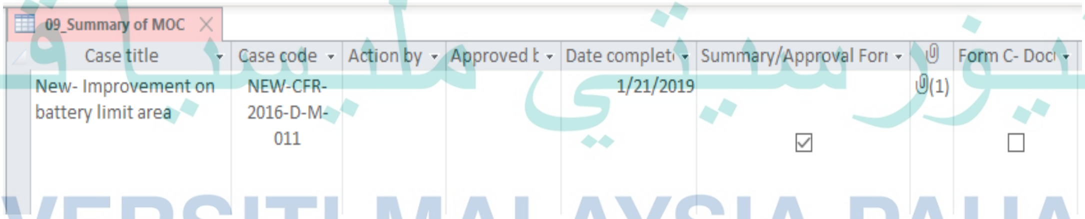


Figure 4.30: MOCMS interface on Risk Summary and Change Approval

4.6 User Response and Analysis

Other than that, a user feedback survey has been conducted upon completion of all pilot tests and presentation on the functions of the established MOCMS. There are two sections in the survey. The first section inquires the level agreement on the improvement and efficiency brought by the system. In contrast, section two measures the overall usability of the system. Details of the survey form are displayed in Appendix C. Overall, there is a high agreement level on the MOCMS's efficiency in terms of improvement in MOC standard compliance, MOC and risk assessment cycle time prediction, tracking temporary cases, and risk assessment checklist, which helps in prioritising risk. To test the goodness of the data, the (result) is established by testing the consistency and stability of the survey data. One of the methods used is by determining the Cronbach's alpha value of the data using the Statistical Package for Social Sciences (SPSS). Cronbach's alpha is known as a coefficient of reliability that indicates how well the items in a set are positively correlated to one another (Wadkar et al., 2016). In general, reliabilities in the range of 0.70 are considered acceptable, while over 0.80 is deemed to be good. Figure 4.31 shows the reliability test, as discussed above. The Cronbach's alpha's value of this data is 0.836 and 0.891, which falls in the good range. Section one of the reliability statistics examines the level of agreement and disagreement on the efficiency of the developed Management of Change Management System (MOCMS). In contrast, section two shows the reliability statistics on MOCMS system usability.

Thus, it can be concluded that the software is reliable and suitable to be used to minimise the highlighted issues. The tabulation of the survey results is displayed in Figure 4.32 and Figure 4.33. All these criteria were 100% agreed by industrial practitioners with a rating of 4 and 5. There was additional feedback received from the industrial practitioners stating the MOCMS system is readily usable for small and medium enterprises with a smaller scale of the management system and documentation.

Reliability Statistics Section 1

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.836	.802	16

Reliability Statistics Section 2

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.891	.885	10

Figure 4.31: Cronbach's Alpha test result on software reliability and efficiency

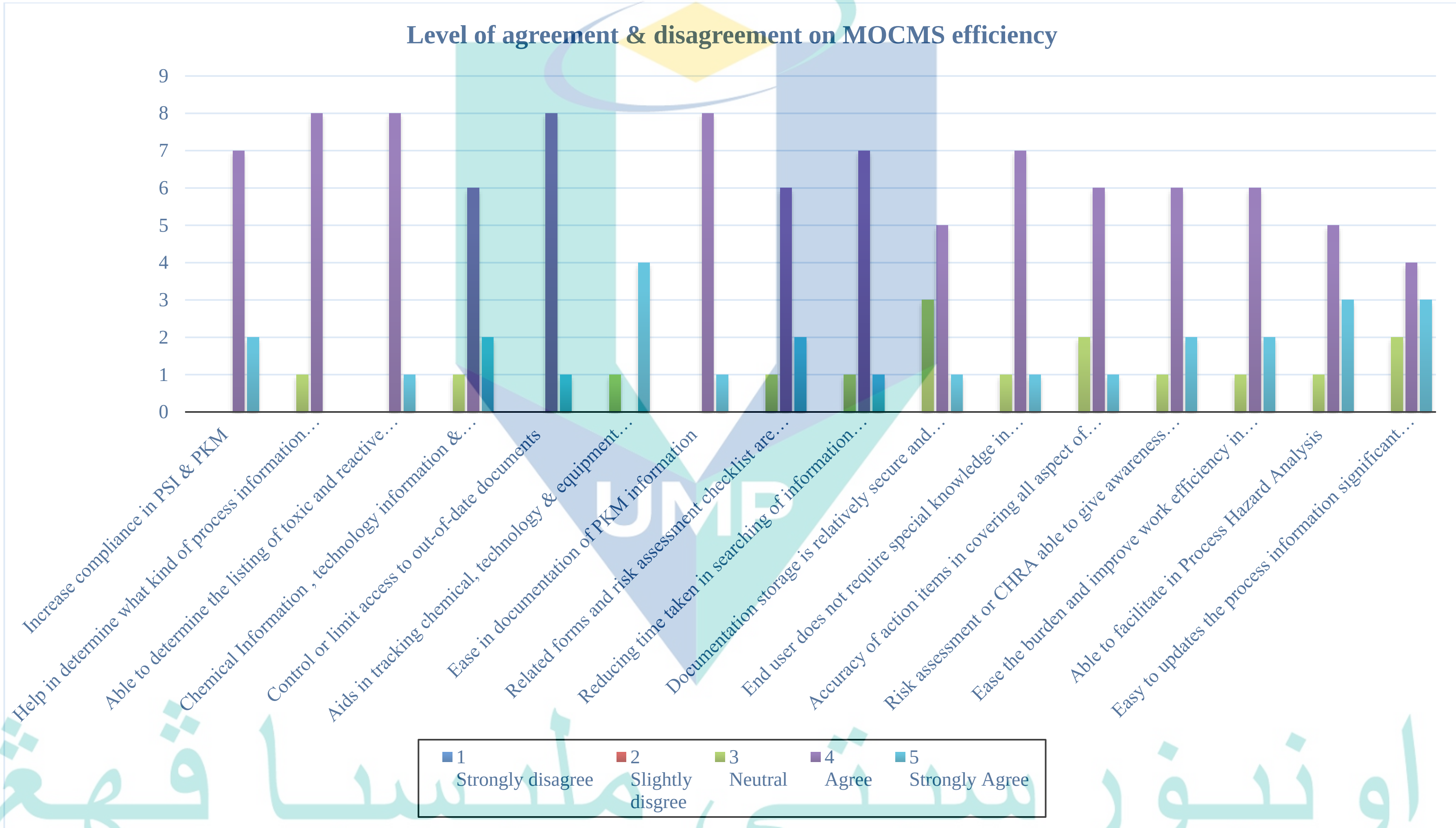


Figure 4.32: MOCMS Efficiency Survey Results

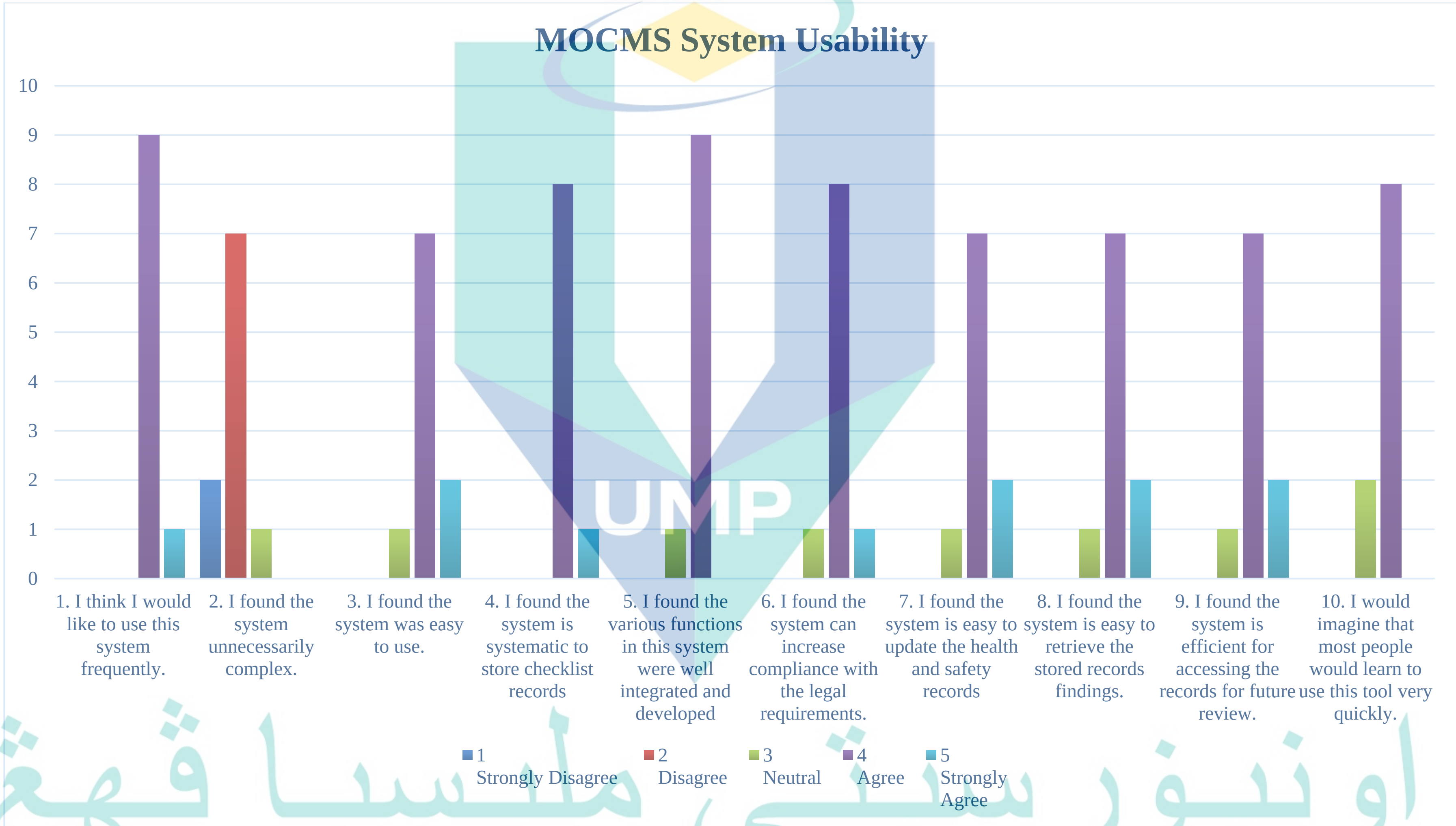


Figure 4.33: MOCMS System Usability Survey Result

4.7 Summary

This section presented the proposed solution's results to minimise the limitation of current management of change, MOC practice, especially towards temporary and emergency cases. MOC frameworks on temporary and emergency cases have been established and validated. Temporary MOC frameworks are separated between urgent and non-urgent change, which highlighted compulsory action items to be completed before the implementation, even with limited time. All temporary and emergency MOC frameworks are equipped with a related risk assessment checklist and a proposed risk rating to improve risk analysis and prioritisation. Management of change management system, MOCMS is the Microsoft Access software databases designed to serve as active guidelines and data inventory for the proposed MOC framework. MOCMS comprises interfaces that function for data inventory, filter search, generation of the report, and data input interface.

Based on pilot studies conducted, the established framework and management system are acknowledged by safety practitioners in process industries. It could make a significant contribution to MOC management and track temporary cases. The temporary and emergency frameworks help in terms of minimising time constraint issues; meanwhile, MOCMS act as active guidelines and system databases to cover the whole MOC process. Both companies have similar approaches in terms of MOC management. However, it is found that management in permanent and temporary changes is inconsistent where less attention and risk assessment is conducted in the temporary change. Therefore, it is believed that this system could contribute to managing temporary change more effectively. The established MOC framework is compared with the existing MOC flow chart from both companies. The current MOC framework in both companies is comprehensive towards permanent change, while less coverage on temporary and absence of emergency change MOC procedure. Nevertheless, newly established frameworks have a similar workflow and some special action items in the current MOC procedure practised in both Plant X and Y, such as change request forms, follow-up action, and change closure. Some unfilled information in the adopted checklist is identified as gaps covering some lacking in current MOC practises in process industries.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS OF FUTURE WORKS

5.1 Introduction

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

5.2 Conclusion

Management of Change (MOC) is one of the critical element in Process Safety Management (PSM). It is interlinked with almost all of the critical elements in PSM, including Process Safety Information (PSI), Process Hazards Analysis (PHA), Operating Procedures (OP), Training (TNG), Process Safety Start-up Review (PSSR), and Mechanical Integrity (MI). However, effective MOC implementation on temporary and emergency cases are hindered by some limitations in current industrial practises. Many industries established permanent MOC procedures limited to temporary and emergency changes. These incomplete practises and considerations have inspired further research and investigation.

The research work presents a developed integrated temporary and emergency MOC framework and management system based on PSM regulation, 29 CFR 1910.119. A PDCA cycle is established to provide an overview of the MOC process and a MOC framework that highlights all the important action items and related risk assessment forms recommended for each action item. The developed framework is different from the existing work, which generally focuses only on permanent changes. An existing permanent MOC framework has been adopted and modified into a temporary and emergency framework without compromising critical action items. Risk assessment checklists have been adopted from the same reference, incorporated with process safety standard risk rating, to enhance risk and mitigation measures prioritisation when there are time constraints and limited resources issues.

Pilot studies have been conducted to validate the established framework, risk assessment checklist and management system to determine the reliability and applicability of the real-life operation process. It is proved that developed results ease the burden of documentation, yet propose a new approach in MOC management. Time begin and completed field in the system is established to enhance time prediction in performing every risk assessment and period required for the whole MOC process. A MOC Management System (MOCMS) is established according to the proposed framework and concept, which stores all related risk assessment forms, change proposal, and storage database for associated documents. This software act as an active guideline of the whole MOC framework from top to bottom. Improvement of open MOC case tracking is another feature developed in MOCMS where end-users can easily retrieve information on any ongoing MOC cases. Any overdue of the MOC case without proper follow-up and closure action may pose another underlying hazard to the process condition as all the risk assessments are conducted based on temporary conditions. The indication of the performance can be shown by the percentage of timely closing of temporary MOC cases and the prediction of time required for every action item.

5.3 Recommendations

Key factors in MOC management are complete risk assessment, mitigation measures, and adequate follow-up actions. A longer research period is required to perform 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 the return of investment (ROI) and detail steps on follow-up action be added into the MOC framework to expand MOC's coverage in real-life practises. The adopted checklist could be improved by covering more detail in the MOC issue. Management system software can be designed more perfectly with extra features to tackle more current issues in MOC. Extra features, such as notification system on upcoming open and temporary change cases as well as risk assessment checklist to be incorporated into management system instead of a separate checklist, could be further improved to enhance user experience and work efficiency.

Future research recommends this software be made into a centralised software that enables users to surf the system anywhere away from the computer in the office. Pilot testing on a new proposed change determines the reliability of the risk assessment checklist and management system in a real process plant.

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APPENDIX A

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 B

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
- ☐ Plant environmental impacts
- ☐ Workplace conditions
- ☐ Other:

Time span:

- ☐ Permanent change - to be effective on
- ☐ Temporary change (from to)

Location (if applicable):

Funding required:

Persons and management levels involved:

ICT software and hardware involved:

Procedures involved:

Other:

Urgent matter: ☐ yes ☐ no

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:

<table>
<tr><td colspan="6" rowspan="2">From Form IX; logically order measures to actions for completion!</td><td colspan="6">To be filled-in after change was implemented</td></tr>
<tr><td colspan="2">Action completed</td><td colspan="2">Action validation</td><td colspan="2">Action closing</td></tr>
<tr><td>No</td><td>Measure to Action</td><td>Action responsible</td><td>Deadline</td><td>Related documents</td><td>(Issue No.)</td><td>Date</td><td>Signature</td><td>Appointed</td><td>Signature</td><td>Was temporary</td><td>Closed</td></tr>
<tr><td>1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td>5</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td>7</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>8</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Other comments, as well as explanations to potential approval:

<table>
<tr><td rowspan="2">Decision:
☐ The proposed change is approved
☐ The proposed change is rejected</td><td colspan="2">Appointed responsible person:</td></tr>
<tr><td>Date:</td><td>Signature:</td></tr>
</table>

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 – ACTIVITIES 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						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						

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]	Likelihood/ Severity	Risk	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								
A.4	Temporary procedural								
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								

APPENDIX C

SYSTEM USABILITY SURVEY FORM

MANAGEMENT OF CHANGE MANAGEMENT SYSTEM (MOCMS) EFFICIENCY SURVEY

Part A: Demographic Information

Job position: ________________________________

Education background: ___________________________

Year of employment with current company: ____________

*Direction: Please indicate your level of agreement or disagreement according to the likert scale shown below.

1	2	3	4	5
Strongly disagree	Slightly disagree	Neutral	Slightly agree	Strongly agree

Question	1	2	3	4	5
1. Increase standard compliance in MOC.					
2. Help in MOC and risk assessment cycle time prediction.					
3. Aids in tracking of temporary cases.					
4. Ease in tracking of open task					
5. Ease in documentation of MOC information					
6. Related forms and risk assessment checklist are easily accessible in the system.					
7. Reducing time taken in searching of previous MOC task.					
8. Documentation storage is relatively secure and convenient.					
9. End user does not require special knowledge in operating the system.					
10. Accuracy of action items in covering all aspect of MOC.					
11. Risk assessment checklist proposed helps in prioritizing risk.					
12. Aids in tracking of proposed change authorization and responsible personnel.					
13. Aids in security of information.					
14. Ease the burden and improve work efficiency in documentation task.					
15. Environment friendly by introducing paperless record logging and risk assessment checklist					
16. Able to act as guidance to complete MOC process					

System Usability Scale (SUS)

This is a standard questionnaire that measures the overall usability of a system. Please select the answer that best expresses how you feel about each statement after using the website today.

Question	1	2	3	4	5
1. I think I would like to use this system frequently.					
2. I found the system unnecessarily complex.					
3. I found the system was easy to use.					
4. I found the system is systematic to store checklist records					
5. I found the various functions in this system were well integrated and developed					
6. I found the system can increase compliance with the legal requirements.					
7. I found the system is easy to update the health and safety records.					
8. I found the system is easy to retrieve the stored records findings.					
9. I found the system is efficient for accessing the records for future review.					
10. I would imagine that most people would learn to use this tool very quickly.					

Other weaknesses of the MOCMS:

Recommendation for improvement:
